

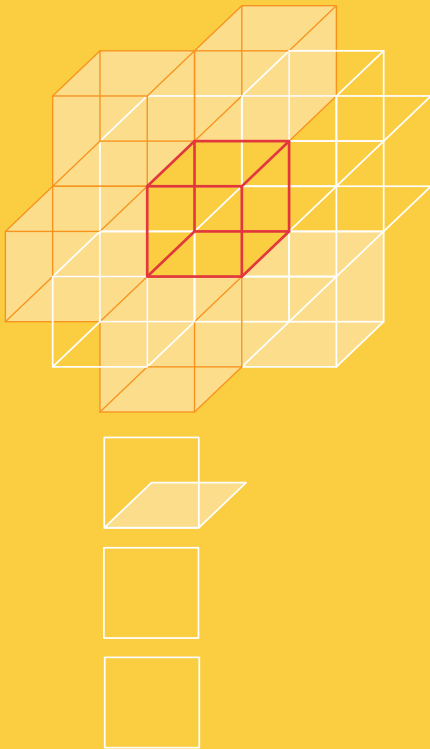


NONSTOP's

*"Supply Chain Management Seminar"*



White Paper Series



# Demand Chain Optimization

## *Pitfalls and Key Principles*



by  
Calvin B. Lee, Ph.D.  
Vice President and Chief Scientist,  
NONSTOP Solutions

## **Demand Chain Optimization: Pitfalls and Key Principles**

**By Calvin B. Lee, Ph.D.**

**Vice President and Chief Scientist, NONSTOP Solutions, Inc.**

Recent estimates from the U.S. Commerce Department indicate that in the United States, \$1.1 trillion in inventory supports \$3.2 trillion in annual retail sales. This inventory is spread out across the value chain, with \$400 billion at retail locations, \$290 billion at wholesalers or distributors, and \$450 billion with manufacturers. With this large stockpile of inventory, stock-outs at the retail level should be very low—one would think. But that is not the case. Studies have shown that 8.2% of shoppers, on average, will fail to find their product in stock. These stock-out events represent 6.5% of all retail sales. Even after recouping some of the loss with sales of alternative product, retailers will suffer net lost sales of 3.1%. This takes an enormous toll on retail margins, not to mention customer goodwill.

So what's the problem? The unsatisfactory service is not for a dearth of inventory. The problem lies in lacking the right product, at the right place, at the right time to service customers. Before exploring remedies to the problem, let me first paint the picture of the *demand chain*.

A demand chain is a network of trading partners that extends from manufacturers to end consumers. The partners exchange information, and finished goods flow through the network's physical infrastructure. The physical facilities include manufacturers' warehouses, wholesalers' distribution centers, retail chains' warehouses, and retail outlets. A demand chain can include multiple business enterprises. As product flows through the network, the partners incur costs—but they also enjoy revenue, as product moves between business enterprises.

The objective in Demand Chain Optimization (DCO) is to increase enterprise value for any part or all of the demand chain. We say “part,” because one can only optimize those components in the demand chain for which control can be exercised. For example, consider the demand chain that extends from *manufacturer to wholesaler to retail chain warehouse to retail store*. It's possible to optimize the demand chain for each trading partner's portion of it, but total optimization requires a common objective that may or may not exist.

DCO can impact enterprise value in many ways. It can produce:

- Higher customer service levels, which lead to greater revenue and net income.
- Higher inventory turnover, which frees up working capital.
- Higher worker productivity, which lowers operating expenses.
- Higher capacity utilization, which increases the return on assets.
- Lower logistics costs, which decreases operating expenses.
- Lower costs of goods sold, which increases net income.

Each one of these will increase an enterprise's return on assets. That, in turns, leads to increased return on equity and shareholder value.

The effects of DCO are broad, influencing the overall financial health of the enterprise; however, the business decisions that drive DCO are ultimately made at the Stock-keeping Unit (SKU) level. A SKU is a specific product at a specific location. SKU management requires many decisions, such as: When should you replenish the SKU? What quantity

should you order? What customer service objective is appropriate for this SKU? Who do you order from? Could you better utilize the inventory for this SKU at another location? Should you even stock this SKU? What will happen to demand if you change the SKU's price? And there are many more questions.

Finding the right answers is not trivial. This complexity is due to the many sources of uncertainty and the large number of decision alternatives. These many alternatives partly stem from the variety of approaches that you may want to consider. SKU demands are highly stochastic, and may vary because of seasonal, day-of-week, and other special-event effects. Product availability and supplier lead times may also play a role.

Making these decisions, and the many others required for effective DCO, requires an understanding of the key principles of DCO and knowledge of the pitfalls that trip up enterprises as they strive to optimize their demand chain.

