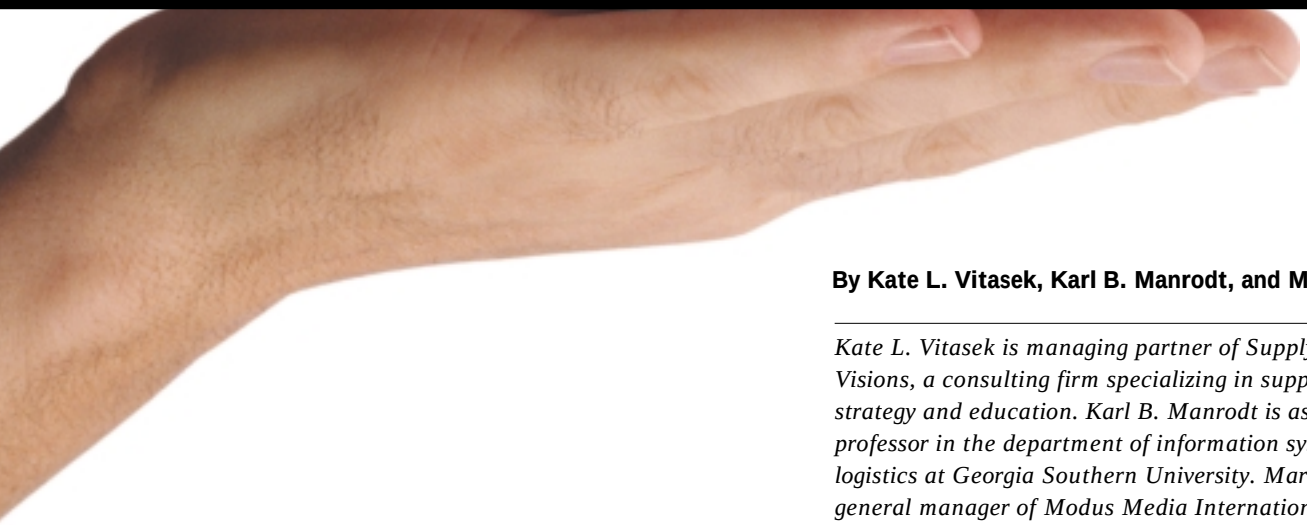
It's an age-old question: How do you match supply with demand while at the same time keeping customers satisfied? No one has come up with the "silver bullet" answer yet. But for many companies, there's an approach that can get them moving in the right direction. It's an innovative technique that builds on analyzing both the volume and variability of demand for products.

Most of us are familiar with the following scenario: The topic of your meeting has been circulated to the attendees the week before. It is the recurring question of: How do we schedule production and distribution to maximize capacity utilization and minimize inventory levels while achieving high levels of customer service. The question is complicated by the fact that demand for the firm's products varies widely. Some of the products with less demand volume experience significant demand fluctuations, which has led to an increase in inventory. Other products are the exact opposite, experiencing stable demand with very little variation.

This question transcends industry and geographic location. But the answer remains elusive for most companies. In an effort to provide an answer and to address the common tradeoff between inventory and customer service levels, we propose a framework that aligns supply chain operations with demand. The framework is based on two principles:

SOLVING THE SUPPLY –



By Kate L. Vitasek, Karl B. Manrodt, and Mark Kelly

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1) Both the volume and the variability of demand must be taken into account. We call this volume-variability demand profiling.

2) Product manufacturing and distribution must be aligned with this profile through a mix of build-to-stock, build-to-order, and make-to-order strategies.

Volume and variability analysis has been used to assist in operational planning and execution since the early 1960s and is widely taught today in operations management and logistics classes. However, aside from simple safety-stock planning, companies very rarely consider both the volume *and* variability of demand in their planning and execution processes. Instead, they typically adopt a "one-size-fits-all" methodology for manufacturing and distribution. As such, variable SKUs with erratic demand often get treated the same as those units with predictable patterns, such as high-volume SKUs with a consistent level of demand.

