A Practitioner's Approach to Responsive Supply Planning

Subhash Wadhwa

Professor, IIT, Delhi

swadhwa@mech.iitd.ernet.in

Manas C. Fuloria

Research Scholar, IIT, Delhi

manas@supplychainge.com

Abstract: The planning of supply for fashion products, seasonal products and technologically innovative products presents certain similar challenges. These products are characterized by high demand uncertainty and require responsive supply chains to effectively match supply to demand. Further, for such products, it is useful to explicitly model how forecast uncertainty is expected to reduce in the future as demand information improves. This paper explores this important domain and defines the domain characteristics unambiguously and in a way useful to practitioners. The concept of *staging potential* of a product is proposed as a new and important concept. The paper investigates how adoption of this concept may impact industry practice. Finally, the paper describes a few simulation studies to illustrate how supply chain practitioners may use the concept of staging potential as a guide to decision making.

Keywords: supply chain management, supply chain planning, responsive supply planning, staging potential, short lifecycle products, innovative products, style goods, fashion products, seasonal products.

Professor Subhash Wadhwa (Eur. Ing., C. Emg.) received his PhD from NUI, Ireland, while working on an ESPRIT project at CIM Research Unit, Galwai. He is currently Professor and Group In-charge (P&I) at the Indian Institute of Technology, Delhi. He has originated novel research themes: decision and information delays involving Decision-Information Synchronization (DIS) applications in CIM, Supply Chain, e-Business; DRIS architecture for Agile Manufacturing; SAMIN architecture in IMS context, etc. He is an active contributor to EC projects in the IT&C domain and has coordinated several EU workshops. He has been a Consultant/Contributor/National-Expert to many international bodies including EC, UNIDO, CW and APO (Tokyo). He is dedicated to the goal of bringing synergy between Academics, Industry and Research.

Manas Chandra Fuloria (MSE Stanford University, B.Tech IIT Delhi) is a doctoral research scholar studying quick response supply chains.

1. Introduction

The similar supply planning challenges posed by fashion products, seasonal products and innovative products have been studied in the context of various industries, such as apparel (Fisher and Raman [1996]), semiconductors (Brown and Lee [1997]), food (McCardle et al [2002]), toys, personal computers and even agricultural chemicals (Raman [1999]). Fisher [1997] notes the similarities in supply planning requirements between products of a fashion-oriented nature and those driven by rapid technological advancements, and uses the term *innovative products* to describe both these categories. He characterizes innovative products as having high demand uncertainty and variable demand, a short selling period, high inventory cost, high profit margins, high product variety, low volumes per SKU, high stock-out cost, and high obsolescence. This domain has also been conceptualized and described variously as the supply planning of *short-lifecycle products*, or of *style goods*, or of *fashion products*, or of *seasonal products*. However, the adequacy of each of these concepts, the relationships among these, and their connection with the resulting supply chain models has not been adequately explored.

The problem of how to manage responsive supply is particularly important in developed and developing economies. For example, let us consider the US apparel industry. Raman [1997] notes that product variety in this industry has increased by a factor of eight since World War II. Basic white shirts have declined as a percentage of all dress shirts - from 72% in 1962 to 52% in 1967 to about 19% in 1986. Demand uncertainty caused by such product variety leads to mismatches between demand and supply. The cost of discounts due to over-supply was 16% of apparel retail sales in the late eighties [Pashigian, 1988], and has grown to 33% [Smith and Achabal, 2002]. Stock-outs are also high, although they are more difficult to estimate with confidence. Staples [2001] suggests the fraction of prematurely stocked-out SKUs in apparel retail are 25-30% of all SKUs that were offered. In 1985, losses due to apparel markdowns in the US were estimated at 13% of net retail sales and stock-outs at 6%, together making up about 80% of the total supply chain inefficiencies of over $25 billion [Hammond and Kelly, 1991].