### **Pitfalls of DCO**

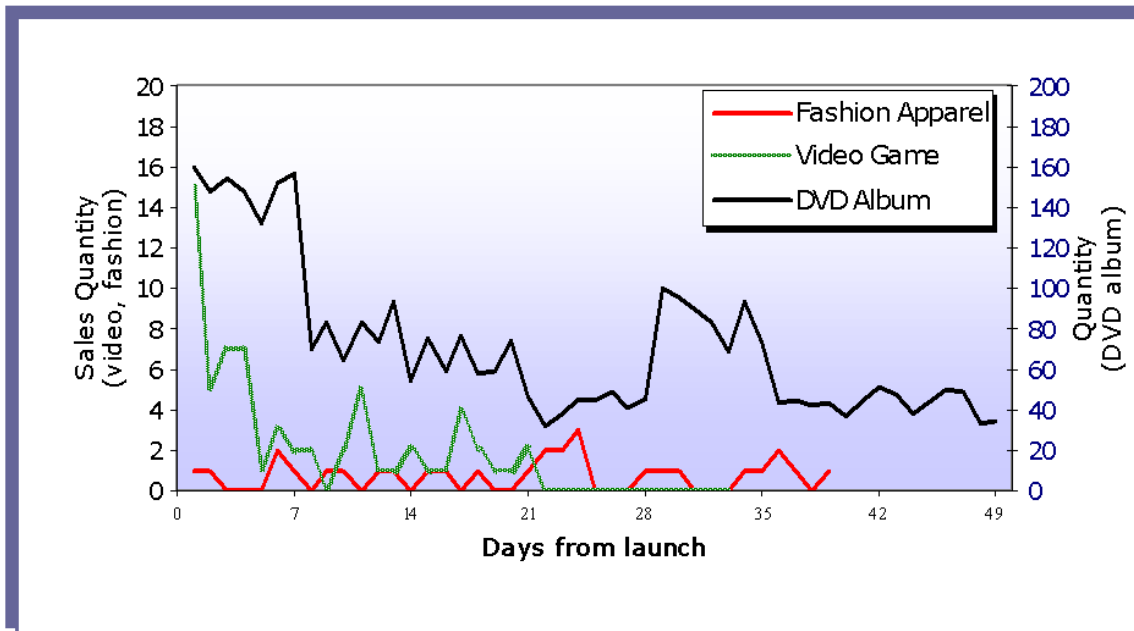
DCO is rife with pitfalls. Many may seem obvious, yet they are typically the reason demand chain improvement efforts fail. Here are some common pitfalls:

1. ***Demand forecasting relies on one approach.*** This is very risky, because demand patterns vary significantly based on both the type of SKU and where the SKU is in its life cycle. Consider a SKU with a short life cycle, such as a computer video game or a DVD. The life cycle for this kind of SKU typically lasts two to six weeks. The figure below shows examples of these types of SKUs, along with a typical fashion apparel SKU. The forecasting technique used for a regular-turn product in the middle of its life cycle is problematic for a short life cycle SKU. By the time a standard forecasting algorithm can catch up with the demand pattern of a short life cycle SKU, the SKU's life may be over—and sales opportunities have evaporated.

Fashion apparel SKUs can be notoriously slow sellers; therefore, they require alternative forecasting techniques. For new products with no historical demand data, you cannot rely on the same forecasting algorithm you use for regular-turn SKUs. Marshall (1997) distinguishes between “functional” and “innovative” products and points out the need to use different approaches when forecasting demand for each type. New products fall into the innovative group and require very responsive forecasting and replenishment approaches.

Even in a business with some of the most durable products, SKU types are highly diverse. The toy industry provides an example. Standard techniques will suffice for steady sellers like traditional board games, but as Johnson (2001) points out, new, fad-sensitive, short life cycle toys call for new forecasting approaches.

SKUs that are part of promotions or other special events require causal techniques to predict the expected demand lifts as well as their cannibalization effects on non-promoted SKUs. The graph below shows how demand for a fashion apparel SKU fluctuates during price markdowns at the end of the SKU’s life cycle.

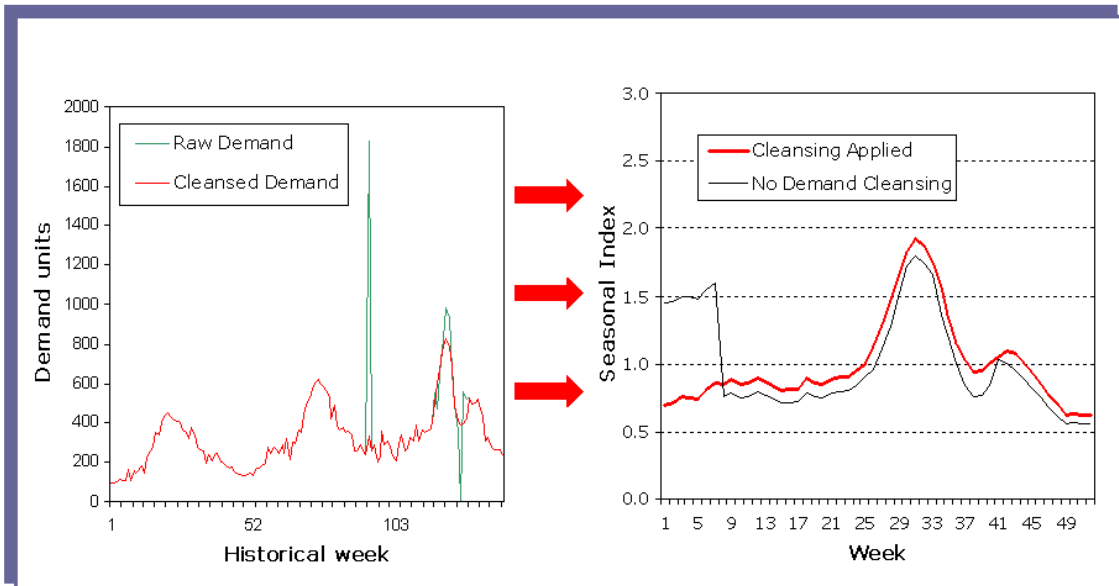
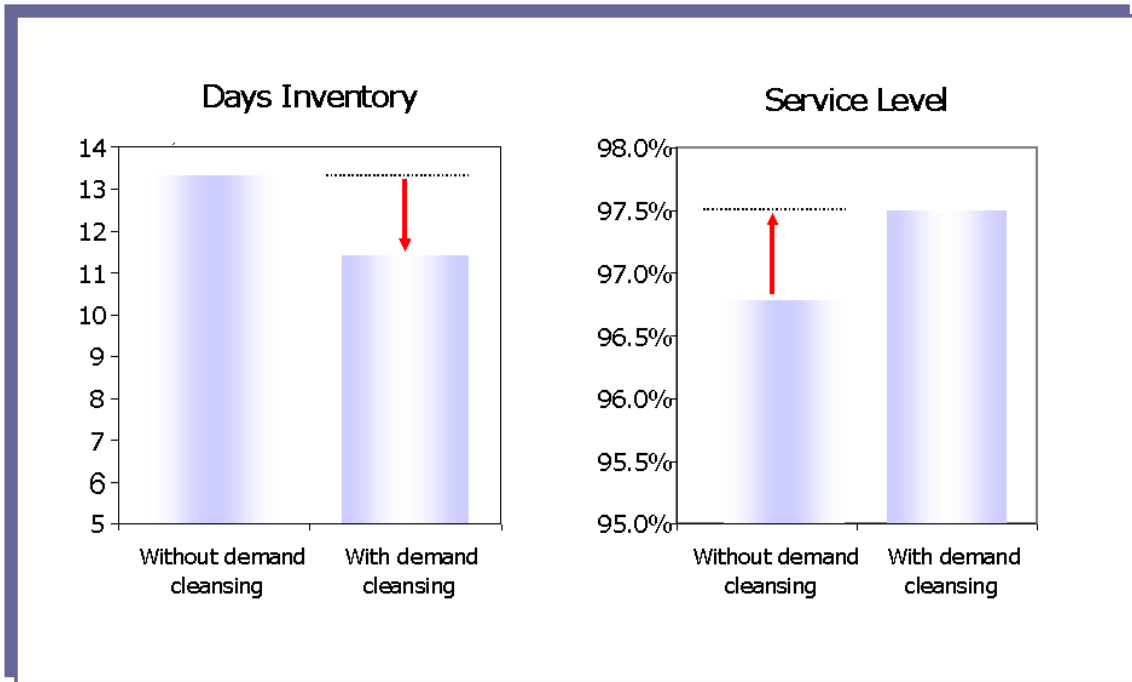


