Maximize ERP Value with Inventory Optimization
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Manufacturers and retailers have improved business operations through the implementation of enterprise resource planning (ERP) and supply chain management (SCM) systems. On the whole, the ERP and SCM investments have been deemed successful by virtue of the positive returns on investment they’ve created through wide-ranging operational and capital management efficiencies. In many cases, those systems have been deployed for purposes other than their original intent, with many manufacturers adapting them in creative ways for special business needs.

However, the successes of ERP and SCM systems have not come without questions and criticisms. Surveys and anecdotal evidence clearly show that C-level executives are uneasy about the ROI of their ERP, manufacturing resource planning (MRP), SCM and other enterprise-level systems after more than 30 years of investments in them. They all talk about squeezing more value from these huge systems.1 In regard to SCM, typical ERP systems attempt to organize supply and demand signals with de facto sequential optimization – a process which leads to inflated demand forecasts and stock overages at numerous points in the supply and manufacturing chains. As worldwide economic activity increases and product demands shift, manufacturing organizations will need to improve their performance in minimizing unacceptable inventory positions.

In response, there is new emphasis on the need to work smarter using analytical and optimization approaches to inventory and supply chain management. Customers’ signals produce advance notice of demand and the systems should respond with necessary adjustments that reduce and eliminate the bullwhip effect. But all too often senior managers are frustrated. Their ERP and SCM systems haven’t been able to generate the more advanced, optimized results that they see as possible – and much needed – to reduce or eliminate inefficiencies and unbalanced inventory and to focus on good management.

Finished goods manufacturers and retailers can use technology solutions for analytics and optimization to set measurable and relevant improvement goals for the enhancement of their ERP/SCM outcomes related to supply chain and inventory. For example, SAS® solutions have been successful in:

- Reducing capital invested in inventory by a minimum of 15 percent.
- Maintaining high service levels while eliminating inventory imbalances.
- Reducing the effort, and improving the quality, of materials requisitions management.

1 Analyst surveys and trade journal articles abound concerning the issue of ROI and ERP. C-level executives in general have an unsettled sense of enterprise systems not delivering what they expected, although, in fairness, few have had clear metrics to measure success and ROI. Here is a sampling of recent studies and articles:
  - http://www.managingautomation.com/maonline/magazine/read/view/The_Circle_of__ERP__Life_3871
  - http://www.automationworld.com/primers-8107
  - http://www.forrester.com/rb/teleconference/cios_plan_effectiveness_reviews_to_squeeze_more/q/id/5928/1

### Inventory Effects on Finished Goods Manufacturers and Retailers

The effects of effective inventory management – or mismanagement – can be wide-ranging. Tracking inventory is essential to running a business efficiently, and managing inventory effectively can have big impacts on profitability. Here are just two situations that occur:

- Customers often will not tolerate product unavailability or delays in delivery. In some cases, a shortage may be a small inconvenience (such as an unavailable part at your favorite hardware store), while in other cases it may cause a severe problem (such as interrupting production-line activity at a computer manufacturer).

On some occasions, sporadic shortages can be expected, but frequent shortages may ultimately damage a company’s reputation, customer loyalty and market share.

- Overabundant, slow-moving inventories can place a serious strain on a company’s available capital and inhibit the company’s ability to take advantage of financial opportunities. In order to compete effectively in today’s business world, it is imperative to efficiently maintain adequate inventories.
This white paper examines why problems emerge when firms try to develop an analytics and optimization mindset about their inventory and SCM practices. The paper will also show why running an inventory optimization solution with already-installed ERP/SCM systems can enable organizations to operate profitably within new market dynamics.

**Optimization Can Occur for All Finished Goods Manufacturers and Retailers**

The limitations to ERP and SCM systems as they apply to finished goods inventories are beginning to manifest in all the manufacturing industries. The following snapshots provide a view of each vertical’s primary delivery objective and the associated benefit that can be derived from analytics and optimization:

- **Consumer Packaged Goods:**
  - *Delivery Objective:* Customer fulfillment is the ultimate goal of CPG supply chains. Improving fulfillment levels creates customer satisfaction and yields impressive financial improvements.
  - *Optimization Goal:* At a constant cost to serve, reducing out-of-stocks increases the top line, dropping most of the additional gross margin to the bottom line.

