Towards a Unified Supply Planning Approach

Manas C. Fuloria

Research Scholar, IIT, Delhi

Subhash Wadhwa

Professor, IIT, Delh.

swadhwa@mech.iitd.ernet.in

Abstract: In industrial practice, a firm may simultaneously offer for sale a number of diverse products. In particular, different products in the portfolio may be offered for sale for different lengths of time, ranging from short (e.g., *fashion* products) to long (e.g., *commodity* products). Further, at any point in time, different products may be at different stages of their lifecycles. More generally, different products offered by the firm may have different *staging potential.* They and may also be sourced through different arrangements with suppliers. This paper outlines a *Unified Supply Planning* approach that allows improved supply planning in the situations described above. In doing so, it emphasizes the convergence of supply chain research models, industry IT systems and practical reality, especially in terms of modeling the demand forecasts, forecast accuracy, and the expected improvement of forecast accuracy over time.

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

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

Professor Subhash Wadhwa (Eur. Ing., C. Emg.) received his PhD from NUI, Ireland, while working on an ESPRIT project at CIM Research Unit, NUI, Galway.. He is currently Professor of Industrial Engineering, at the Indian Institute of Technology, Delhi. He is an active contributor to EC projects in the IT&C domain and has coordinated several EU workshops in India. He has over 100 research publications including those in renowned international journals such as IJFMS, IJPR, Computers & Industrial Engineering, International Journal of Technology Management and SIC. He has proposed and demonstrated the utility of new IT based architectures in Intelligent Systems such as SAMIN (ANN based proactive planning), DRIS (GA based integrated planning and scheduling in re-configurable Agile Systems) and DIS (Decision Information Synchronization) applications to Flexible Supply Chain and Enterprise Synchronization. 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.

1. Introduction

In general, it is recognized that different types of products may need different types of supply chains [Fisher, 1997]. There is a need for evolving flexibility based supply chain decisions involving both manufacturing and supply chains as discussed by Wadhwa and Rao (2004). Wadhwa and Bhagwat (1999) have shown the need for decision information synchronization in flexible systems and hence need for effective IT solutions. Researchers have suggested several models for supply chain decision-making in various scenarios. For instance, Chan et al (2004) have shown the role of heuristic decisions in demand driven collaborative supply chain. Yet, industry adoption of such models is often low despite their apparent usefulness, as noted by Raman [1999]. This paper deals with one of the major challenges to industry adoption of many supply chain research models. Most firms manage, at any time, a portfolio of products with diverse characteristics that are at different stages in their lifecycles and are sourced in different ways. On the other hand, most supply chain planning research models typically focus on an abstracted, well-defined problem for a particular type of product. Therefore, it is often difficult to neatly fit the same single research model of supply chain planning to every product in a firm's portfolio. Also, it is difficult for a practitioner to use two or more distinct supply chain planning models simultaneously for the portfolio (for example, one infinite-horizon model and one single-period model) and select one or the other for each product. There are IT complexities to this approach as well as the issue that many products may not neatly fit one or the other model. Hence, for adoption by a firm, a research model must appropriately represent the key aspects of most or all the products in the firm's portfolio, even if it means that the optimum solution for the model cannot be found analytically.

Simultaneously, some of the important data that defines a product's profile from a supply chain point of view may not exist in a firm's IT systems. Industry IT systems typically work across the entire product portfolio, focusing on the essential supply execution aspects across all products like quantities and price. However, they typically have less coverage over certain data related to characterizing the product from a supply chain standpoint. For example, demand uncertainty, how it is expected to improve with time, price elasticity, and expected demand correlation across various products in the portfolio, may often not be incorporated in the firm's IT data structures. Wadhwa and Rao (2000) suggest the usefulness of IT supported dynamic decision-making in flexible systems. This paper is motivated by some of these concepts and is aims at dealing with the highly flexible environment needs that are changing quite often.

This paper suggests an explicit approach to supply planning that is being termed as *Unified Supply Planning*. Unified Supply Planning may be defined as an approach to supply planning that can be applied across a portfolio of products that may have different characteristics, that may be at different stages in their lifecycles, and that may be sourced in different ways. Such an approach involves building a supply chain model that is closer to the complexity of industry practice, as well as building firms' IT data structures to be more aligned with the needs of such a model. In this paper, we analyze certain salient characteristics of this approach.