As a result, both types of SKUs are often produced following a similar make-to-stock model. A 2003 benchmarking study by management consultants PRTM reveals how common this strategy is. According to the survey, 74 percent of all companies rely on make-to-stock production, using forecasts to drive volumes.[1] Such a make-to-stock strategy, however, is not optimal for variable products, which have low forecast accuracy levels. When variable products are produced in a make-to-stock environment, stockouts and inventory write-offs frequently occur.

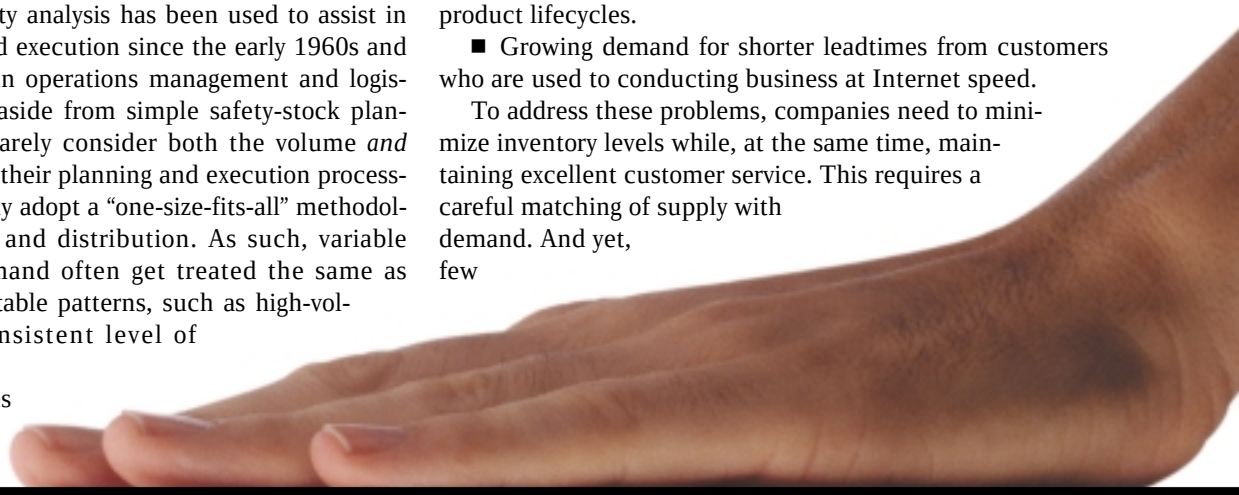
By adopting a multitier operational strategy based on volume and variability profiling, however, companies can better optimize the tradeoff between service and inventory levels. Later in the article, we describe how one company, Modus Media, is successfully implementing this approach.

- Excessive levels of inventory created by unpredictable demand.
- Difficulty in forecasting accurately because of the high speed of change in the marketplace, which means historical data is not necessarily a good predictor of future demand.
- Increasing problems with obsolescence caused by short product lifecycles.
- Growing demand for shorter leadtimes from customers who are used to conducting business at Internet speed.

To address these problems, companies need to minimize inventory levels while, at the same time, maintaining excellent customer service. This requires a careful matching of supply with demand. And yet, few companies have developed a complete demand profile upon which they can base a manufacturing and distribution strategy that best suits the product.

Instead, the widespread adoption of enterprise resource planning (ERP) systems has only encouraged companies to implement make-to-stock practices across the board. ERP systems make it easy for companies to drive their entire shop floor operations by simply loading in a forecast. A typical business will receive orders and put them into its manufacturing production schedule (MPS). Forecasts are fed in, and the value of confirmed orders is later subtracted from forecasted levels. However, forecast-accuracy averages in most industries usually do not exceed 70 percent. As a result, using the forecast as a build plan for a manufacturing requirement planning (MRP) system inevitably leads to too much or too little inventory on hand. This, in turn, ultimately leads to stockouts or inventory write-offs—especially for high-variability SKUs, which are difficult to forecast.

In short, companies are, by default, manufacturing products in the wrong quantities and mix. Invariably they have



– DEMAND MISMATCH

The Supply-Demand Mismatch

To understand the potential of the volume-variability approach, it's important to comprehend more fully the types of supply-demand problems companies typically face. Among the most common are these:

plenty of inventory; it's just not the right product at the right time. This supply-demand mismatch is further exacerbated by the common problem known as the bullwhip effect, in which slight demand variations downstream in the supply chain result in huge inventory build-ups upstream at the supplier levels.