- 2. Data cleansing is performed perfunctorily, and differentiation between systematic and random change is not handled rigorously.*** You must be sure your data are cleansed of atypical outliers and patterns before it enters a forecasting model. The techniques used to perform this task range from simple to complex. As the adage “garbage in, garbage out” suggests, you must not underestimate the value of data cleansing. Point of Sale (POS) data are the demand data retailers typically use to drive replenishment. Unfortunately, promotional activities, entry errors, unusual customer returns, incorrect returns processing, system glitches, item markdowns, and external shocks to the retail operation (such as a terrorist attack or a natural disaster) distort the demand signal from POS data. It is essential to remove, but not necessarily discard, these distorting effects from the original demand data. Otherwise, the resulting base demand forecasts will factor in irrelevant effects.

Having studied volumes of retail sales data for short life cycle products, Marshall et al (2000) emphasize the importance of clean, accurate data in the retail space. But cleansing demand data is complicated. Starting with the raw demand signal, the process requires a careful differentiation between systematic and random change in demand. A shock to the demand signal from a terrorist attack is a one-time event that should be adjusted out of the demand signal. But demand for a drug or an auto part product may display clear seasonal patterns. In this case, demand cleansing can help you create appropriate seasonal profiles.

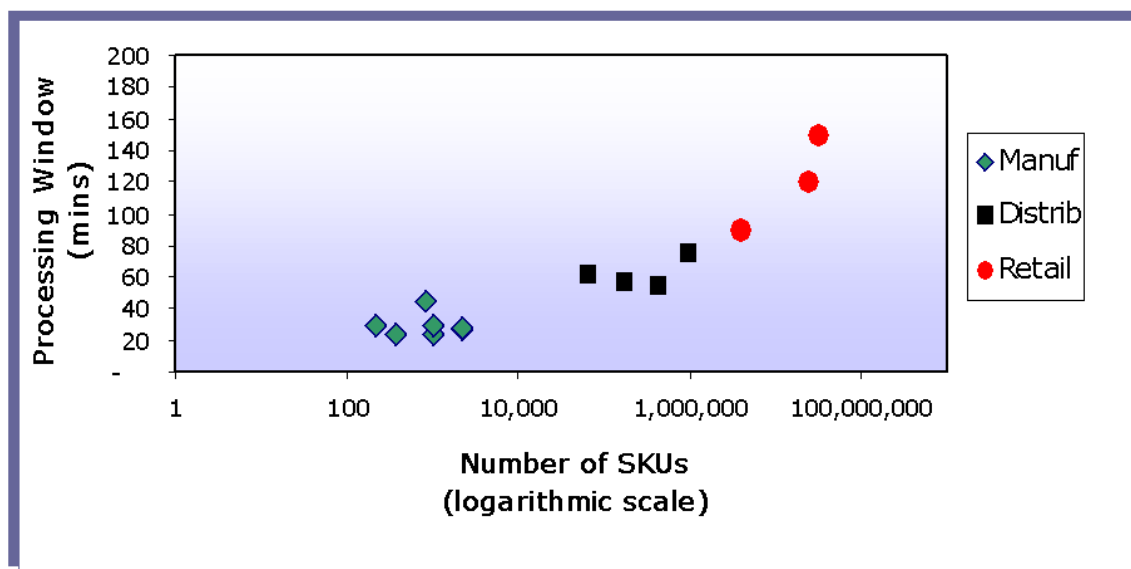
Demand data command the greatest attention in data cleansing. Supplier lead times also must be cleansed of anomalous values. One-time extraordinary lead times, which weather, natural disasters, or labor disputes can cause, must be cleansed so as to not distort the lead time estimates used in replenishment calculations.

The figures below illustrate the benefits of proper demand cleansing. The first set of charts shows the potential gains in inventory and service for more than 30,000 SKUs of a major distributor. The second set of charts shows how demand cleansing impacts seasonal profile accuracy.



3. **Computational efficiency is not a major consideration.** People sometimes think, “Computers are getting faster and faster, so why be overly concerned about computational speed?” This is fallacious thinking, because of the huge number of SKUs that require computations. The number of computations rises significantly as the demand chain moves from manufacturer to retail outlets. In the retail space—because of the number of sales outlets and the multiplicity of styles, colors, and sizes—the phenomenon of “SKU explosion” can raise the number of SKUs, for a single line of product, to tens of millions. A recent report indicates one large retailer has 30 million *shoe* SKUs.