2. Review of Research and Practice

Analytical supply chain planning models in research range from one-demand-period models like the Newsvendor Model, 2-demand-period models (e.g., Hausman and Peterson [1972]), to infinite horizon models like the EOQ and (s,S) models. Supply chain models also differ in the way they represent demand uncertainty. This is shown in Figure 1.

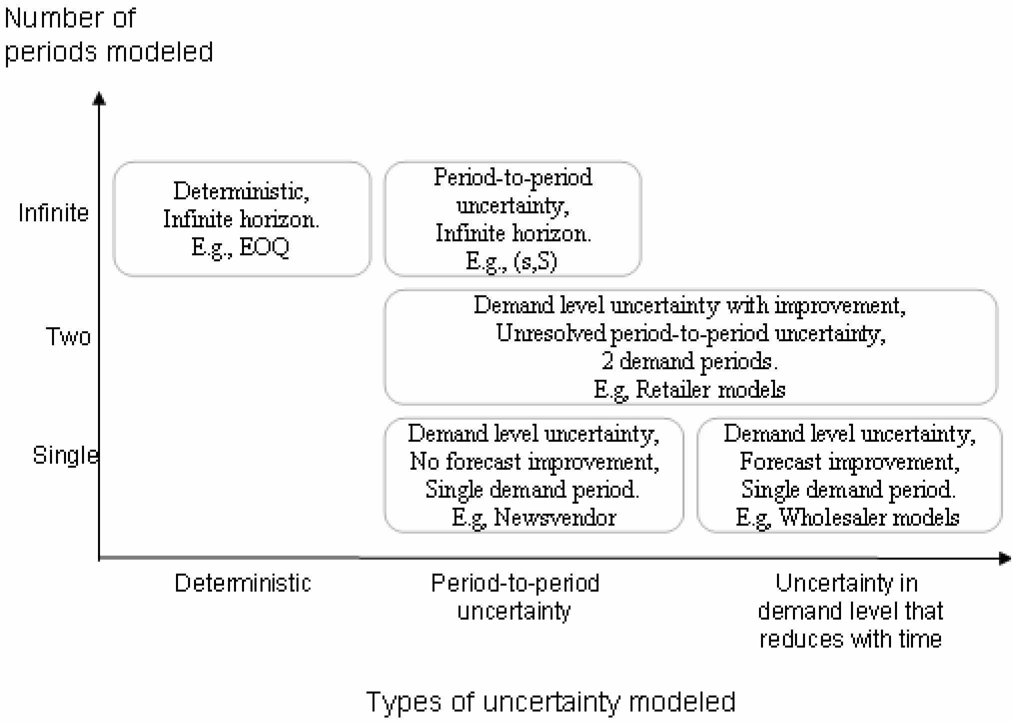

Figure 1: A Categorization of Supply Chain Planning Models Based on Number of Demand Periods and Types of Uncertainty Modelled.

Deterministic models include the EOQ model. These assume zero demand uncertainty and are therefore fully appropriate only in a few practical situations.

One typical approach to incorporate demand uncertainty is to assume a random but known and stationary distribution for the demand in each demand period. This is the approach in the commonly used (s,S) safety stock models, examples of which are given in Porteus [1995]. We may refer to this type of demand uncertainty as *period-to-period uncertainty* that cannot be resolved by observing the realized demand and therefore continues to exist throughout the planning horizon. An example of the source of period-to-period demand uncertainty for a firm may be the number of customers actually visiting the firm's store in a demand period, when the firm cannot detect any reason for this variation or draw any conclusions about future traffic levels from the levels in prior weeks.

In industry practice, such infinite-horizon models with period-to-period uncertainty are commonly used and embedded in supply chain planning software. A typical structure of these models is as follows: given a target service level, the known demand distribution, and a cost of re-ordering, the model recommends the order-at and order-up-to levels. In some cases, these may be multi-echelon models. In general, such models may be suitable for products with long or infinite selling periods, such as gasoline, coal, and food grains.

In the evolving business environment, many products do not fit the models described above. In particular, products with a fashion-oriented nature and those driven by rapid technological advancements require *responsive* supply chains to counter the high uncertainty in their demand level by responding to an expected *forecast improvement*. Fisher [1997] and Lee [2002] use the term *innovative products* to describe such products. They are characterized as having a 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.