- **Electronics:**
  - *Delivery Objective:* Consumer electronics and mobile devices are like fashion items with short product life cycles that demand fast turnaround. Manufacturers must keep fresh assortments before customers, despite a growing array of SKUs.
  - *Optimization Goal:* Increased commoditization and customer expectations of on-demand stock have driven turnaround times to as low as 24 hours and created a need for readily available inventory and a more balanced stocking strategy.

- **Food & Beverage:**
  - *Delivery Objective:* Out-of-stocks equate to lost sales, requiring companies to be sensitive to maintaining very high customer service-level goals.
  - *Optimization Goal:* Operations departments can get caught between sales departments that want outstanding service and production planning departments that control the inventory. Delivery optimization is critical.

- **Health Care and Pharmaceuticals:**
  - *Delivery Objective:* Health care and pharmaceutical sector companies are expected, or even required, to deliver very high customer service levels, even for slow-moving products. Product obsolescence must be managed, particularly for products with expiration constraints measured in months or even days.
  - *Optimization Goal:* Combining seasonal behavior and sell-by dates makes inventory planning even more challenging, but must be achieved.
Industrial and Durables:

- Delivery Objective: Manufacturing these goods is particularly challenging when markets require smaller volumes that translate into large mixes and slower moving products whose demand is highly variable and harder to predict.

- Optimization Goal: When sales are made through wholesalers and retailers, a high service level is expected. Big customers move a lot of product and want close integration with suppliers, even to the point of requiring inventory to be directly managed by suppliers (vendor-managed inventory, or VMI).

Wholesale Distribution

- Delivery Objective: High customer service levels are critically important to wholesale distributors, where an unserved order usually means a lost sale. Service-level shortfalls reduce the top line directly.

- Optimization Goal: Achieving outstanding service levels is difficult. When you increase your inventories, costs increase and service levels respond slightly, if at all.

Pressures on ERP Systems in Supply Chain Planning

Finished goods manufacturers and retailers know that efficient management of their supply chain can be a competitive differentiator, but they struggle with customers’ ever-increasing demands on overtaxed transactional and operational systems.

Industry executives increasingly acknowledge that moving from a push environment, where suppliers have relative control over their inventories, to today’s pull environment, where customers dictate inventory, adds extra volatility to their ERP and SCM systems.

As a result, manufacturing companies are hedging their bets by acquiring and maintaining safety stocks to counteract the potential disruptive forces of unanticipated customer demand. From an SCM systems perspective, companies are using workarounds or special alert systems developed on an ad hoc, reactive basis. The companies have still failed to achieve an optimized, balanced and efficient state due to the inherent structure of ERP systems that creates problems for those trying to reduce safety stocks with analytics and optimization. What if ERP systems could conduct their own advanced optimization activities?

The following sections look at the challenges posed by de-normalized tables, sequential optimization, upstream service levels, accumulated demand variance and multiple hierarchies of service-level requirements.
De-Normalized Tables

The transactional nature of ERP systems requires them to operate in near-real time using normalized tables – large tables that have been converted into a number of smaller tables to eliminate as much information redundancy as possible. The small tables, called star schemas, are arranged so that the user can extract the information needed from other tables. Each table can quickly make the correct connections to other table combinations to retrieve necessary information. For instance, as the result of star schemas extracting data from various tables, a call center agent who needs some, but not all, customer information would see the name, address, cellphone number, cellphone model and previous notes when responding to a technical problem.

When the user needs online analytical processing (OLAP) de-normalization, data is extracted, transformed and loaded (ETL) from normalized tables into a format that can be analyzed (instead of simply being displayed). This array of table information for OLAP is called a snowflake schema and is designed to quickly pull data into usable OLAP cubes that can be viewed from several different perspectives. For example, OLAP data could be viewed as combinations of information over time; OLAP cubes are the basis for analytical review of transactional activities.