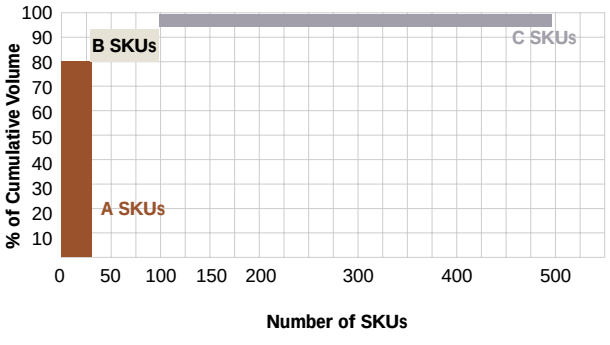
By adhering to the two principles introduced above, companies can address the chronic supply-demand mismatch and related bullwhip problems.

Principle 1: Both demand volume and variability must be taken into account.

Companies can better match supply to demand for the product if they have a complete demand profile that includes both volume and variability. Many companies today are only performing routine volume-based SKU analysis. In a volume-based analysis, products are segmented into different classes or "buckets" depending on the volume of demand. For example, fast-moving, popular items are classified as "A" items, while slower-moving products are characterized as "C" items. Most companies use a rule of thumb that "A" SKUs account for 80 percent of their overall demand volume, "B" SKUs account for 15 percent, and "C" SKUs account for the last 5 percent. Yet, "A" SKUs are only 5 percent of all items, "B" are another 15 percent, and "C" items make up the remainder. Using this approach, a company with 500 SKUs would expect to have a total of 25 "A" SKUs (5% x 500), 75 "B" SKUs (15% x 500), and 400 "C" SKUs (80% x 500). (Such an analysis is shown in Exhibit 1 below.)

In the past 20 years, companies have increased their use of volume-based analysis, particularly for determining the product's manufacturing and distribution strategies. For example, in the 1980s, some companies began using manufacturing cells for their lower-volume products. Distribution departments also began looking at volume analysis for the design of their warehouse layouts, using a zone approach for more efficient picking. Under this approach, higher-volume "A" SKUs are placed in a zone that would need less travel. Warehouse design also began moving to specialized flow racking for lower-volume SKUs.

EXHIBIT 1

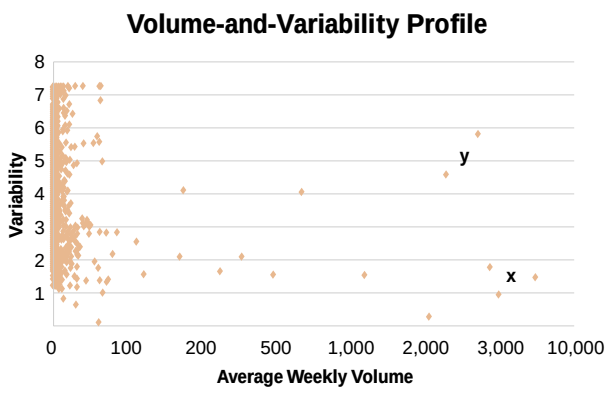


What is missing from this traditional analysis is the dimension of variability. In other words, is demand relatively constant for the "A" items, or is there a wide range of variability? Given the volume being shipped, we would argue that most "A" items experience relatively less demand variation than the other two product groups. This makes production stratification much more predictable.

Lower-volume SKUs, however, usually have much more variable demand. For this reason, we suggest augmenting the traditional SKU classification to include variability. In a volume-variability demand profile, each SKU is classified by both its volume (based on unit volume or dollar volume) and its variability (represented by standard deviation or normal standard deviation). Exhibit 2 shows an example of a volume and variability profile.

Each dot on the chart indicates where a particular SKU falls in terms of its combined volume and variability. Note that some of the SKUs have a relatively low weekly volume with a fairly normal distribution of variability. A few of the products show a high weekly volume pattern with relatively low variability (point x on the figure). Two items (point y) experience both high degrees of variability and high levels of weekly volume. It is these items that can cause significant disruption in the manufacturing and distribution processes. Supply chain professionals typically either hold larger quantities of inventory to handle the variation in demand, or they attempt to manufacture the products in a shortened time window.