Wadhwa and Fuloria [2004] suggest the concept of *staging potential* that helps determine the preferred supply chain planning approach for a product at each stage of its lifecycle. The staging potential is defined as *the amount 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. In the evolving business environment, more and more products have a high staging potential for at least a part of their lifecycle and are better planned with models that incorporate* forecast improvement.

Hence, a second major research approach to demand uncertainty has been to assume that one of the parameters of the demand distribution is also unknown. This unknown parameter is usually the mean or a component of the mean, and therefore this approach may be referred to as modelling *uncertainty in demand level*. Typically the planner can postpone certain decisions till after the estimate of this parameter improves, which may be referred to as *forecast improvement*. The estimate of this parameter may improve either before any demand is realized or on the basis of the observed demand in the first demand period. In the former case, the models usually represent a single demand period problem and are referred to as "manufacturer models" whereas in the latter case, usually two demand periods are modelled and such models are referred to as "retailer models" [Raman, 1999]. These are also depicted in Figure 1. However, such models are seldom used in industry practice.

3. Industry Example

It is instructive to take an industry example to illustrate the reasons cited in Section 1 of this paper for the low adoption of many such supply chain models, namely, the problem of fitting one or more supply chain models to a diverse portfolio of products. We take the example of an international multi-billion dollar apparel brand and retailer headquartered in the United States of America. This retailer offers thousands of garment styles to consumers every year. The selling terms of these products ranges from 6 weeks to many years. Table 1 below lists some of the categories of products.

Table 1. Typical Categories of Apparel Offered by an International Retailer

	Typical length of selling term	Typical supply lead time
Women's denim and khaki trousers	104 weeks	12 weeks
Women's seasonal T-shirts	13 weeks	6 weeks
Women's seasonal lingerie	26 weeks	20 weeks
Women's seasonal blouses	13 weeks	32 weeks
Women's high fashion blouses	6 weeks	32 weeks

The firm has adopted one supply chain model – an infinite-horizon (s,S) model. Not all products are planned according to this model. Products not using this model are sourced from suppliers only once in their lifecycle and never replenished, with the buy being driven by intuition rather than analytics or simulation. Whether or not a product uses the (s,S) model is decided simply based on the length of the selling term. Products that are sold for six months or more are termed "Basics" and are managed using the (s,S) safety stock model. This is true even when the supply lead time is comparable to the length of the selling-period (for example, in the case of women's seasonal lingerie in Table 1) and the assumption of an infinite-horizon is not appropriate. Further, a product may be classified in the "Basics" category even when it is early in its lifecycle and the demand uncertainty associated with the product is very high.

On the other hand, products that are sold for less than six months are termed "Single-Shot Styles" and are ordered only once, even where there is enough time for several replenishments (for example, women's seasonal T-shirts in Table 1) and the assumption of no replenishments is not appropriate. In such cases, the buy is based on intuition and Newsvendor or other approaches are not used.

The firm has several IT challenges due to the complete separation of the way these two categories of products are managed. Many new software purchases must be configured separately for each of these two categories. The IT systems in this company also do not contain adequate data on expected demand uncertainty of the product, how forecasts are likely to improve with time based on test-marketing or based on early sales, the price elasticity of the product, the pricing policies for getting rid of excess products, and so on. Hence, many models that rely on some of this missing data, including even the simple Newsvendor model, cannot be applied in practice. Further, the definition of demand periods in the IT systems is one week. Therefore, it is not easy to apply certain research models to the data. For example, applying a two-demand-period model would first require a reformulation of the weekly data into two demand periods artificially defined for the purposes of the research models.

4. Salient Characteristics of a Unified Supply Planning Approach

As seen above in the context of an industry example, a supply planning approach is needed that is appropriate for various types of products at various stages in their lifecycles and that addresses the significant data needs of the supply chain planning model or models used. The key characteristics required to bring supply chain planning models and industry practice closer are discussed below as components of a Unified Supply Planning Approach. These are discussed in terms of IT requirements, in the context that in order for industry adoption, any such approach needs to be embedded in software and IT systems.