While an exhaustive review of research literature in this domain is beyond the scope of this paper, some representative research is discussed here. Hausman and Peterson [1972] develop heuristics for a model with a single demand period for which the product is required, while information on demand is revealed in two stages and production commitments are made at each of these two stages. Iyer and Bergen [1997] and Brown and Lee [1997] also present models of this type which they solve analytically. Bassok and Anupindi [2002] and Tsay and Lovejoy [1999] develop models that include two distinct demand periods with correlated demands. The first production commitment involves buying products for the first period and booking production resources for the second period, while the second production commitment to finished goods is based on the demand outcome in the first period. Similarly, Donohue [1996] investigates *production option contracts* whereby an option is purchased for production in a future period. Eppen and Iyer [1997] study *backup agreements* in the apparel catalogue industry where the buyer is allowed a certain backup quantity in excess of the initial forecast at no premium, but pays a penalty for any of these units not purchased. They show that the value of flexibility is more dependent on the learning effect after early sales than on the coefficient of variance of demand. Brown and Lee [1997] study *pay to delay* arrangements. Barnes-Schuster et al [2002] present a generalized model of the 2-stage one-demand-period and two-demand-period problems and show that many of the extant research models are special cases of this general model.

2. Existing Domain Concepts and Their Limitations

This area of supply chain planning may be identified as a separate practice domain since supply chain models to analyse it share some definitive characteristics. First, such models incorporate *demand uncertainty*, that is, the forecasts of demand are not perfectly accurate. Second, they model *forecast updating*, which means the accuracy of demand forecasts improves with time (Raman [1999]). Commitments to production resources can be made at different times corresponding to at least two different levels of forecast accuracy. We call this the *staging* of production commitments. Third, such models typically have a finite *selling term* over which the product or products are offered for sale. In this, they differ from infinite-horizon supply chain models such as the EOQ and the (s,S) models.

The domain has often been demarcated as the supply planning of short lifecycle products, *to indicate that the products are offered in the market for a short time. A common definition has been that* the ratio of replenishment lead time and the length of the selling term be such that the number of replenishments that can take place during the selling term is a small number *(Hausman and Sides [1973] and Fisher et al. [2001]). However, this definition* directly *addresses none of the three important requirements of the domain listed in the above paragraph, namely, demand uncertainty, forecast updating, and multiple production commitments. In fact, some models could fall in the domain despite having only one delivery of finished goods, with the planning being deconstructed into two supply decisions, each occurring at a different point in time. For example, one decision could be capacity booking while the other could be finalization of finished goods quantities. One such model is proposed by Iyer and Bergen [1997]. To remedy this failing, other researchers have explicitly defined the area as requiring multiple production commitments instead of multiple replenishments. Subsequently, forecast updating has been explicitly added to this definition (Raman [1999]).*

However, even this upgraded definition does not address the case of products with long selling-terms but with a pronounced demand peak that make them ideal for models in this domain. For example, Agrawal et al. [2002] study the case of a perennial product with high seasonality and production that is capacity constrained, leading to characteristics similar to those of short-selling term products. Second, even for products that allow only a few replenishments in the normal course, deconstructing the production commitments into separate commitments for capacity booking, raw material purchases, manufacturing and transport can increase the number of commitments. The limitation on the number of commitments in the definition is more a result of the limitations of the techniques used to analyse these models rather than of the intrinsic nature of the domain itself. Third, this definition does not take into account the importance of price elasticity of demand. Oversupply can cheaply be corrected using pricing for products with high price elasticity, but this is expensive for products with low price elasticity. Similarly, under-supply is less costly for products in a mix with a high degree of substitutability, while it is expensive for a non-substitutable products mix. Fourth, long-selling-term products may behave like fashion products at the start of their selling term (high uncertainty) or at the end of their selling term (high costs of oversupply). Finally, it is difficult in an industrial context to clearly identify short-selling-term products from long-selling-term products since there is often a nearly continuous distribution of selling terms (Fuloria and Wadhwa [2003]).

There are also other practical problems with the short lifecycle *terminology.* The term *lifecycle* is often used to denote not just the period when the product is offered for sale, but the entire time from concept or ideation through design, development, production, marketing, selling and phase-out. Further, the phrase short *lifecycle* tends to get confused with short-shelf-life, which denotes perishable products like flowers or vegetables. Other terminology often used in connection with this area includes *supply planning of fashion products* or *style-goods*, which are too apparel-specific to be of broad use, and *supply planning for seasonal products*, which is restrictive since many of the domain applications are not seasonal. Finally, the phrase *supply planning for innovative products* has been proposed. The main drawback of this phrase is that it assumes that the demand uncertainty is due to product newness and not due to any other reasons. Also, like the other terms discussed above, this term focuses on the characteristics of the demand side and not enough on those of the supply side.