EXHIBIT 2



Note: Variability can be classified as Standard Deviation or Normal Standard Deviation.

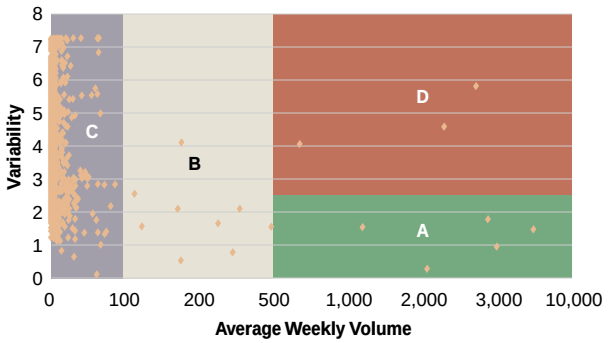
Through this volume-variability analysis, companies use a new way to classify products into four main categories based on their volume-variability demand profile as shown in Exhibit 3. Each of these four categories is discussed below.

"A" SKUs represent high-volume products with predictable demand. These types of products are usually the companies' bread and butter. Scheduling for these items is fairly straightforward, as the overall volume is predictable.

"B" SKUs represent products with medium volume and low-to-medium variability. These are typically your average products. They are not your top sellers—but they are also not your "dogs."

EXHIBIT 3

New SKU Classifiction System Based on Demand Volume and Variability



"C" SKUs represent all low-volume products. Traditionally "C" SKUs have been the biggest headaches for operations. Most operations managers strive to optimize throughput of manufacturing equipment, and these SKUs slow down production and cause changeovers. This leads to an increase in inventory levels and associated costs. Although "C" items represent only a small amount of volume, they have the poorest service levels. The reason: They are often pushed aside to make room for high-volume products that drive revenue and fill rates.

"D" SKUs have both medium-to-high volume and high variability. These might be items that are often put on promotion to increase sales. They have the most potential to negatively affect overall customer service. For example, a typical approach may be to have 2,000 "D" units on hand for weekly average demand across all of your customers. But a single special order for that product can exceed the current level of inventory, leaving the company in an out-of-stock position for the rest of its customers.

Demand profiling by both volume and variability can help companies more effectively manage products in each of these SKU categories. By looking at both volume and variability, a company can begin to understand the impact of a particular SKU on its operations. In other words, by understanding the nature and associated variability of demand, companies can more efficiently optimize their operations to meet the real needs of the marketplace.

Principle 2: Product manufacturing and distribution must be aligned with the demand volume-variability profile through a mix of build-to-stock, build-to-order, and make-to-order strategies.

Until the 1980s, most companies were still relying on traditional assembly-line manufacturing methodologies popularized by Henry Ford with the Model T. The last two decades, however, have brought an influx of innovative manufacturing and distribution techniques aimed at helping companies become more efficient in managing day-to-day operations. For example, the widespread adoption of MRP systems greatly enhanced a company's manufacturing productivity by allowing it to load in forecasts and complex bills of materials. Cellular manufacturing became a popular "high service" option to the traditional assembly line. In the late 1990s, accountants began to preach the benefits of using a rate-based approach to planning operational capacity.[2] In distribution, quality leaders such as Motorola, Xerox, and Toyota have led the way in bringing the *kanban* concept to the United States after much success in Japan. In addition, volume-based SKU profiling has become a popular method for designing warehouse layout to drive picking efficiencies.

But how does a company know what is the right method to use? We propose that companies use a mix of manufacturing and distribution strategies based on a volume and variability demand profile. In essence, this means selecting the most efficient techniques for the demand profile to drive high service levels while at the same time minimizing inventory. Exhibit 4 gives some suggested manufacturing and distribution strategies based on a product's volume-variability demand profile. Each of these strategies is discussed in greater detail below.