The chart below shows the SKU explosion, moving down the demand chain. The processing time per SKU might be small, but when you multiply that processing time by the number of SKUs, it can be extremely challenging to finish all the computations within a tight time window. As the demand network grows more complex, as echelons get added, or as the number of locations within an echelon increases, the number of SKUs can grow geometrically. (An *echelon* is a set of locations that are replenished by a common set of suppliers.) The optimization solution must be scalable, or it will hit the figurative brick wall when retailers apply it at the lowest retail level. The illustration below depicts the general relationship between SKU counts and processing windows for a set of manufacturers, distributors, and retailers.



4. ***The replenishment methodology is simplistic or is the same for all SKUs.*** For replenishment of regular-turn SKUs, the traditional order-point, order-up-to-level approach has wide application. The order point is the inventory position that triggers a replenishment order. The order-up-to level is the inventory position objective of your next order, if you do order. Often, these set points are determined subjectively. For example, it is not uncommon for a retailer to have infrequently updated values that depend primarily on merchandising factors like presentation or model stock; factors like demand, lead time variability, and desired customer service are not part of the equation.

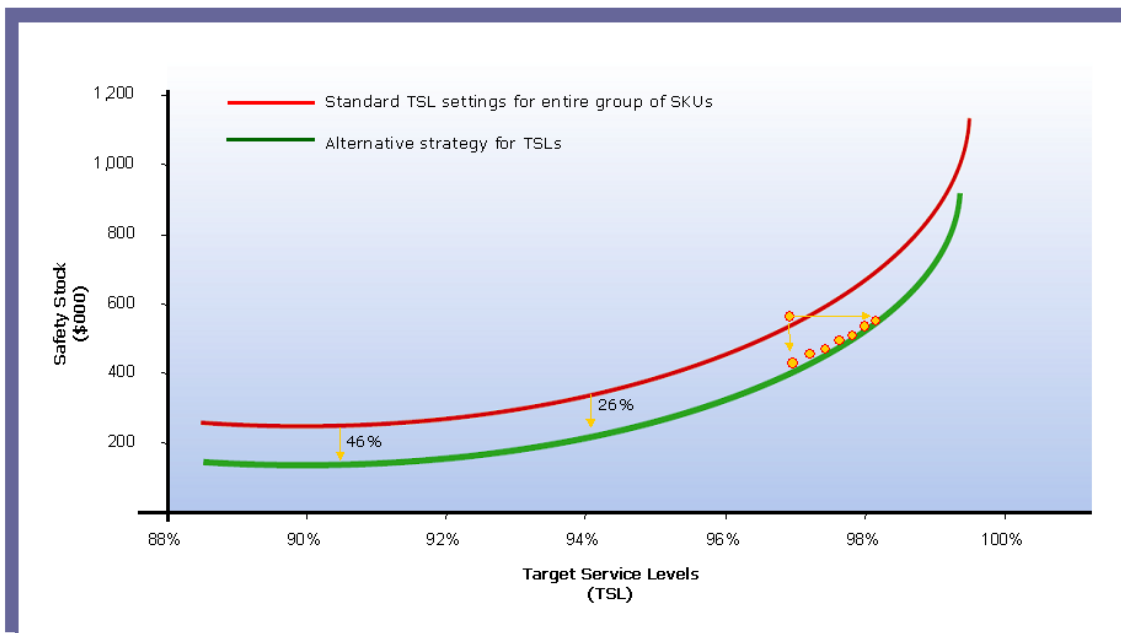
The logic for determining when and how much to order should depend on SKU characteristics like demand velocity (e.g., slow movers); stage in life cycle; and temporary impacts on demand, such as promotional events. These characteristics influence the amount of safety stock, the frequency of inventory status reviews, the forecast update cycle, and the order postponement decision.

In fact, many companies use the so-called ABC method to manage inventory replenishment. They classify items into “A,” “B,” and “C” classes and then apply one standard methodology for each class. For example: All “A” items get two weeks of safety stock, all “B” items get three weeks, and all “C” items get four weeks. This approach is flawed, for several reasons. Specifically, the classification schemes typically are based on volumes, item values, suppliers, and other characteristics that may not have any direct linkage to safety stock needs. The schemes ignore true inventory drivers, such as lead times, demand uncertainties, and supplier delivery reliabilities. Furthermore, it is not clear that three classes can capture the diversity and differences of the large number of SKUs many retailers and distributors carry.

Additional factors that replenishment strategies tend to ignore are the criticality of a product to the business and the availability of a recovery mechanism in emergency shortage situations. As an example, a product may be costly to stock but relatively inexpensive to ship from a different location within the demand network. To maintain

high service levels for this item, the customer demand locations could keep lower inventory levels, while a central location keeps a pooled safety stock for emergency shipments. Another case where centralized inventory pooling is warranted is for products with low service criticality. Cohen et al (2000) describe how Saturn uses such a strategy to manage its service parts inventory.

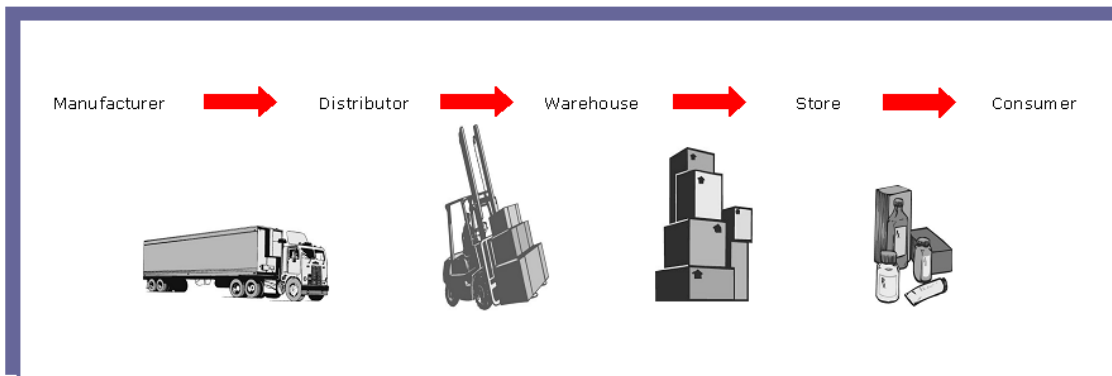
5. ***When a target service goal is assigned to a group of SKUs, every SKU in that group receives the same target service percentage.*** When you use the ABC method to group SKUs, the standard approach is to assign the same target service level for all SKUs in the same group. If all the SKUs in the group have equal acquisition costs, equal carrying costs, and equal sell margins, then the previously described method for establishing target service goals can work. In reality, however, there is enough variation in costs and margins between SKUs to warrant individual target service goals for each SKU. The result is to achieve service commitments for the group as a whole, but at significantly lower costs or higher profits. The figure below illustrates this point, using results from 114 of a major distributor’s “A” items.