3. Proposed Concepts and Terminology

Keeping the above discussion in mind, we propose the concept of *Staging Potential* that may be useful for researchers and practitioners. **The Staging Potential of a product for a period is defined as the degree of financial risk of overage and underage of product for the period that can be reduced by partly postponing commitments to supply resources in order to take advantage of improved demand information.**

Thus, the domain may be referred to as the ***supply planning of products with a high staging potential***. The multi-dimensional nature of the domain is folded into the definition. Note that the staging potential is defined not for a product *per se*, but for a product-period combination. Thus, in keeping with our previous discussions, a product with a long selling-term may have a high staging potential for peak demand periods or for phase-in and phase-out situations. The definition does not refer to short-lifecycles, seasonality, fashion or style – terms that have limitations as discussed. Yet, it is clear that short-lifecycle, seasonal and fashion products will frequently have a high staging potential. Note also that the definition does not classify products rigidly, indicating that the amenability of real world problems to the domain is a continuum rather than discrete true-false values. The emphasis is on financial risk rather than quantity risk, in line with practitioner concerns. Finally, the definition automatically implies that supply decisions are taken at more than one point in time, with some being taken after the forecast has improved.

Figure 1 traces the interaction of various aspects of the domain, and is discussed in the remainder of this section. Note that, as per the figure, two key aspects of the domain are the financial risk of demand-supply mismatches and the staging of decisions. Demand uncertainty increases the financial risk of demand-supply mismatches. In turn, demand uncertainty is highest for new products, for short selling-terms, as well as where product variety and resulting demand fragmentation is greatest. Demand uncertainty is also increased by technological and psychological *network effects*, where the value of a good or service to a potential customer increases when the number of customers already owning that good or using that service is high.

As discussed earlier, lower price elasticity implies a higher cost of overage. As holding costs increase, the cost of overage increases. When a product is phased out, perhaps to be replaced by a new product, the costs of overage typically increase. As discussed briefly above, a large demand peak, often corresponding with festival sales, may also increase the staging potential. Any overproduction for demand during this peak takes longer to be consumed and drawn down. This results in a high cost of overage. Further, if the factory producing goods for a large seasonal peak has to be level loaded through the year, considerable quantities may have to be made much ahead of time, leading to high demand uncertainty when supply commitments may have to be made.

For products where direct or variable costs are a small fraction of the selling price, the opportunity cost of underage is high, leading to a higher staging potential. Staging potential can also be increased by the policies of the firm. Companies focused on financial results and metrics are reluctant to hold inventory from period to period. In the limiting case, if a company decides to never hold stock from one month to the next, even a perennial long-selling-time product will have to be treated like a fashion product in some ways.