"A" SKUs – High-volume, low-variability SKUs ideally should be run through a straight assembly line in a make-to-stock (MTS) environment. Harkening back to Henry Ford, all manufacturers know that this is the most labor-, time-, and

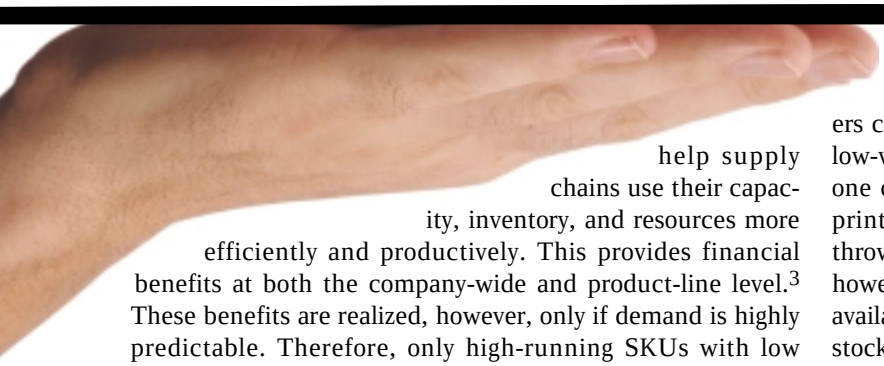
EXHIBIT 4

Distribution and Manufacturing Stategies By Volume-Variability Profile

Volume-Variability Profile	Possible Manufacturing Strategies	Possible Distribution Replenishment Strategies
A	· Assembly Lines · Make to Stock (Component Inventory on Hand) · Factory Level Loading	· Fill from Stock (Finished-Good Inventory on Hand) · Rate-Based Planning to Trigger Manufacturing Replenishment
B	· Assembly Lines or Cellular Manufacturing · Build to Order from Kanbans (Component Inventory on Hand)	· Fill from stock Finished-Good Inventory on Hand if Long Manufacturing Leadtime or Kanban/JIT Replenishment from Manufacturing if Shorter Leadtimes are Available · Kanban Planning to Trigger Manufacturing Replenishment
C	· Cellular Manufacturing · Make to Order (no Component Inventory on Hand) · On-Demand Manufacturing (if Available)	· No Finished-Good Inventory on Hand (Fulfill from Manufacturing via Make to Order)
D	· Assembly Lines · Make to Order	· Finished-Good Inventory on Hand for Maximum Order Quantity Projections Only. · Orders Exceeding Order Quantities Have Longer Leadtimes

cost-efficient way to manufacture and distribute a large quantity of goods. Because demand for "A" SKUs is so predictable, companies can produce items in anticipation of demand with reasonable confidence that they won't end up carrying excess or obsolete inventory. As a result, planning can be rate based—in other words, based on the average rate of demand for the product. This predictability, in turn, helps companies to level load the factory with consistent and pre-planned manufacturing runs, thereby better managing capacity and production operations. By matching capacity to actual demand, rate-based planning and execution (RBPE) tools help supply chains use their capacity, inventory, and resources more efficiently and productively. This provides financial benefits at both the company-wide and product-line level.[3] These benefits are realized, however, only if demand is highly predictable. Therefore, only high-running SKUs with low variability should be MTS. Using a make-to-stock strategy and RBPE tools for SKUs with more variable demand results in inventory excess and obsolescence, which is expensive and inefficient.

Companies should select their business models and inventory levels based on real customer demand instead of forecasted demand.



"B" SKUs – Medium-volume SKUs with low-to-medium variability can best be managed under a kanban or a just-in-time (JIT) model. These build-to-order (BTO) approaches achieve both good customer service and optimized inventory levels for this SKU group. They allow companies to have enough component and part inventory on hand to respond to medium-volume demand in a timely manner. But, by not carrying finished-goods inventory, the companies can also keep inventory levels relatively low. These manufacturing approaches also eliminate the need for advanced planning of these SKUs. Rather than running an MRP on these items, the kanbans will trigger the manufacturing and distribution process. This ultimately eases administrative tasks associated with detailed shop-floor planning.

These and other low-volume SKUs typically employ cellular manufacturing instead of assembly lines because the efficiencies created by assembly-line production are lost if the company is only manufacturing a small batch of goods. If the company has to keep stopping and changing the assembly line to produce a different product, it drives up switching times and costs. Cellular manufacturing, however, allows a company to quickly assemble low or medium volumes of goods from on-hand components that are conveniently grouped together in a manufacturing cell.