De-normalized tables create problems when users attempt to perform higher-level analytics or optimization with them. Analytics and optimization require calculations using variables – lots of variables. While most normalized tables and schemas adhere to a three normal forms (3NF) design, the number of variables required for optimization creates large numbers of de-normalized tables. The difficulty comes in arranging the de-normalized tables into logical snowflake patterns because in fast-moving transactional systems, computing performance can erode quickly. In response, ERP managers tend to create shortcuts to circumvent the problems caused by variables. The concerns then become ones of confidence: whether the information has value, is deficient or is misleading because of some miscalculation or because of a misalignment of table data.

The opportunities for miscalculated or misleading information are nearly infinite.

Consider, for example, the complexity of a simple product like shampoo. Where did its raw materials come from? How many warehouses stored the materials? Where did the raw materials get combined, processed and manufactured? The complexity grows exponentially when considering the millions of product combinations produced by consumer packaged goods, electronics, food and beverages, health care products, pharmaceuticals and industrial and durable goods companies.

Because of the enormity of the data requirements, high-powered analytics and optimization processes normally run as a weekend batch job, to extract, transform and load data from disparate, diverse sources into an optimization run. The objective is to pull this information together so the system can attempt to understand the complex networks of inventory flow.
ERP systems have a limited ability to create de-normalized tables so that batch run optimization can occur with high levels of confidence. Instead, the ERP system will tend to create “islands of efficiency,” where it views a location or node as a single entity and then attempts to compile data specific for that location to produce projected best practice rules for the item-location pairings.

**Sequential Optimization**

The next step in ERP processing of de-normalized tables is sequential optimization, where (as shown in Figure 1) the islands of efficiency links in the chain are optimized, and the system goes to the next link up the chain to continue optimization in sequence. The ERP process is locked into this sequential optimization format; there are few or no “arc” connections between the link locations, a limitation that reduces the number of variables that can be used, essentially creating a de facto optimization process of its own, with little flexibility or agility.

While sequentially optimized islands of efficiency do generate some benefits, they also will amplify demand variations and literally make supply variability invisible. This occurs because they operate without knowledge of, visibility of or communication with the chain, making it nearly impossible to maintain optimized inventories. The bullwhip effect then can throw everything else out of alignment when companies are attempting to use transactional ERP or SCM systems to develop optimized supply chain planning.

The following sections examine these activities and why they create problems in a transactional ERP/SCM system.

**Upstream Service Levels**

Figure 2 depicts how the ERP/SCM system tries to optimize the customer-facing storefront (POS_1) with a 95 percent service level. Because the shortcut process in the transactional system is to optimize the island of efficiency, it is not going to cross over any variables from the upstream location (WH_1). The system’s business rule or assumption is to provide a 100 percent service level at WH_1 to the downstream customer-facing location (POS_1).
For a sequential approach, the upstream service level is always 100%, assuming availability is infinite. This is never the case. Single-echelon systems do not have inputs for upstream service levels.

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Multi-echelon systems allow inputs for upstream service levels and take into consideration the uncertainty of resources from upstream.

Because there is no assumed uncertainty in the supply of inventory, the downstream POS_1 has an artificially low safety stock position. The demand variable has been factored in, but the supply variable has been withdrawn from the equation, and the buyer would become understandably panicked, possibly rushing stock from an internal warehouse or outside vendor because of unforeseen supply issues. The buyer suffers the consequences of removing the supply variability factor from the inventory calculations.

One immediately apparent remedy is to reduce the expected service level to 90 or 95 percent. This would require the system to develop large numbers of de-normalized tables to account for each service-level combination, adding enormous complexity to the transactional systems’ attempts to optimize the data.