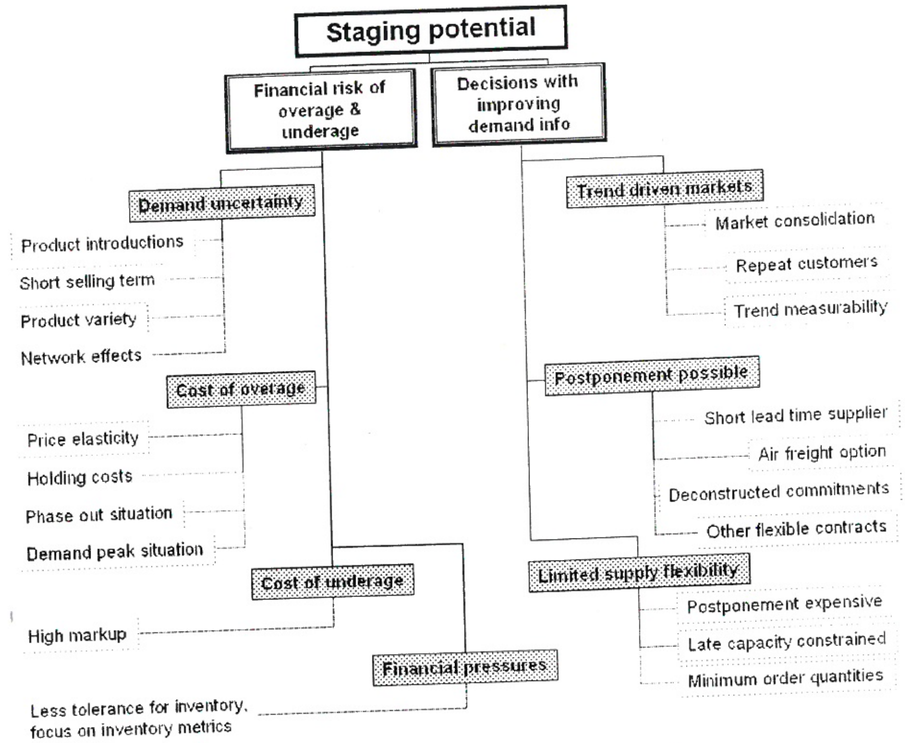

Figure 1: Interaction of Various Aspects of the Domain

Increased consolidation and globalisation of the market result in stronger market trends. Customers may return to buy the same product again while it is offered. In this way, early sales may be an indicator of future sales, leading to increased staging potential. Yet, for various business and technical reasons, trends may not be easy to detect and measure. Trend analysis may take considerable time or may yield inaccurate results. The staging potential may decrease in such a case.

For staging, postponement must be possible. At the same time the ability to postpone must either be constrained or must cost extra, otherwise one would postpone all decisions and there would be no staging. The availability of postponement options may include: suppliers with a shorter order-to-delivery lead time, use of air freight instead of surface freight, special flexibility contracts, and the deconstruction of conventional finished goods orders into separate instructions for capacity booking, materials purchase, manufacturing and transportation. Disincentives and constraints to postponement may include an increased cost or a capacity constraint. The presence of minimum order quantities can also make the problem non-trivial.

4. Impact on Industrial Practice

The staging potential of a product may affect industrial practice in many ways. In a situation with high staging potential, product design choices that increase parts commonality are more attractive, since this reduces the risk involved in pre-positioning or staging materials. In terms of vendor selection, a high staging potential may favour responsive suppliers when the trade-off between the cost and speed of supply is investigated. In contrast, where staging potential is low, choosing the lowest cost vendor is often an adequate solution.

The impact of a staged environment may be illustrated with the example of the Spanish retailer Inditex, a highly sophisticated company from a supply chain standpoint. Inditex recognizes that products with a high staging potential should have highly responsive supply chains, even if that comes at an increased cost. Inditex designs many of its products from common un-dyed fabrics in order to allow for postponement and staging. At the tactical level, it chooses many European vendors for manufacturing that are closer to the market, even though it is more expensive to manufacture in Europe than in Asia. Finally, Inditex's emphasis on speed and responsiveness carries over to the operational decisions – it pre-positions materials, implicitly books capacity, plans production just-in-time, and does not hesitate as much to use air freight.

5. Illustrative Simulation Studies

To illustrate how supply chain practitioners may use the concept of staging potential as a guide to decision making, we consider and tackle the following problem. A company has two suppliers, one that is responsive but expensive, and another that is cost-effective but slow. The company has a single product, which is offered for sale in a single demand period. Supply decisions are taken at two points in time. At the earlier time t_A, it is decided to make X1 units using the cost-effective supplier at a cost of C_C per unit. At this time, it is also decided to purchase certain important long lead-time resources (e.g., capacity) with the responsive supplier. Such purchase of resources is, in effect, the purchase of an *option to produce* at a later date. X2 units of such options are purchased at a unit cost of C_{R1}. At a later time t_B, the decision is made on how much to manufacture with the responsive supplier, which is at an additional cost of C_{R2} per unit of finished goods. The maximum that can be manufactured with the responsive supplier at t_B is constrained by the number of options X2 purchased earlier at t_A. The undiscounted selling price of the product is S and the clearance price at which excess product must be sold is Z. The objective of the practitioner is to maximize profit, i.e. revenues minus costs.