Compounding the problem, companies often assign target service goals based on arbitrary judgments (or simply by following historical tradition), and that they fail to carefully analyze the relationship between the customer service target level and the cost of excessive stock versus a shortfall.

6. ***Product unit conversions are ignored as demand is projected up the demand chain.***

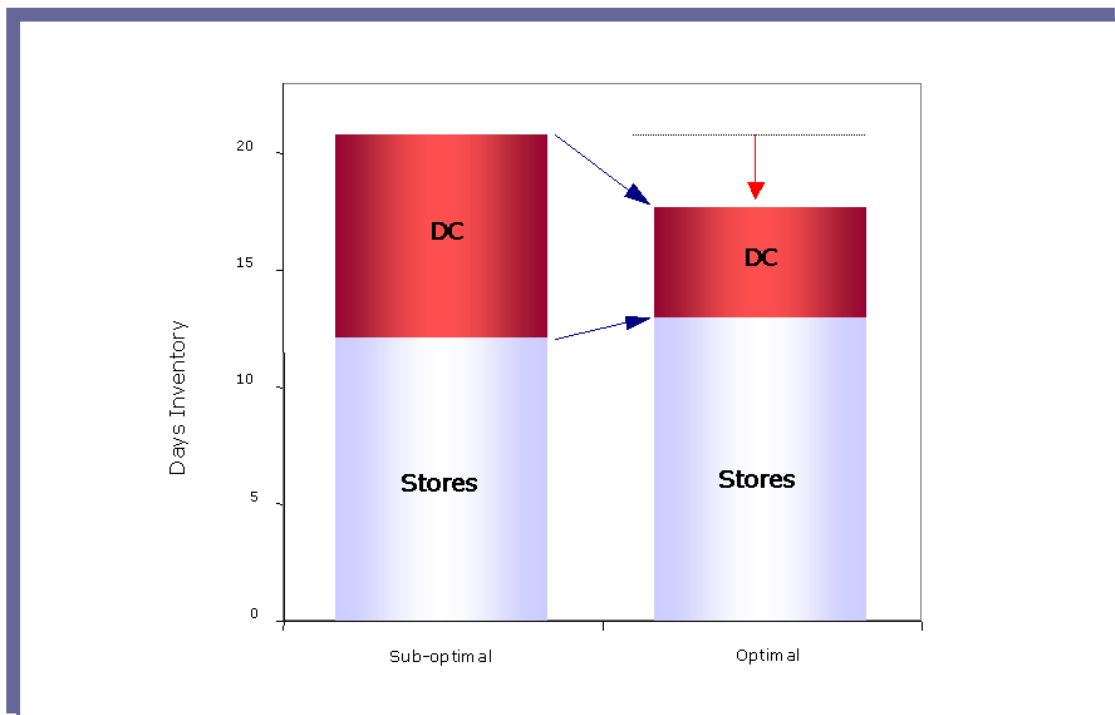
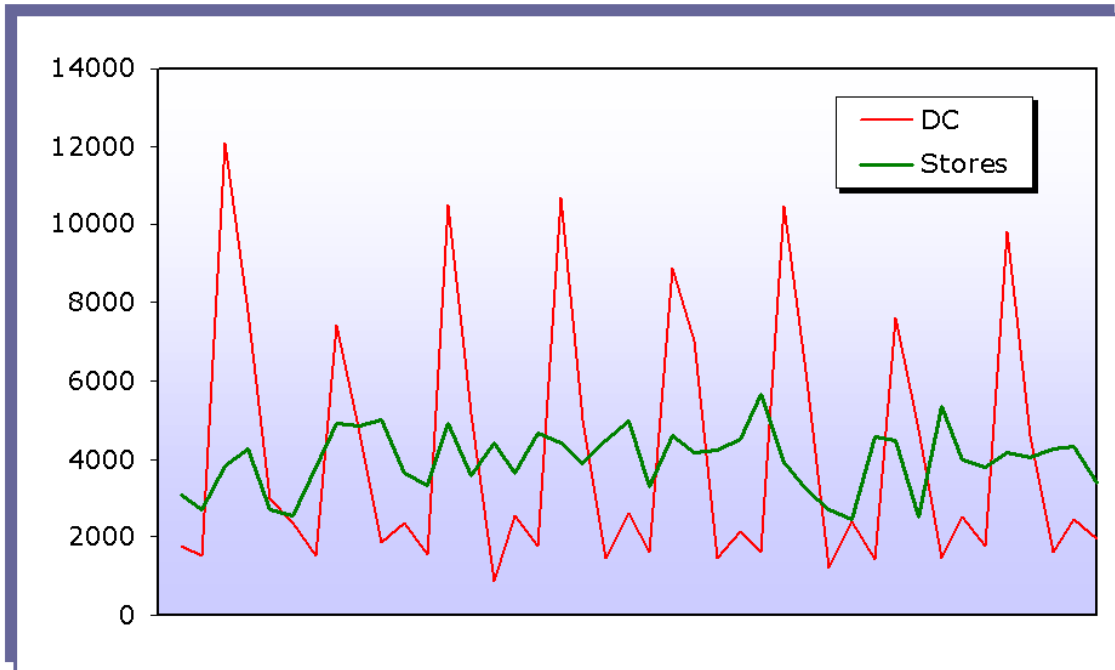
Each trading partner requires demand projections in units of measure that are most usable and economical to its business. These units change as you travel up the demand chain. Consider a shampoo product, as an example. The unit for shampoo is bottles, for sale to the consumer; cases, for shipment to retail stores; pallets, for shipment to retail warehouses; and truckloads, for shipment to the wholesaler's warehouses. The differences in shipping units are related to the inventory, handling, and transportation economics of each echelon. These unit conversions must be automatically performed and factored into the optimization.