In these circumstances, most organizations will try to circumvent the problem by either artificially increasing the safety stock on key items at customer locations or trying to create an early-warning system for potential shortages and increasing stock at the upstream location. Both workarounds create additional inventory. In fact, the second workaround actually amplifies the next problem occurring in sequential optimization – accounting for accumulated demand variance.

Figure 2: Sequential optimization assumes the upstream service level will always be 100 percent, whereas systematic optimization recognizes that upstream service level varies.
Accumulated Demand Variance

Accumulated demand variances create the need for additional shortcuts and have the effect of producing more inefficiency. Figure 3 depicts customer-facing locations having service-level requirements based on the upstream location always having stock and each of the POC nodes having a 95 percent service level based on a demand projection with a built-in demand variance. Islands of efficiencies exist in every downstream location because each passed on its accumulated demand variances back to WH_1. This dramatically increases the inventory in WH_1 to overcome the assumed 100 percent service level required and prompts the first wave of the bullwhip effect.

Since it is sequential, WH_1 has no visibility of the demand patterns of POS_1, assumes the pattern to be 200 every two weeks.
- Problem compounded with introduction of POS_2.

Multi-echelon system accounts for demand patterns downstream.
- Takes into account “skuloc” ID.
- Treats POS_2 as unique with its own service level.

WH_1 Service level assumed 100%
POS_1 Service level = 95%
Order of 200 every 2 weeks
Sale of 100 every week
POS_2 Service level = 95%

WH_1 Service level = 90%
POS_1 Service level = 95%
POS_2 Service level = 95%

Figure 3: The accumulated demand variance is pushed upstream with sequential optimization, but systematic optimization treats each downstream location as a separate, non-aggregated demand signal.

When distance and time increase from the initial demand signal, the systems produce notifications that more accumulated inventory is needed to offset the “demand amplification.” Termed “redundant inventory,” this escalating stock-up is in reaction to the accumulated demand variance repeated over and over. Upstream parts suppliers in the automotive industry have been rendered insolvent when they were stuck with massive, obsolete inventories due to the bullwhip effect.
Multiple Hierarchies of Service-Level Requirements

When ERP systems see accumulated demand working its way up the chain, it views that demand as an aggregated total and does not provide any additional insights into the different service-level requirements necessary to meet that demand, either by site or by SKU. This causes the organization to protect itself with even more safety stock add-ons than it would in the previous two examples of demand variance and assumed upstream service levels.

The usual workaround for adjusting inventories to accumulated demand is the installation of simple ABC classifications. However, the ERP system struggles with millions upon millions of product and location pairings in a complex supply chain. Whether it’s a downtime service-level agreement with huge penalties, or ensuring that enough cases of cola are at a featured event in a company’s mountain and beach stores, incorrect service levels will create problems. The second part of the workaround is to assign review time with alerts for analysts to examine the “A” items that are beyond established tolerances.

**Figure 4**: Sequential optimization cannot recognize different service levels, but systematic optimization allows for downstream location-product combinations to have unique service-level requirements.
The Systematic Multi-Echelon Inventory Optimization Process

Figure 5: Systematic optimization overcomes the shortcomings of sequential optimization to create a supply chain that runs in harmony.

To summarize, the ERP shortcomings—de-normalized tables, de facto sequential optimization, accounting for accumulated demand variance and multiple hierarchies of service-level requirements—challenge the ability of transaction-oriented ERP systems to perform analytics and optimization in the supply chain. While single-echelon islands of efficiency can produce some benefits with supply chain planning, it is usually due to reporting and increased visibility into outlier problems. There still remains the problem of sequential optimization when the nodes or links in the chain are not connected systematically.

To remedy these shortcomings, there are technology solutions that augment transactional systems with systematic, multi-echelon, inventory optimization processes that enable the transactional system to run more efficiently and continue providing ROI for the ERP/SCM investment.

Multi-echelon inventory optimization works because the algorithms at its core replace rule-of-thumb inventory policy parameters. The algorithms can be customized to every product and location pairing to effectively manage inventory by optimizing the costs of buying, holding, producing and selling inventory.