Demand information improves from t_A to t_B.

F_A = *Mean of distribution of demand as forecast at* t_A

F_B = *Mean of distribution of demand as forecast at* t_B

$F_B = N(F_A, \sigma_A)$

Realized demand = $N(F_B, \sigma_B)$

5.1. Effect of cost of the option to produce with the responsive supplier

The cost of the *option to produce* with the responsive supplier affects the preferred split of sourced quantities between the cost-effective source and the responsive source. As indicated in section 4, design using common parts may reduce the cost of such an option. Hence, it is of practical interest to study the effect of the ratio $C_{R1}/(C_{R1}+C_{R2})$. To do this, for each value of $C_{R1}/(C_{R1}+C_{R2})$, we simulate a large number of points on the X1-X2 plane to find preferred values of X1 and X2. These preferred values of X1 and X2 are plotted in Figure 2. *The following realistic parameters were used for this study:* $F_A = 1000$, $\sigma_A = 300$, $\sigma_B = 100$, $C_C = \$\,35$, $C_{R1}+C_{R2} = \$\,37.5$, $S = \$\,50$, $Z = \$\,15$.

As can be seen in Figure 2, as the option booking price becomes a larger fraction of the total per unit cost of the responsive source, the preferred X1 increases while the preferred X2 declines. In other words, the share of the responsive source declines as does the staging potential. In the example, when the cost of booking is about 40% of the total unit cost, use of the responsive source appears to no longer be advantageous.

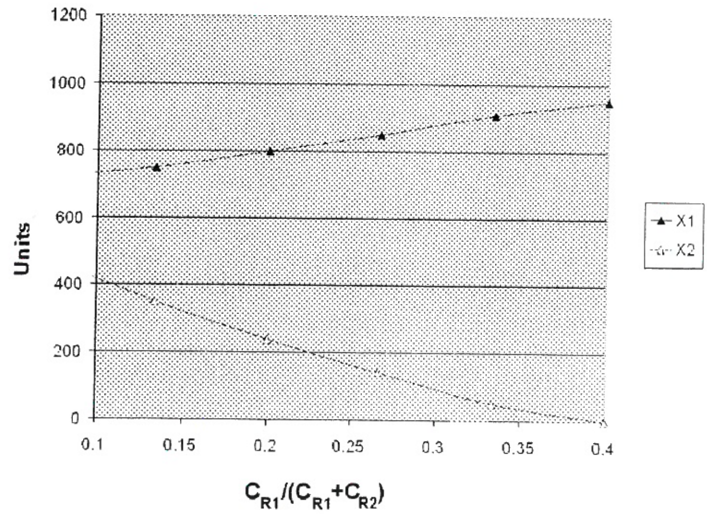

Figure 2: Effect of the Cost of Booking Options on the Preferred Supply Chain Strategy

5.2. Effect of Ratio of Clearance Price to Initial Sale Price

With the same values of the other parameters as in Section 5.1, we vary the value of the clearance price Z. The aim is to discover how this affects the preferred strategy. The results of the experiment are shown in Figure 3. An increasing ratio of Z/S appears to reduce the importance of the responsive source and the staging potential. Interestingly, as the value of Z/S reduces, the effect of any incremental change in Z/S appears to reduce, that is, the curves lie closer to each other. This suggests that companies wanting to move production to cost-effective sources from responsive sources, while maintaining the soundness of their supply strategy, should perhaps first try to increase the clearance price of products that already have a high clearance price.

