Management Insights

An Application of Master Schedule Smoothing and Planned Lead Time Control
Chee-Chong Teo, Rohit Bhatnagar, Stephen C. Graves

This paper presents a case study of a producer of customized offshore oil-rigs that highlights the challenges faced by many make-to-order manufacturers. The oil-rig manufacturer experienced escalating subcontracting costs, as it had to rely heavily on subcontractors to meet its highly variable demand. The authors propose a planning framework with a master production schedule (MPS) for each sub-assembly and planned lead times for each work station. Longer planned lead times, along with a smoother MPS, lead to more leveled production at each workstation and to less subcontracting. But both the smoothing of the MPS and the planned lead times at the work stations are constrained by the requirement of a fixed delivery lead time for all orders. The authors solve an optimization model to determine the optimal MPS smoothing and planned lead times given this constraint. The following insights are gained: (1) more MPS smoothing is preferred for a sub-assembly that faces more variable demand, with less workload variability at the workstations; (2) more workstation smoothing from longer planned lead times are needed for sub-assemblies with greater variability in processing requirements, and with higher workstation utilization rates and/or unit subcontracting costs; (3) smoothing at an upstream station has the added advantage of smoothing arrivals to downstream stations.

Optimal Production and Admission Policies in Make-to-Stock/Make-to-Order Manufacturing Systems
Seyed M. R. Iravani, Tieming Liu, David Simchi-Levi

Manufacturing systems that can work in both the make-to-stock (MTS) and the make-to-order (MTO) modes are important in practice today. For example, in the automobile industry, a part supplier may produce products for both original equipment manufacturers (OEMs) and the aftermarket. OEM sales are based on long-term contracts, and thus they are made to stock and have higher priority. Aftermarket items have lower priority and are MTO due to their large variety. Iravani, Liu, and Simchi-Levi study the optimal production, rationing, and admission control policies in a manufacturing system that produces a high-priority MTS and a low-priority MTO product. The authors shows that the optimal policies are characterized by a simple partial-linear structure. Out of the three controls, only part of the admission threshold might be non-linear. The authors further show that a linear heuristic characterized by three parameters, namely, the base-stock level (S), the rationing level (R), and the backlog-up-to level (B), closely approximates the optimal policy. The partial-linear optimal policy and its linear heuristic provide interesting managerial insights and facilitate industrial implementations.

Lifecycle Pricing for Installed Base Management with Constrained Capacity and Remanufacturing
Andreas Robotis, Shantanu Bhattacharya, Luk N. Van Wassenhove

Across a diverse set of industries, especially in the business-to-business (B2B) sector, an increasing number of manufacturers are transforming themselves from pure manufacturers to service providers by bundling the usage of products along with maintenance services. Installed base management (or operational leasing) is a prime example of a key strategic option adopted by these firms. The leasing arrangement put in place provides a new revenue opportunity through product remanufacturing, as the ownership of the product rests with the firm. A natural question that arises is how this product/service bundle should be priced during the product's lifecycle. In leasing arrangements, pricing decisions are more complex since unlike traditional product purchases, they involve decisions not only for the price but also for the length of the leasing duration. Robotis, Bhattacharya, and Van Wassenhove show that capacity restrictions along with remanufacturing savings play an important role in pricing decisions and we provide guidelines for managers faced with these decisions.

Assortment Planning for Vertically Differentiated Products
Xiajun Amy Pan and Dorothee Honhon

Consider the problem of a retailer selling vertically differentiated products such as USB flash drives.

Manufacturers produce the flash drives in different memory sizes (2GB, 4GB, 8GB, etc.). All else equal, a customer always prefers to buy the flash drive with the highest memory capacity. But at different prices, customers purchase different products based on how they value a unit of memory. Pan and Honhon. show that, when the products are sold at the manufacturer's suggested retail price (MSRP), the best assortment could include dominated products, i.e., products which are less attractive than at least one other product, on every possible dimension (price, quality, and cost). This is not the case when the retailer is free to set the price of the products in the assortment as well. The authors provide solution methods for efficiently solving the two optimization problems. The authors also test the applicability of our methods with a case study involving realistic data for two product categories: Lexar flash drives and Apple's iPad.