4.1. Incorporate Multi-period Demand and Forecast Accuracy Profiles

There are various ways to model the forecast, forecast accuracy and accuracy evolution data so that it can be used for supply decision making. We suggest one method which fits the spectrum from innovative products to products with known and stable demand patterns and allows the application of many extant supply chain research models as special cases.

In the suggested model, any number of demand periods may be specified for a product. For each product and demand period, we estimate and store values for the expected demand, the price at which this demand is expected, the current *uncertainty in demand level,* the uncertainty in demand level after future forecast improvement, the time period in which the forecast will be updated, and the *period-to-period uncertainty*.

The uncertainty in demand level for a product in a demand period reduces as we get closer to the demand period as additional information may be obtained, possibly from demand realization in prior periods. This is modelled by storing, for each product and demand period, a value for both an initial uncertainty in demand level and an uncertainty in demand level after forecast improvement. The date when the forecast improvement is to take place is also stored. It is assumed that the uncertainty in demand level after forecast improvement can be estimated in advance of the improvement.

In terms of notation, for any product i and demand period j, we store:

1. F_{1ij}, the mean of the distribution of the *demand level* for product i in period j, given current information. F_{1ij} is assumed known.
2. p_{ij}, the price at which the product i is expected to be offered for sale in period j and which corresponds to the estimate of F_{1ij}. It is assumed that p_{ij} is known.
3. S_{1ij}, the standard deviation of the demand level about F_{1i}. S_{1ij} is assumed known.
4. The date u_{ij} on which the forecast for the demand level of product i in period j will be updated in light of improved information, resulting in a revision of the forecast mean from F_{1ij} to some F_{2ij}. This *forecast improvement* may be from the observation of demand in earlier periods for that product or may be based on the demand performance of products with similar attributes, as suggested by Iyer and Bergen [1997]. F_{2ij} is of course not known at the current point in time.
5. S_{2ij}, the standard deviation of the realized demand level D_{ij} about the improved forecast F_{2ij}. S_{2ij} is assumed known. Since forecast accuracy improves or at least does not worsen with the update, $S_{2ij} <= S_{1ij.}$
6. S_{3ij}, the standard deviation of the actual demand d_{ij} about the realized demand level D_{ij}. This corresponds to the period-to-period uncertainty.

One simplifying assumption that proves useful in practice for the analysis of practical situations is that the sign of the error in the estimate of the demand level does not vary over the planning horizon. That is, under this assumption, it is not possible that the demand level is lower than forecast for one demand period but higher than forecast for another demand period. This implies that each demand period can effectively be decoupled for the purpose of tackling uncertainty in demand level, since overages, if they occur, will occur for all periods in the planning horizon. Hence, under this assumption, a situation may never arise where the resolution of demand level uncertainty in one period leads to excess inventories which can help meet a shortage in a future period that is also caused by the resolution of demand level uncertainty. In other words, for a product i, if j and k are any two periods in the planning horizon, we may assume that

a. $F_{1ij} > F_{2ij}$ necessarily implies that $F_{1ik} > F_{2ik}$.
   $F_{1ij} < F_{2ij}$ necessarily implies that $F_{1ik} < F_{2ik}$.
b. $D_{ij} > F_{1ij}$ necessarily implies that $D_{ik} > F_{1ik}$.
   $D_{ij} < F_{1ij}$ necessarily implies that $D_{ik} < F_{1ik}$.
c. $D_{ij} > F_{2ij}$ necessarily implies that $D_{ik} > F_{2ik}$.
   $D_{ij} < F_{2ij}$ necessarily implies that $D_{ik} < F_{2ik}$.

This method of modelling the forecast data provides considerable flexibility in the application of extant supply chain models. When F_{1ij} is uniformly constant and S_{1ij} is equal to zero (i.e. there is no uncertainty) over a sufficiently large number of periods j, we have the demand conditions that approximate the EOQ model. If then S_{1ij} is made non-zero, we have the demand conditions for an (s,S) model. Similarly, when F_{1ij} is non-zero only for one period and S_{1ij} is also non-zero for that period, and there is no forecast improvement on updating (i.e. $S_{2ij}=S_{1ij}$), we have the demand conditions for the single stage Newsvendor model. If this is augmented by forecast improvement before the demand period (i.e. $S_{2ij}<S_{1ij}$), we have the *manufacturer* model for 2-stage fashion supply. If F_{1ij} is non-zero for only two contiguous demand periods, and demand information for the first does not improve while demand information for the second improves after observing the demand incurred in the first demand period, we have a situation that approximates many extant *retailer* models for 2-stage fashion supply, such as that presented in Fisher and Raman [1996].