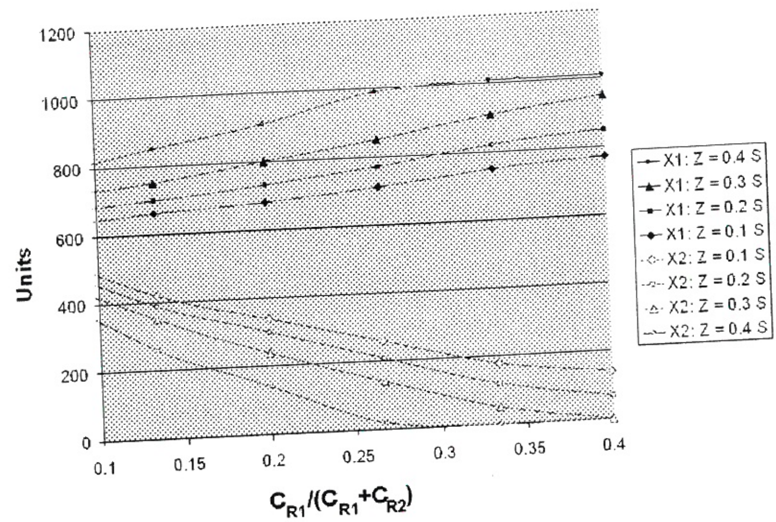

Figure 3: Effect of Clearance Price on Preferred Sourcing Strategies

Another observation is that the curves appear to get steeper with a higher value of Z/S. That is, as the clearance price increases, the preferred supply strategy appears to be more sensitive to the option price. Of course, if the clearance price is high enough, the responsive source may not be part of the preferred supply strategy at all.

5.3. Effect of Forecast Updating

With the same values of the other parameters as in Section 5.1, we vary the values of σ_A and σ_B to study the effect of the quality of forecast update. The value $(\sigma_A^2+\sigma_A^2)$ is kept constant, i.e., the quality of the initial forecast is the same for all observations.

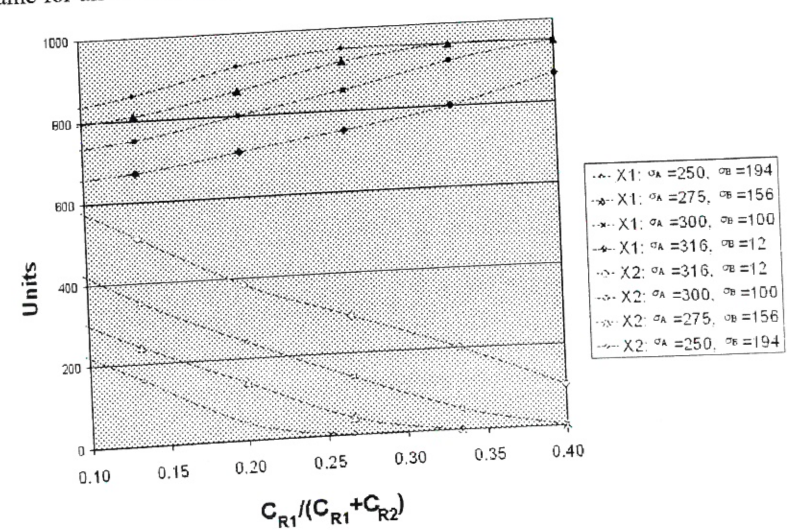

Figure 4: Effect of Quality of Forecast Update on Preferred Sourcing Strategy

The results of the experiment are shown in Figure 4. An increase in the quality of the updated forecast appears to lead to a higher importance of the responsive source and therefore higher staging potential. Note that even with a very high accuracy of forecast update, the effect of the option price is still high. This suggests that in certain circumstances, companies may prefer to lay priority on reducing option price through product design, rather than on improving the accuracy of forecast update.

6. Summary and Conclusion

The key contribution of this paper is to propose and develop the important concept of Staging Potential, which is a multi-dimensional concept. The concept covers aspects of both the demand conditions and the characteristics of the supply choices available. Further, the paper extends the domain in line with the important fact that products may display different characteristics over different parts of their selling term. The proposed concept of staging potential is industry-neutral and can be used for all industries that deal with fashion products, short lifecycle products, seasonal products and innovative products. At the same time, the definition is precise and embraces various key aspects of research literature in the domain. In addition, the paper presents certain simulation studies as examples of the investigations that may be prompted by a greater emphasis on the role of the staging potential in practical decision making. In the experience of the authors, such approaches may enrich the supply chain practice in many important industries.