Out of One Loss Category, into Another
As discussed, single service-level inventory management creates problems for large manufacturers through no fault of their own in seeking various remedies. One leading consumer goods company attempted working with its vendor-managed inventory (VMI) system to categorize all products and load all its important customers into a massive Excel spreadsheet, then updated the results on a monthly basis. The results allowed it to assign service levels to the major customers, major products and the collective advertising budgets. From this information the company was able to update upstream inventory locations with spreadsheet-assigned inventory projections. For a while, it seemed to work: The company was winning industry awards for its ability to perform VMI functions. However, in its efforts to support VMI, the company had simply transferred the inventory burden up the chain. In order to maintain the service levels required by the customers, the organization was spending massive amounts of money on expedited orders from its internal warehouses. Its realized inventory savings were quickly consumed by cost of goods sold. No doubt the organization had a good idea, but its execution using the technology in place prevented a real solution.
**MAXIMIZE ERP VALUE WITH INVENTORY OPTIMIZATION**

**Costs and Issues for Inventory Policies**

<table>
<thead>
<tr>
<th>Category</th>
<th>Costs</th>
<th>Balancing Issue</th>
<th>Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordering production</td>
<td>Fixed ordering/unit costs</td>
<td>Volume purchase, long production runs and large raw material</td>
<td>When should orders be placed to restock inventory?</td>
</tr>
<tr>
<td>Holding</td>
<td>Holding costs</td>
<td>How should inventory be replenished (how much should be ordered) to reduce costs and increase turns?</td>
<td></td>
</tr>
<tr>
<td>Sales</td>
<td>Stock-out*</td>
<td></td>
<td>What will demand be? What is the projected customer service level?</td>
</tr>
</tbody>
</table>

*Table 1: This table provides examples of business categories, cost names and issues that must be weighed for optimization, and the policy outcome of that optimization.*

Multi-echelon inventory optimization operates by creating matrices that produce business rules for the organization, as shown in Table 1. The customized policies link together those islands of efficiencies so that they act in concert with the customer-facing location’s service-level requirements. The inventory optimization system weighs the fixed ordering, unit, holding and potential penalty costs of not having enough stock for each product and location combination. It also takes into account the demand, demand variability, lead time and supply variability to come up with an inventory control parameter that determines:

- The inventory stock range for the location:
  - The maximum stock or order level.
  - The minimum stock level, considering both demand and supply variability.
- Timing for order placement (i.e., ordering in time to meet minimum stock levels).
- Order size for lowest costs.

Answering such questions requires a systematic approach to data management in which the ERP/SCM system provides the required transactional activities, but pulls information from additional sources to enable the development of variables to deliver the optimal result. Those variables are typical supply chain concerns:

- Upstream service levels less than 100 percent.
- Accounting for accumulated demand variance.
- Multiple service-level requirements.

The systematic multi-echelon inventory optimization process thus necessarily requires very careful and thorough management of its data. Systematic approaches should effectively manage data on millions of SKUs, gather and consolidate huge data volumes in every echelon of the distribution chain, and then transform, standardize and cleanse the data (reconciling inconsistent naming conventions, removing redundancy, etc.) to prepare it for accurate forecasting.
In addition, the systematic approach should be able to achieve accurate forecasts at every level – top-down, bottom-up, middle-out – and also produce a variety of statistically based forecasts (short-term, long-term, new products, end-of-life, etc.) at frequent intervals.

### Transactional Versus Systematic Multi-Echelon Inventory Optimization

It's helpful to compare the functional differences between transactional and multi-echelon inventory optimization in view of their capabilities for demand and supply visibility, economic order quantity shortcomings and demand signal delays:

#### Demand and Supply Visibility

Multi-echelon inventory optimization forecasts focus on leaf node or customer-facing locations. When the demand at leaf nodes is known and matched to service levels, the information can be relayed effectively up the chain in a systematic way. This matching reduces demand amplification in a transactional chain with islands of efficiencies. The resulting demand signal reduces the amount of redundant inventory when each node in the chain has separate forecasts. By introducing both demand and supply variability, ordering and carrying costs can be balanced at each node in the chain. This means that the chain's ordering is stable.