This approach suffices for products that have independent demands. However, demand for certain products may affect demand for other products. From practical experience, it is suggested that a supply chain planning approach and system support two common cases:

1. Case 1: **When a set of individual products have demand that is perfectly correlated**. A set of such products is termed a *correlated set*. An example of a correlated set may be different sizes of a particular style of apparel. The demand for each different size will display a high degree of correlation that can be approximated as perfect correlation for reasons of practicality. Forecast accuracy information may preferably be specified at the set level rather than the individual product level. This information on correlated sets is important for the purpose of intelligent supply planning. For example, if sizes of the same style of apparel with perfectly positively correlated demands use a common raw material, then risk pooling does not take place. This must be factored into the planning process.
2. Case 2: **When the sum of demands for a set of individual products, or a set of correlated sets, or a combination of individual products and correlated sets, is never to exceed a known quantity**. Such a set is termed a *category constrained set*. An example of such a set may be total demand for men's dress shirts. While demand for different styles may be difficult to estimate, it may be possible to accurately establish an upper bound in advance on the total demand for the category. Such an approach is described by Fuloria and Wadhwa [2003].

4.2. Incorporate Ways to Estimate Forecast Accuracy Profiles

For using many supply planning models, software functionality is required to measure data on forecast accuracy and how it is expected to improve with time. The forecast accuracy and its evolution may vary by product type, product attributes, or by individual product, and may also vary over different periods through the selling term.

Figure 2 shows one possible method for creating a forecast accuracy profile for each product-period. The basis for this profile is the comparison of historical demand data and historical forecast snapshots in order to determine historical forecast accuracy. However, the comparison of the demand and forecast data requires they be brought to the same baseline price, since demand or forecast quantity has meaning only in context of a price. The forecasts may also include some intentional discounting and must be adjusted for this. The historical demand data must be similarly adjusted for the price manipulation that is commonly used for innovative products [Pashigian, 1988].