7. ***The bullwhip effect is ignored or is tackled incorrectly.*** The *bullwhip effect* is the distortion of demand information as it is transmitted up the demand chain. This distortion shows up as increasingly greater demand variation between trading partners as the demand signal moves further away from the consumer. The increased variation leads to many undesirable results in the demand chain, including excessive safety stock inventories, poorer forecast projections, inefficient use of capacities, higher operational costs, and lower customer service. As discussed in Lee, et al (1997), the causes of the bullwhip effect relate to independent rational decisions in demand signal processing, order batching, reacting to price variations, and shortage gaming.

When optimizing the demand chain, you need to measure the bullwhip effect and identify its causes to reduce or eliminate its impact on demand chain performance. The algorithms should avoid independent multiple forecasts in the demand chain; this is the first cause of the bullwhip effect. Repetitive processing of the primary consumer demand signal causes members of the demand chain to stockpile unnecessary inventory. Using inappropriate demand signals or demand forecast updating in the replenishment process destroys enterprise value. The optimization should use multi-echelon models that correctly assess the impact of different forecasting and ordering strategies on demand variability up the demand chain. These models also incorporate the right linkages between inventories in sites located on different echelons. As Clark and Scarf (1960) proved, and Lee et al (1997) reiterated, “Echelon-based inventory is the key to optimal inventory control.” The alternative strategies include: Shorter order cycles, to counteract the order batching problem; and better synchronization of ordering activities, to reduce lead times between echelons.

The first figure below illustrates the bullwhip effect in action. One line plots the demand at the stores; the other line plots the orders the distribution center (DC) sees from the stores. The total store demand and the total DC orders are approximately the same, as one would expect. The store demand variation, however, is significantly lower than the variation in the DC orders. The root cause in this case is order batching at the store level. The second figure shows potential savings from optimizing the total inventory in both the stores and the DC versus independent optimizations at the stores and the DC.



8. ***Time-phased forecasts for demands and lead times are inadequately calculated and utilized.*** Extended demand forecasts are critical for supporting long-range production and sales planning efforts. They also are essential inputs for determining optimal investment buys. When supplier lead times are very long, accurate extended forecasts

are required. A common approach is to provide such forecasts in aggregate form by using a simple rule based on the current period's demand forecast. For example, a six-month forecast is obtained by taking the current month's forecast and multiplying it by six, or the current week's forecast and multiplying it by 26.

A more useful forecast would be time phased—spread out by day or week or month. Such a forecast could better support manufacturing and warehouse capacity planning, work force assignments, sales forecasting, and budgeting. To obtain an accurate time-phased forecast requires careful modeling of day-of-week, trend, and seasonal effects and consideration of supplier constraints within the demand chain. The corresponding time-phased projections of inventory (which can be useful in their own right for cash flow analyses), vendor lead times, and order receipts also are required. From a shorter time-frame perspective, accurate demand forecasts and expected receipts *by day* are key drivers to managing SKUs with short life cycles or short shelf lives. For these types of items, accurate day-of-week patterns must be modeled and used. One other area where time-phased forecasts are crucial is in managing special events that impact the demand chain. Examples would be promotions, special purchases, new item introductions, and new customer loads. Forecasts for these events must incorporate external causal factors as well as historical performance data.

9. ***Buy-side profit opportunities are not considered or fully exploited.*** Typically, the sell side is the focal point in replenishing the demand chain. And that is understandable, because high customer service levels are paramount for customer satisfaction. However, retailers and distributors can gain a great deal of economic value by taking advantage of buying opportunities that provide substantial price breaks from one-time deals or forward buys. Sometimes the parameters behind these opportunities are clear-cut, such as when vendors offer set price discounts, rebates, or more favorable payment terms. Other times, the opportunities are more speculative, as in the case of forward buying in anticipation of an expected—but not certain—price increase. These investment buys incur extra carrying costs, but that can be offset by lower acquisition, transportation, and (possibly) handling costs. A careful

economic analysis requires accurate time-phased forecasts to ensure the proper sell-through. Because these buys generate extra on-hand inventory, they deliver the extra benefit of providing even higher customer service levels. In business sectors with declining sell margins, or where sell margins are razor thin, these buy-side opportunities can significantly impact the bottom line.

10. ***Performance metrics are poorly kept or updated.*** You must have accurate and timely performance metrics to gauge demand chain performance. Examples of Key Performance Indicators (KPIs) include: achieved service levels (all flavors, such as units, dollars, lines, zero inventory occurrences), inventory on-hand and in the pipeline, supplier fill rates, and lead times within the demand chain. The data behind these KPIs must be granular enough to allow drill downs into specific SKUs or network locations. At the same time, the data must be substantial enough to support root cause analysis when the KPIs reveal performance inadequacies. For example, it is not sufficient to have on-hand inventory information only for a snapshot in time. This inventory information must be over time, and it must be segmented into layers that would support root cause analysis of undesirable overstocks. To support root cause analysis of service failures, you need data that are related to all impacts on inventory.

Johnson and Davis (1998, 1995) point out that managers need to measure only the right things, avoid meaningless efforts, and use the measurements productively. You can achieve this by using the KPIs and their drivers as feedback signals to improve the performance of the demand chain (i.e., move the performance metric into a more acceptable range). Having good, updated performance metrics is not a new idea by any means. Lee and Billingham (1992) made this same point, in their list of supply chain management pitfalls.