Impact of Storage Assignment Decisions on a Bucket Brigade Order Picking Line
Scott Webster, Robert A. Ruben, Kum-Khiong Yang

A bucket brigade order picking system prescribes that workers pick in a fixed sequence with periodic hand-offs along a storage rack in a warehouse. The system automatically adjusts the picks of each worker to the variation in work content across pick lists. Webster, Ruben, and Yang examine the impact of product stocking decisions and other factors on the throughput of a bucket brigade order picking system. Their analysis leads to a number of managerial guidelines:

1. Throughput is most sensitive to the product stocking decision when variation in worker skill is high, variation in SKU volume is high, and walking-to-picking work content per pick list is moderate (e.g., around 50%). 2. If differences in worker walking speeds dominate differences in picking speeds, then intermixing SKUs of different volumes throughout the rack (i.e., uniform layout) is a prudent choice. 3. If differences in worker picking speeds dominate differences in walking speeds, then stocking SKUs in order of lowest-to-highest volume (i.e., end-loaded layout) can significantly increase throughput relative to a uniform layout (e.g., by as much as 20% for the systems considered). 4. Managers faced with high worker turnover will generally find that an end-loaded layout is able to reduce the impact of introducing a new and slower worker on throughput.

Inventory Policy with Parametric Demand: Operational Statistics, Linear Correction and Regression
Vivek Ramamurthy, J. George Shanthikumar, Zuo-Jun Max Shen

The newsvendor problem involves determining the inventory of goods to stock in anticipation of future, uncertain demand. This remains a serious problem for firms even today, whether due to chronic product shortages or costly inventory surpluses. This is often due to making probabilistic assumptions about demand that may not hold in practice, and also the limited availability of past demand data. For example, it may be reasonably assumed that the I-Pod Touch 2 would have a Gamma demand distribution, based on the sales data of the I-Pod Touch (i). However, due to limited sales data for the I-Pod Touch 2, it is likely that there will be a great deal of uncertainty about the parameters of its demand distribution. In this research, Ramamurthy, Shanthikumar, and Shen, develop and illustrate some data-driven approaches to the newsvendor problem. They focus on using limited, past demand data, in order to devise efficient inventory control policies.

On Optimal Expediting Policy for Supply Systems with Uncertain Lead-Times
Panos Kouvelis, Sammi Y.Tang

Panos Kouvelis and Sammi Tang examine the role of expediting in dealing with lead-time uncertainties associated with global supply chains of "functional products" (products having high volume and low demand uncertainty). They study the optimal way to utilize an expediting service when firms are able to obtain detailed lead-time information when shipments pass through some intermediate point along the supply chain. They find that depending on the relative cost premium of the expediting service and the lead-time information obtained, it may be optimal to expedite only a portion of the whole order, and it may not be true that longer delays always lead to expediting a larger portion of the order. Their study also shows that the expediting option supports the placement of larger replenishment orders, thus taking increased advantage of economies of scale. Also, expediting allows firms to place orders closer to the start of the selling season, serving as a substitute for the safety lead-time and adding to the system responsiveness. Based on their study, the authors propose simple heuristics to help managers implement the optimal expediting policy.

Price and Service Competition in an Outsourced Supply Chain
Yue Jin, Jennifer K. Ryan

The use of outsourcing and contract manufacturing has increased dramatically in recent years. Once a manufacturer has made the decision to outsource, several important questions arise, including the

number of suppliers to source from and how to balance price and other supplier attributes, such as service, when allocating demand between competing suppliers. To address these questions, Yue Jin and Jennifer Ryan study a manufacturer who outsources the production of a product to multiple suppliers who compete on both price and service. The manufacturer allocates demand to the suppliers using a two-dimensional score function, which depends on the prices and service levels offered by each supplier. The authors consider how the manufacturer should determine the relative importance of price vs. service when making the order allocation decision, taking into consideration how the suppliers compete against each other to earn a portion of the manufacturer's demand. They study how the manufacturer's costs depend on the number of suppliers and find that the increase in operational costs caused by the splitting of demand among a large number of suppliers outweighs any competitive benefits that the manufacturer can achieve from sourcing from a large number of suppliers. Therefore, the manufacturer prefers to work with a small number of suppliers.