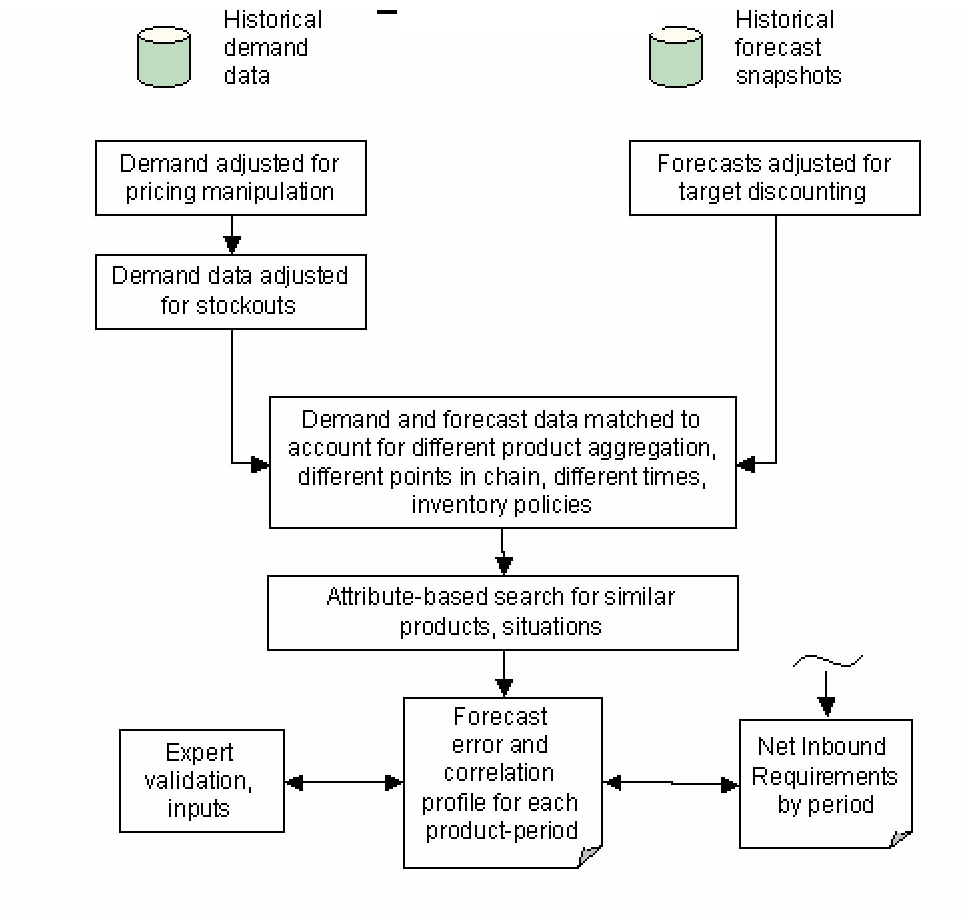

Figure 2: One Method for Estimating Forecast Profile for a Product-period

The historical demand data also typically has the problem that lost sales may not be explicitly recorded. In such cases, a method of estimating lost sales must be applied. Nahmias [1994] proposes one such method. Further, the forecast and demand data must be matched to make sure the comparison takes place at the same level of aggregation, for demand at the same point in the chain, and for demand at the same point in time. For example, a monthly forecast may be made regarding supply requirements at an aggregate level to a network of stores, while the historical demand data may correspond to daily store sales to consumers. In order to relate the two, several effects must be adjusted for, including the periodicity of the data and the amount of inventory maintained at each store.

4.3. Incorporate Various Procurement Methods

Supply chain planning models and IT systems intended for practical application must incorporate the fact that products may be procured in different ways. In the simplest case, a finished product may be procured from a single vendor who will deliver the product to the customer firm. However, the procurement may be more complex. *Split-vendor procurement* denotes that the purchasing company sources an identical or substitutable finished product, sub-assembly, component, raw material, transport service, or other product or service from more than one vendor. For example, Hausman et al [1995] analyze a supply planning model where there are dual supply modes, one with different lead times. *Multi-tier procurement* denotes that the purchasing company interacts with two or more vendors that supply sets of resources that are not identical and not perfect substitutes. *Deconstructed procurement* denotes that procurement decisions related to a single unit of product, such as the purchase, acquisition or activation of various goods or services required to procure the product, occur at least two separate points in time.

In addition, many *supply arrangements* can be structured and are an important reality of industry practice. IT systems and supply chain models intended for use in practice should allow definition of diverse arrangements that exist in practice. The simplest supply arrangements may include arrangements regarding lead times, price, and minimum order quantities. These arrangements may be in the form of a contract or an understanding that the supplier will only accept orders that adhere to these conditions. Arrangements may also be optional and not compulsory. For example, Tang et al [2002] analyze how optional advance booking discounts may be used to manage demand uncertainty for short lifecycle products. The awareness of the existence of these arrangements may result in different supply chain decisions.

Advanced supply arrangements may include that the customer firm will place orders that respect a capacity constraint or will follow pre-agreed rules for level-loading of capacity. Alternatively, the supplier may offer a *quantity flexibility* arrangement that allows for an upward and downward adjustment in production quantities, subject to certain pre-agreed limits and compensation terms. Similarly, a supplier may offer to allow product mix variations if the total quantities over a category of products are not varied. Eppen and Iyer [1997] analyze *backup agreements* in fashion buying, where the customer firm obtains an option to buy a fashion product a second time within the selling term if it observes strong demand for it.

The practice of postponement for a product with a high staging potential may be linked not just with the ability to delay conversion of *pre-positioned* raw materials into finished goods but, when necessary, to scrap the pre-positioned raw materials instead of converting them into finished goods. Often a salvage value may be obtained on scrapping these materials. An important type of supply arrangement is where the supplier pre-position materials on the direction of the customer firm but buys back excess materials under pre-agreed terms. Alternatively, the customer firm may be able to find other buyers for excess materials. This *reversibility* of materials procurement must be supported in the software. The commitment to materials and their possible subsequent salvage can be practiced in various ways. We illustrate some examples here. One, the material may be purchased outright and brought on to the financial books of the customer firm and then possibly later sold at a salvage value. Two, if the party from which the material is purchased is the same as the party to which the material is sold back if unused, then the initial payment may be the difference between the full price of the material and the salvage value, while the salvage value may be paid if and when the firm chooses to utilize the material. In this case, the first payment is in the nature of an option purchase, while the second payment is in the nature of the exercise of an option. Three, if the party which is supplying the material is also manufacturing the product, the brand company may not actually purchase anything at the time when it instructs suppliers to pre-position materials. It may instead pay for finished goods on a per unit basis, including the cost of all materials, and separately pay scrapping costs for unused materials bought under its instructions.