The selection of accurate and descriptive conceptualization and terminology for research domains is important in facilitating their adoption by industry. An example of the impact of good terminology and definitions is the creation of the concept of Bullwhip Effect by Procter and Gamble executives to denote the magnification of demand fluctuations as orders move up the supply chain [Lee et al, 1997]. Although the problem had been known to researchers including Forrester [1958], the new conceptualization allowed practitioners to easily visualize, understand and assimilate the issues. In the same way, it is hoped that the unambiguous conceptualization and definitions proposed in this paper may facilitate the research and practical discussions of the domain.

REFERENCES

1. AGRAWAL, N., S.A. SMITH, and A.A. TSAY, **Multi-vendor sourcing in a retail supply chain**, Production and Operations Management, 11:2, 2002.
2. BARNES-SCHUSTER, D., Y. BASSOK, and R. ANUPINDI, **Coordination and flexibility in supply chain contracts with options**, Manufacturing and Service Operations Management, 4:3, 2002.
3. BASSOK, Y. and R. ANUPINDI, **Analysis of supply contracts with commitments and flexibility**, Working Paper, Northwestern University, 2002.
4. BROWN, A.O. and H.L. LEE, **Optimal pay-to-delay capacity reservation with application to the semiconductor industry**, Working paper, Department of Industrial Engineering and Engineering Management, Stanford University, 1997.
5. DONOHUE, K., **Supply contracts and fashion goods: optimizing channel profit**, Working Paper, The Wharton School, University of Pennsylvania, 1996.
6. EPPEN, G. and A. IYER, **Backup agreements in fashion buying – the value of upstream flexibility**, Management Science, 43:11, 1997.
7. FISHER, M., **What is the right supply chain for your product?**, Harvard Business Review, March-April, 1997.
8. FISHER, M. and A. RAMAN, **Reducing the cost of demand uncertainty through Accurate Response to early sales**, Operations Research, 44:1, 1996.
9. FISHER, M., K. RAJARAM, and A. RAMAN, **Optimizing inventory replenishment of retail fashion products,** Manufacturing & Service Operations Management, 3:3, 2001.
10. FULORIA, M.C. and S. WADHWA, **Towards a unified supply chain planning approach**, International Conference in CAD/CAM/Robotics for Autonomous Factories, New Delhi, 2003.
11. FORRESTER, J.W., **Industrial dynamics: A major breakthrough for decision makers**, Harvard Business Review, 36:4, 1958.

12. HAMMOND, J.H. and M.G. KELLY, **Quick Response in the apparel industry**, Harvard Business School case study, Revised April, 1991.

13. HAUSMAN, W.H. and R. PETERSON, **Multiproduct production scheduling for style goods with limited capacity, forecast revisions and terminal delivery**, Management Science, 18:7, 1972.

14. HAUSMAN, W.H. and R.S.G. SIDES, **Mail-order demands for style goods: theory and data analysis**, Management Science, 20:2, 1973.

15. IYER, A.V. and M.E. BERGEN, **Quick Response in manufacturer-retailer channels**, Management Science, 43:4, 1997.

16. LEE, H.L., V. PADMANABHAN, and S. WHANG, **The Bullwhip Effect in supply chains**, Sloan Management Review, Spring 1997.

17. MCCARDLE, K., K. RAJARAM and C.S. TANG, **Advance booking discount programs under retail competition**, Working Paper, University of California at Los Angeles, 2002.

18. PASHIGIAN, B.P., **Demand uncertainty and sales: a study of fashion and markdown pricing**, American Economic Review, 78:5, 1988.

19. RAMAN, A., **Apparel exports and the Indian economy**, Harvard Business School case study, Harvard Publishing, Revised 1997.

20. **RAMAN, A., Managing inventory for fashion products**, Quantitative Models for Supply Chain Management, Kluwer Academic Publishers, 1999.

21. SMITH, S.A. and D.D. ACHABAL, **Clearance pricing and end-of-season inventory management for retail chains**; Proceedings of the Informs Practice Conference, 2002.

22. STAPLES, N., **Paired production, high speed replenishment, supporting technology and mass customization for survival**, Clemson Apparel Research Center, http://car.clemson.edu/research/Paired%20Production.pdf; May 2001.

23. TSAY, A. and W. LOVEJOY, **Quantity flexibility contracts and supply chain performance**, Journal of Manufacturing and Service Operations Management, 1:2, 1999.