Contracting and Coordination under Asymmetric Production Cost Information

Metin Çakanyıldırım, Qi Feng, Xianghua Gan and Suresh P. Sethi

While sourcing from suppliers, retailers often have only limited knowledge of the suppliers' exact cost components, such as raw material costs, labor costs, and production yield. Such information asymmetry is expected to lead to inefficient supply chain performance in contractual relationships. This notion has been formed in supply chain contracting studies, which assume that a supplier has the same trading options in the *outside market* (without the retailer) regardless of his cost efficiency. In reality, however, a more cost efficient supplier is likely to obtain better alternative trading options in the outside market. By allowing the supplier's outside option to be dependent on his cost, Çakanyıldırım, Feng, Gan and Sethi show that channel coordination may be achieved in spite of information asymmetry between the supplier and the retailer. Only when a low-cost supplier, relative to a high-cost supplier, is much overvalued or undervalued by the outside market, can information asymmetry induce suboptimal channel performance. When this happens, the retailer may incur a significant profit loss. Then the retailer should consider investing on learning the supplier's cost components. The value of learning, however, diminishes with the level of uncertainty in retailer's demand. These findings have implications for the retailers and manufacturers that engage in outsourcing and contract manufacturing with suppliers.

Combined Pricing and Portfolio Option Procurement

Qi Fu, Sean X. Zhou, Xiuli Chao, Chung-Yee Lee

In today's fast changing and highly competitive market environment, only those companies that can incorporate "change" into their supply and demand management process will have the capability to survive the ruthless competition. To this end, companies can, on the one hand, employ a portfolio sourcing approach to enhance supply flexibility, and on the other hand, adjust product price dynamically over time to mange customer demand. Qi Fu, Sean X. Zhou, Xiuli Chao, and Chung-Yee Lee consider a firm that adopts both strategies to serve random and price sensitive demand over a finite planning horizon. The optimal pricing, option reservation, and inventory replenishment strategies are characterized. In particular, the optimal inventory replenishment policy is order-up-to type with a sequence of thresholds. The optimal option reservation quantity decreases with both the selling price and the starting inventory level. And the optimal price decreases with the starting inventory level when demand function is additive. Moreover, the authors find the values of the option contracts procurement and dynamic pricing to the firm are more significant when the market demand is more volatile.

Multiple In-Cycle Transshipments with Positive Delivery Times

Nagihan Çömez, Kathryn E. Stecke, Metin Çakanyıldırım

Transshipments among retailers allow for the implementation of the inventory sharing strategy without physically pooling inventories at a single location. In practice, many retailers resort to transshipments to quickly meet sparse (slow-moving) customer demand without excessively increasing their inventories. However, transshipments are not perfect; each has a transportation cost, time and must be executed immediately after the corresponding customer arrival, if at all. When these realistic aspects are brought into consideration, it sometimes makes sense to transship. An optimally behaving inventory manager of a system suggests each retailer to send transshipment only when her current inventory exceeds her hold-back level. This level is robust as it is independent of her replenishment quantities and actual demands. We also establish that each sales cycle (season) has a particular but uncertain time until which transshipments are made but not afterwards. These and the ease of computing hold-back levels facilitate the implementation of the optimal transshipment policy. The optimal policy is flexible compared to complete-pooling and

no-pooling, and provide substantial cost savings. These observations extend to multiple cycles if replenishment time from the manufacturer is negligible. Otherwise, transshipment and replenishment decisions become intertwined but still can be handled with an effective heuristic. Nagihan Çömez, Kathryn E. Stecke, and Metin Çakanyıldırım present *optimal and flexible transshipments* among centrally managed retailers for a model whose *fidelity-to-reality* is increased by explicitly considering multiple in-cycle transshipments, transshipment costs/times, replenishment times and multiple cycles.

Reassessing Tradeoffs Inherent to Simultaneous Maintenance and Production Planning
Sakine Batun, Lisa Maillart

Maintenance and production planning are key operational decisions in any manufacturing environment. Clearly, it can be beneficial to make these decisions jointly as opposed to setting a production schedule after determining a maintenance policy or vice versa. In this context, two types of production policies are possible—those that change as a function of the level of deterioration and those that do not (i.e., those that are first-come-serve). Similarly, two types of maintenance policies are possible—those that set a control-limit on the deterioration level and those that do not. In this study, Sakine Batun and Lisa Maillart reexamine these types of policies in the context of a single-machine, multi-product environment with random yield and a set of product mix requirements. Based on an improved model of first-come-first-serve production policies, the results refute the notion that there is more benefit to be gained from flexible production policies than flexible maintenance policies. Moreover, the results reveal that the combined impact of planning simultaneously (as opposed to sequentially) and using deterioration-state-dependent production policies (as opposed to first-come-first-serve) is significantly greater than the sum of the individual benefits of these actions.