5. Summary and Conclusions

Models of supply chain planning have been designed from the perspective of researchers rather than from the perspective of industry users. Researchers have focused on solving specific problems related to particular product types given certain assumptions. On the other hand, industry users are most concerned about using their IT systems to manage a portfolio of products that may include products of various types, at various stages in their lifecycles and sourced in different ways. It is necessary to present users with unified approach that helps them plan the supply for the portfolio in a consistent way. The impact of such an approach will be highest for fashion or innovative products that are currently not planned systematically and where there is great potential for improvement [Wadhwa and Fuloria, 2003].

REFERENCES

1. EPPEN, G. and A. IYER, **Backup agreements in fashion buying – the value of upstream flexibility**, Management Science, 43:11, 1997.
2. FISHER, M., **What is the right supply chain for your product?** , Harvard Business Review, March-April, 1997.
3. FISHER, M. and A. RAMAN, **Reducing the cost of demand uncertainty through Accurate Response to early sales**, Operations Research, 44:1, 1996.
4. FULORIA, M. and WADHWA, S., **Demand Plan Constraints in Fashion Supply Planning**, Canadian Operations Research Society Conference at Vancouver, 2003.
5. HAUSMAN, W.H., H.L. LEE, and V.L. ZHANG, **Optimal ordering for inventory systems with dual lead times** , Working Paper, Department of Industrial Engg and Engg Mgmt, Stanford University, 1995.
6. HAUSMAN, W. and PETERSON, R**., Multiproduct Production Scheduling for Style Goods with Limited Capacity, Forecast Revisions and Terminal Delivery**(with R. Peterson), Management Science, March 1972.
7. IYER, A.V. and M.E. BERGEN, **Quick Response in manufacturer-retailer channels**, Management Science, 43:4, 1997.
8. LEE, H.L., **Aligning supply chain strategies with product uncertainties**, California Management Review, 44:3, 2002.
9. NAHMIAS, S**., Demand estimation in lost sales inventory systems**, Naval Research Logistics, 41, 1994.
10. PASHIGIAN, B.P**.**, **Demand uncertainty and sales: a study of fashion and markdown pricing**, American Economic Review, 78:5, 1988.
11. PORTEUS, E.L., **Numerical Comparisons of Inventory Policies for Periodic Review Systems**, Operations Research, Vol. 33, 1985.
12. RAMAN, A**.**, **Managing inventory for fashion products**, Quantitative Models for Supply Chain Management, 1999.
13. TANG, C.S., K. RAJARAM, and J. OU, **Managing demand uncertainty for short life cycle products using advance booking discount programs**; Supply Chain Management: Models, Applications and Research Directions, Kluwer Academic Publishers, 2002.
14. WADHWA, S. and FULORIA, M**.**, **A Practitioner's Approach to Responsive Supply Planning**, Studies in Informatics and Control, September 2004.
15. WADHWA S., RAO K.S., **Flexibility: An emerging meta-competence for managing High Technology**. International Journal of Technology Management, 19 (7/8), 2000.
16. WADHWA, S., BHAGWAT, R**., Semi-Computerized Flexible Manufacturing** (SCFM) Systems under Alternative Status Monitoring Modes, Studies in Informatics and Control, vol.8, no.2, 1999.
17. WADHWA, S., RAO, K.S., **A Unified Framework for Manufacturing and Supply Chain Flexibility**, Global Journal of Flexible Systems Management, Vol 5, pp.15-22, 2004.
18. CHAN, F.T.S., CHUNG, S. H., WADHWA, S., **A heuristic methodology for order distribution in a demand driven collaborative supply chain**, International Journal of Production Research, vol.42, no.1, 1-19, 2004.