## Key Principles of DCO

With the above pitfalls in mind, the key principles of DCO become apparent:

1. ***The optimization objective is the total value impact on the enterprise.*** In the final analysis, the optimal decisions in DCO must be the ones that increase enterprise value. Toward this end, in computing costs, you must use the total cost. The key cost components are inventory, handling, transportation, and purchase. Forecasting and replenishment strategies directly impact each of these cost components. You will find clear tradeoffs between the components when you try to increase overall enterprise value. For example, carrying more inventory will increase customer service levels—but at the price of lower inventory turns. Buying product in greater quantities per order and increasing the length of order cycles could decrease handling, transportation, and purchase costs, but it could also foster higher inventory carrying costs and/or lower customer service.

You cannot perform a proper economic tradeoff analysis unless all cost components are available. As Lee (2000) points out, cost reduction in a demand chain is a worthwhile objective, but you can also increase enterprise value through higher profits, greater market share, and increased competitive advantage. A company can miss out on higher profits by failing to adequately evaluate and fully capitalize on price-advantaged buying opportunities.

Longs Drug Stores has achieved tremendous improvements in inventory and service levels since 1998. With more than 400 stores, Longs is one of the largest drug chains in the United States. The company deployed DCO tools that balance the tradeoffs between inventory, warehouse operations, and transportation costs. The company learned to build replenishment orders based on optimal policies for order frequency and service level goals. DCO has significantly increased Longs' enterprise value. Lee and Whang (2001) provide a detailed account of Longs' move to demand chain excellence.

2. ***Information transparency exists in the demand chain.*** To reduce lead times and to achieve greater coordination across the demand chain, information flow must be seamless. This flow includes sharing end consumer demand information as well as sharing visibility into inventory on hand, product in transit, sales forecasts, and even capacity information. Indeed, the lack of visibility beyond the immediate trading partners in a demand chain can undercut results. For example, in a multi-echelon network, forecasts that depend solely on the demand signal from immediate downstream customers result in excessive safety stock. This is a direct effect of the bullwhip effect discussed above. Independent multiple forecasts in a demand chain is an example of improper demand signal processing in a multi-echelon environment.

Lee and Whang (2000) describe how information transparency can mitigate many of the bullwhip's negative effects. For example, sharing capacity information permits better planning and coordination between trading partners and helps reduce the gaming that occurs in product shortage situations. Another example is the sharing of order information through Electronic Data Interchange (EDI) or the Internet. These lower cost ways to place replenishment orders make smaller order batches more economically attractive. Partners that share replenishment and order filling schedules can synchronize their work more effectively and reduce lead times. All these information-sharing activities aim straight at the heart of the bullwhip effect.

The value in sharing inventory and sales information between companies is well illustrated in successful Vendor Managed Inventory (VMI) implementations. Companies like Wal-Mart, Procter & Gamble, Campbell Soup, and Johnson & Johnson have achieved improvements in service, inventory levels, and production costs using VMI initiatives. Waller et al (1999) delve into how VMI concurrently satisfies suppliers' needs for lower demand variability and greater flexibility in order building *and* buyers' needs for lower cycle stocks and high service levels while achieving performance commitments.

Wyeth, an \$11 billion division of American Home Products, implemented VMI with its wholesale and retail trading partners and consequently boosted its service level from 90% to 99%—while increasing inventory turns from 10 to 22. HEB Grocery, through a VMI program with Schein Pharmaceutical, increased its inventory turns from 5.9 to 23 while maintaining a 99.5% service level. Additional benefits included a significant drop in product returns to Schein, and decreased operational cost thanks to the elimination of purchase orders.

3. ***Optimization blankets the entire demand chain.*** It is not enough to achieve optimal results for subsets of the network, because these results could be suboptimal for the whole network. As pointed out in the previous section, if you make purchasing decisions that are rational and beneficial on one echelon of a multi-echelon network without regard for the impact of these policies on the other echelons, you can actually decrease overall enterprise value. This is exactly what happens when independent, multi-staged models are used in place of multi-echelon models. The latter factor in all the interactions and value impacts between demand chain entities and also quantify the benefits of coordination between the entities. This coordination provides another weapon against the bullwhip effect.

For example, consider the retail chain that must replenish its warehouses. The retail warehouses, in turn, replenish the chain's retail stores. Store level demands, captured as POS data, drive store replenishment. To maintain lower inventory levels, the stores may insist on very high target fill rates from the warehouses. Unfortunately, such high target fill rates can cause significantly higher safety stock at the warehouses. The net effect is not optimal, from the demand chain perspective, because both the store and warehouse echelons are carrying higher overall inventory. The proper approach is to optimize both echelons simultaneously.

A leading wholesale drug distributor is a prime example of a successful implementation of multi-echelon inventory management. With more than \$40 billion in annual revenue and a distribution network that includes a regional distribution

center and customer-facing distribution centers, this company optimizes inventory over both echelons to meet end-customer service commitments. This distributor also avoids the error of re-forecasting at the higher echelon, as described in the last key principle.

4. ***Pull replenishment strategies are used over push strategies.*** Push policies generally rely on demand forecasts from the immediate downstream customers without visibility into the customers' stock statuses and future needs. If you use safety stock, it is usually a deterministic calculation or based on rules of thumb. Push strategies produce inventory overstocks, inefficient use of resources, and even lower customer service levels.

A demand signal close to the end consumer typically drives pull strategies. Because decisions are better coordinated to end-consumer demands, lead times and inventories can be reduced, and more agile responses to demand changes are possible with pull strategies. In terms of coping with the bullwhip effect, pull policies have the upper hand because they can apply proper demand signal processing on the primary consumer demands. In addition, you can apply proper demand cleansing to the consumer demands and use these cleansed demands to drive the pull replenishment. Pull strategies also enable more sophisticated forecasting and replenishment models, and they enforce correct product unit conversions up the demand chain. Finally, by starting with demands closest to the consumer, pull strategies must directly address the need for efficiency in the computations.