#### Economic Order Quantity Shortcomings

Once stability in the chain's ordering process is achieved, the multi-echelon inventory replenishment takes transactional functionality to a new level. Normally, the ordering processes of ERP/SCM systems are determined by the economic order quantity (EOQ), a formula that balances inventory cost against ordering cost. But when compared to an optimized, systematic approach, the EOQ formula has several shortcomings:

- **EOQ cannot calculate batch sizing based on costs.** A standard EOQ calculation cannot handle an extensive list of costing variables – based on location, handling and batch sizes – a condition that causes inventory to spread equally over the chain rather than being strategically placed in lower-cost locations.

- **Stock decisions for one SKU cannot be made independently of other SKUs.** The ERP system uses systemwide cost and service-level targets. Removing the product from stock changes the overall target service levels. By treating each product service level independently, the systematic process fine-tunes the service levels by product and location.
• **EOQ does not account for backorders.** ERP only allows for one reorder point in the EOQ formula. Backorders result in a second, third or even fourth reorder point, a multiplier which cannot be supported. By contrast, the systematic approach allows for the insertion of backorders and reduces redundant inventory caused by backorders being counted as multiple instances of the same order.

• **EOQ cannot optimize service levels based on costs.** Because islands of efficiencies always assume a 100 percent upstream service level, there is no concept of a penalty cost for not having stock available. In the real world, lost sales and penalty costs can have a huge effect on business decisions. By contrast, the systematic approach equates an optimal balance between the costs of inventory at different service levels with calculations about the penalty costs.

**Demand Signal Delays**

An ERP system’s sequential supply chain approach responds to changes in demand signals by adjusting inventory levels, but because there is no visibility into downstream demand signals, delays occur in inventory level corrections further up the chain. The delays can have huge effects on upstream locations, creating large amounts of stock, as evidenced by the prevalence of inventory write-offs at the plant or central warehouse when unanticipated drops in demand aren’t recognized until too late. Indeed, obsolete inventory can sound the death knell for an organization.

By contrast, the systematic approach allows for networkwide visibility of demand signals occurring at customer-facing locations so that demand is understood at the upper levels of the supply chain much faster than would be seen in a sequential approach. The effect is twofold. Because there is far less redundant safety stock inventory at the upper portions of the company’s supply chain, cash is available to invest in less risky investments than inventory. In addition, visibility into demand and stocks can be reduced faster, making present inventory investment less risky.
Conclusion

In many industries, inventory management is a key component to the effective, profit-making operations of a business. In the finished goods industry, companies must balance inventory costs against the promotional activities that drive the business. In the retail industry, companies must maintain large volumes of different items at various locations and monitor quantities, estimate usage and place orders for replenishment. Slow-moving items are discontinued, while new items are introduced.

More management teams are discovering that previous approaches to inventory planning are not measuring up to economic conditions and consumer demand. As a result, companies are suffering from the effects of high inventories, out-of-stocks and declining market share.

Systematic multi-echelon inventory optimization can help take better control of inventories and make supply chain planning and execution a competitive advantage.

These solutions go beyond the standard EOQ policies by helping finished goods manufacturers and retailers create an accurate forecasting environment designed specifically for finished goods. While typical ERP systems attempt to optimize sequentially—leading to inflated demand forecasts and stock overages—SAS enables simultaneous multilevel optimization for every SKU at every location in a network.

The SAS solution provides visibility at various organizational levels to help monitor, track, alert and optimize. Key benefits include:

• Reducing inventory holding, ordering and backorder penalty costs.

• Calculating optimal inventory replenishment policies.

• Developing better replenishment strategies for fast-moving items.

• Basing finished goods distribution strategy on information from all distribution systems across the enterprise.

• Aligning finished goods strategies by sharing appropriate information with distribution professionals throughout the organization.