"C" SKUs – All low-volume SKUs are ideally suited for a make-to-order (MTO) model—especially if there is a cost-effective, manufacturing-on-demand solution available. Using a manufacturing-on-demand technique (if available) enables companies to have the best of both worlds. It allows them to have a quick cycle time for fast customer service while also eliminating excess and obsolete inventory. Even though there is often a higher per-unit cost associated with manufacturing on demand, it is ultimately a much more cost-efficient process for low-volume goods. This is because the company does not risk having to dispose of unused products or components. Companies can conduct a break-even analysis to determine the volumes at which on-demand manufacturing becomes cost efficient.

This particular approach has proven effective in certain business sectors. For example, traditional print and CD manufacturers can leverage print-on-demand and CD-R technologies for low-volume runs. In many cases, it is more efficient to print one copy of a low-demand book for 4 cents per page than to print 500 copies at .01 cents per page and risk having to throw the majority of those copies away. Not all industries, however, have a viable on-demand manufacturing technique available for key components. In these cases, we recommend stocking only raw materials to keep inventory obsolescence to a minimum.

"D" SKUs – These high-volume, high-variability SKUs have the most potential to impact overall customer-service fill rates because companies can blow out all their inventory trying to fulfill one or two big orders. "D" SKUs are often related to items that have higher variability because they are promotionally driven. For example, a SKU may typically sell 1,000 items per week, but when Wal-Mart decides to do a promotion, the order volume goes up to 25,000. When a customer places a big order that has not been properly planned for in distribution, it drives out-of-stocks—not just for the customer that placed the order but also for all the customers that need that product. Furthermore, sometimes these one-time orders can wipe out a common component that the product shares with other SKUs in manufacturing. This will hurt the company's fill rate for these products as well. Instead of depleting the company's safety-stock inventory, "D" SKUs are best handled as special orders and should be made to order on an assembly line. Companies that do not have an alternative manufacturing-on-demand option with a quick cycle time can increase customer-service levels by stating maximum order quantities on the price list. Customers should be informed that orders larger than these maximums will be MTO and may require an incremental increase in leadtimes. While this approach may result in slightly longer leadtimes, it

will improve overall customer-service levels by preventing an out-of-stock situation for that particular SKU for the majority of customers.

It is important to note that a SKU's classification by volume and variability is not fixed. Instead, companies can modify each SKU's classification, as needed, in the planning phases. For example, marketing may have a promotion on a particular product; by knowing this in advance, the SKU can be reclassified into a more optimal production category (for example from "A" to "D"). Likewise, if market intelligence shows sales are not materializing as hoped, a particular SKU can be downgraded to a different SKU classification (for example from "A" to "B") and placed into a kanban-type planning model to help bleed inventory.

Furthermore, companies may mix and match various strategies to best meet their needs. For example, a company with a one- or two-day turnaround from manufacturing may want to hold finished-goods stock in distribution (instead of manufacturing) because the turn time is good. But a company with a seven-day leadtime may want to maintain quick customer-service turnarounds by maintaining stock in manufacturing.