5. ***All drivers to product demand, availability, and placement are considered.*** This includes factors relating to the current status of the SKU as well as future states. That is, besides current forecasted demands and lead times, demand variability, lead time variability, current prices (buy and sell), and marketing programs in force, the optimization also considers future events like planned promotions, markdowns, vendor deals, price changes, assortment changes, as well as new avenues for product sourcing. All these factors and events impact demand.

For instance, promotions can offer temporary demand lifts for the promoted SKU, but they may also depress demand for cannibalized SKUs. You must cleanse the effects of exogenous events on historical demands and supplier deliveries. And your decision on how much to buy today must also take into account any price-advantage buying opportunities that become available in the near term. Constraints that affect product placement at stores—such as presentation stock, fixtures, and backroom storage—also are part of the optimization problem.

## **Conclusion**

This paper focused on tactical issues in DCO. It did not address operational or strategic problems that are part of every demand chain. A basic assumption was that the optimization is over a fixed distribution network. If the network itself can be reconfigured, then additional optimization opportunities exist. But those decisions are strategic and wield long-term influence on an enterprise. The focus in this paper has been on issues that impact the demand chain performance over the next week, the next month, or within the next year.

To be effective, DCO requires the right business processes, personnel, information, and tools. Those tools include sophisticated mathematical models and advanced algorithms that are built into automated software solutions. Manual solutions are impractical because of the sheer number of SKUs, the multitudinous uncertainties, the massive amount of information that needs to be processed, and the speed at which you need to dispatch decisions. When a demand chain drives toward optimal performance, tremendous value to the enterprise results. And best of all, the consumer is the ultimate winner.

## **Glossary**

*ABC Method:* The classification of SKUs into A, B, C, and sometimes D and F categories, with the “A” items given the highest target service goal, “B” items the next highest, and so forth.

*Bullwhip Effect:* The distortion of demand information as it is transmitted up the demand chain. This distortion shows up as increasingly greater demand variation between trading partners as the demand signal moves further away from the consumer.

*Demand Chain:* A network of trading partners that extends from manufacturers to end consumers. The partners exchange information, and finished goods flow through the network’s physical infrastructure. The physical facilities include manufacturers’ warehouses, wholesalers’ distribution centers, retail chains’ warehouses, and retail outlets.

*Echelon:* A set of facilities in a distribution network that have a common set of suppliers and are equally distant from the primary demand source.

*Information Transparency:* The availability and sharing of information on inventory, sales, demand forecasts, order status, production and delivery schedules, capacity, and even performance metrics within a supply chain.

*Inventory Turnover:* Annual sales divided by average inventory on hand; a measure of inventory management effectiveness. Both sales and inventory are measured at cost.

*Investment Buy:* A product purchase that is above normal replenishment requirements, usually because of a price advantage or favorable vendor terms. Types of investment buys include forward buys and speculative buys.

*Key Performance Indicators (KPIs):* Measures that provide insight into supply and demand chain effectiveness. Examples include achieved service levels, inventory on hand and in the pipeline, supplier fill rates, and lead times within the demand chain.

*Lead Time:* Elapsed time from placing an order for a product until the ordered item becomes available for satisfying customer demands.

*Order cycle:* The effective time interval between replenishment orders.

*Outlier:* A value that is outside the limits of expected values; usually determined by statistical means.

*Product Life Cycle:* The different stages in a product's life, extending from introduction to early life to maturity to end of life.

*Pull Replenishment:* Replenishment orders that are driven by statistical forecasts of customer demands, inventory statuses, supplier lead times, and lead time variability, and safety stock based on service goals. Order releases are triggered by changes in inventory or back order levels.

*Push Replenishment:* Replenishment orders that are driven by total projected requirements based on expected demands, receipts, and set safety stock levels. Order releases are made to satisfy future requirements, offset by supplier lead times.

*Return on Assets (ROA):* A number that indicates how effectively your business has put its assets to work. It is the ratio of net income to total assets. Companies can use this ratio to compare their business' performance to industry norms.

*Return on Equity (ROE):* An indicator that encompasses the three main management "levers"—profitability, asset management, and financial leverage. It is the ratio of net income to total common equity. One of the quickest ways to gauge whether a company

is an asset creator or a cash consumer is to look at the return on equity it generates. By relating the earnings generated to the shareholder's equity, an investor can quickly see how much cash is created from the existing assets. If the return on equity is 20%, for instance, then 20 cents in assets are created for each dollar the company originally invested.

*Safety Stock:* Inventory carried in excess of normal demand usage; used to provide a buffer against product shortages.

*Stochastic:* Characterized by chance, random variables, or probabilities. Opposite of deterministic.

*Stock-keeping Unit (SKU):* A specific product at a specific location.

*Target Service Goal:* The desired percentage of customer demands to be filled from on-hand inventory. This directly impacts the amount of safety stock to be carried.

*Vendor Managed Inventory (VMI):* A program established between a supplier and customer (such as a manufacturer and a retailer) in which the supplier manages the inventory for the customer—making all replenishment decisions, monitoring customer inventory levels, and processing customer demands.

## **Author Bio**

Calvin B. Lee has more than 25 years experience in the transportation, wholesale distribution, and retail industries. Prior to joining NONSTOP Solutions, Inc., Dr. Lee was Director of Merchandising Logistics at Webvan Group, Inc. Previously, he was Vice President of Operations Research at McKesson Corp., where he made major contributions to inventory management and distribution network redesign initiatives. Dr. Lee managed the analytic services team at Southern Pacific Transportation (now part of Union Pacific) and oversaw its operations research and decision support activities. Currently, he is on the adjunct faculty of several Bay Area universities. Dr. Lee holds a Ph.D. in Applied Mathematics and an M.A. in Mathematics, both from the University of California, Berkeley.

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