The Volume-Variability Benefits

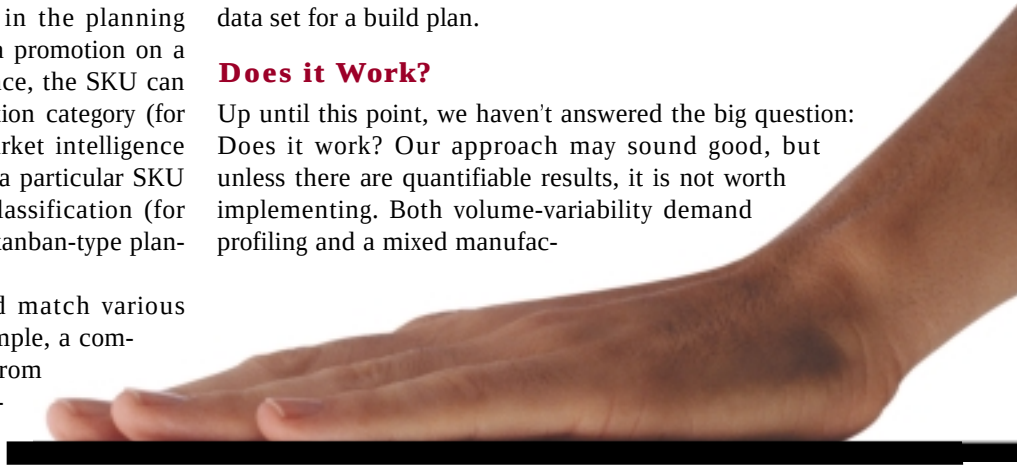
By selecting appropriate manufacturing and distribution methods based on volume and variability, companies can improve operational efficiencies by optimizing service levels while keeping inventories to a minimum. Service-level expectations can be managed by communicating leadtime and other exceptions on the order form. In addition, companies can use statistical analyses that combine both volume and variability to set safety-stocks levels that are most efficient to meet customer service goals.

The key element of this approach is the use of different operational models to buffer demand volatility in the supply chain. Under this approach, companies are selecting their business models and inventory levels based on real customer demand instead of forecasted demand (as occurs when companies use an across-the-board MTS strategy). By classifying SKUs by their demand profile, companies can identify when the risk of holding inventory for a SKU is too great and, in such cases, adopt a BTO approach with a fast turnaround. The approach also makes it clear that a company should only bet on needing finished-goods inventory with high-volume, low-variability SKUs. Having finished-goods inventory gives the organization the best possible chance of satisfying customer requirements at optimal cost when demand for those SKUs materializes.

Finally, this combined volume-and-variability approach mitigates the reliance on, and risk associated with, inaccurate forecasts. Forecasts are traditionally used for planning. When forecasts are used to release orders in anticipation of demand, stock is built prior to known demand. The longer the time period between order release and sale, the greater the opportunity for misallocating capacity for a given product. Under a combined volume-variability approach, the forecast is just one data element in the planning process vs. the fixed data set for a build plan.

Does it Work?

Up until this point, we haven't answered the big question: Does it work? Our approach may sound good, but unless there are quantifiable results, it is not worth implementing. Both volume-variability demand profiling and a mixed manufacturing/distribution methodology are used at Modus Media International, a global supply chain services provider to many of the world's largest technology companies.



Few companies have developed a complete demand profile upon which they can base a manufacturing and distribution strategy that best suits the product.

As a provider of outsourced manufacturing and distribution services, Modus must deal with the challenge of tailoring its operating practices to meet diverse customer requirements. For example, many customers want Modus to manage min/max and vendor-managed-inventory programs based on a combination of forecasts and predetermined coverage levels for finished goods in terms of days or weeks. Yet, in order to maintain high service levels for all of its accounts, Modus faced the prospect of increasing inventories and working capital requirements. Modus needed a standardized solution for materials management and order fulfillment that would address the specific operational requirements of its different customers while also optimizing Modus' inventory and capacity levels. Modus also wanted a solution that would leverage its ERP system and be 100 percent transferable across customers and facilities. In 1998, the company and one of its largest original-equipment-manufacturer (OEM) customers began exploring solutions to meet this objective at the Modus facility in Cumbernauld, Scotland. They decided to use both volume and variability as key drivers for their planning and execution processes.

In simple terms, Modus has enhanced its sales and operational planning cycles by considering both the volume and variability of its SKUs. To accomplish this, the company has expanded its planning process from strictly forecasted quanti-

tative methods to include trend analysis information and other qualitative data.

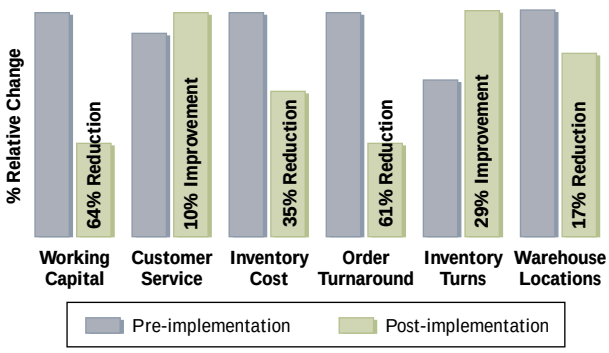
A second key to Modus' success was to use a simple two-tier manufacturing and distribution approach. Under this approach, "C" SKUs (low-volume, low-variability products) are made to order, while all other SKUs use a kanban approach. Modus' MRP system generates internal orders that are used either to replenish an inventory target (that is, a kanban) or immediate shipment requirements for MTO SKUs. Simple rules dictate that all MTO parts have the highest priority within the facility and are dealt with first. The reason for this is that kanban SKUs have inventory on hand and Modus can ship from stock to maintain high service levels. Orders for kanban SKUs are sent directly to distribution for fulfillment while orders for MTO SKUs are sent directly to manufacturing.

Once manufacturing for MTO parts has been satisfied, the kanban items are dealt with. A color-coded system is used in distribution to determine the priorities within the kanban parts that are sent to manufacturing. For example, kanbans are coded green, yellow, and red for all products. A part with red kanbans has less inventory and is at a high risk of running out of stock. Therefore, it has a higher priority than a part with either yellow or green kanbans. Similarly, yellow kanbans are higher priority than green. Modus aligns all manufacturing at the shop floor by this simple color-coded priority system. By focusing on manufacturing items with the highest risk of out-of-stocks in distribution, Modus is in essence aligning supply with demand.

Before Modus implemented the solution, a lot of time and effort was lost in the interaction between the customer-facing business-management teams and the production planners. Trying to plan a weekly production schedule proved very difficult. By using SKU-based profiling to drive planning at the end-item level, each part now is identified as either MTO or kanban replenishment. The whole planning process is made much simpler and more efficient by using simple replenishment rules to drive shop-floor scheduling. This approach has streamlined the flow of products throughout the manufacturing and distribution process. Production builds and ships to the simple two-tier sequence (MTO first, then kanbans by color-coded priority) for that shift and then gets a new list and sequence from the MRP at the start of the next shift. This works similarly for purchasing. On a daily basis, buyers place orders for all MTO items first and then for the red and yellow kanban supply requirements.

Overall quantitative results are impressive, yielding benefits in inventory, working capital, and service levels. Exhibit 5 shows the percentage improvements across key metrics. Additional verification of the new process came in April 2002, when Modus won a Supply-Chain Council award for technology excellence for its efforts. The firm is currently in the process of implementing the volume-variability approach across all of its facilities.

EXHIBIT 5



Making a Better Match

More and more, success in today's marketplace depends on solving the question that has plagued Monday morning meetings for ages—How do you optimize inventory while maintaining high service levels? According to Ohio State University Professor Emeritus and supply chain thought leader Bud La Londe, "There is a sustainable competitive advantage for whoever figures that out first."[4] The Modus case study demonstrates one company's response. Instead of blindly implementing a make-to-stock operational strategy for all products across the board, companies can utilize a best-fit, multitier manufacturing and distribution method. Implementing the right operational strategy, however, depends heavily on understanding a product's demand—and not just its volume but also its variability. Companies that understand their products' demand and can adapt their manufacturing and distribution strategies accordingly will achieve the win-win situation of improved customer-service fill rates and lowered inventory positions.

Some might argue that these principles may not work in their particular industry. However, we believe that to some extent all companies can apply the basic concepts of volume-and-variability profiling regardless of their industry. For example, even companies in the most complex industries—say, aerospace—can apply these concepts to their basic SKUs and common components. At the very least, all companies can benefit from using volume-variability demand profiling to identify the manufacturing and distribution approach that can best address their supply-demand mismatch.

Footnotes

[1]Performance Benchmark Group. *2002 Supply Chain Planning Benchmarking Study*, presented at the Supply Chain Council's Supply Chain World Conference, April 2003.

[2]Reeve, Jim. "The Financial Advantages of a Lean Supply Chain," *Supply Chain Management Review*, Vol. 6, No. 2, March / April 2002, pp. 42 - 49.

[3]Ibid.

[4]Bonney, Joseph and Helen Atkinson. "An Unexpected Discovery," *Journal of Commerce*, Feb. 18 - 24, 2003, p. 22.