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Advanced Analytics for Sales & Operations Planning

Effective S&OP decision-making can't be achieved without insights from analytics.

by Jeremy E. Shapiro

Sales & operations planning is a methodology for coordinating supply chain and demand management decisions [7]. Many companies, including Procter & Gamble, Motorola and Caterpillar, have implemented S&OP processes. Thus far, these processes rely on software that acquires and integrates data relevant to S&OP but do not employ advanced analytics — optimization models integrated with descriptive models — to support S&OP decision-making.

Despite the many S&OP system implementations, recent surveys [1, 6] indicate that improvements due to them have stalled. Although reasons for the slowdown can be debated, a strong argument is that effective S&OP decision-making cannot be achieved without insights from advanced analytics. Given accurate data inputs, a properly implemented optimization model can unravel the complex interactions and ripple effects across sourcing, production, distribution, inventory and demand management decisions that make S&OP difficult and important. Companies also need to implement new S&OP processes that develop and exploit the insights provided by advanced analytics.

As shown in Figure 1, advanced analytics for S&OP are comprised of a supply chain network optimization (SCNO) model and a collection of descriptive models. The SCNO models are linear programming (LP) or mixed integer programming (MIP) models, which are the only tools capable of holistically analyzing complex S&OP problems. A SCNO model for a specific application defines the S&OP decision database that contains both data inputs to the optimization model and the optimal solutions it computes. Typical planning horizons addressed by the SCNO model are 12 to 24 months.

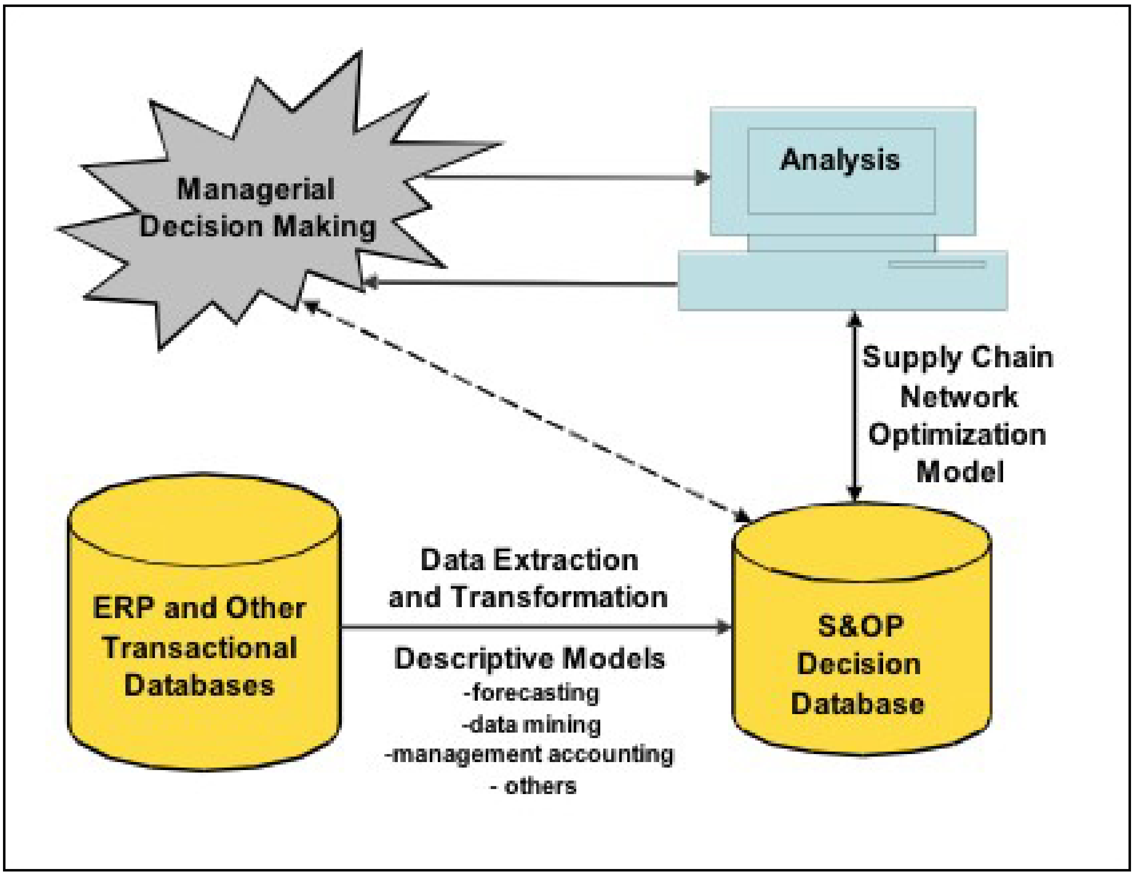

Figure 1: S&OP analytic schema.

Descriptive models are used to determine demand forecasts, manufacturing and distribution costs and cost relationships, future raw material costs and availabilities, and a variety of other parameters and relationships required by the S&OP decision database. Various aggregations of the transactional data, such as product aggregations or aggregations of customers who are geographically close, may be performed. As shown, the decision database will also contain inputs from managers expressing their judgments about performance constraints to be imposed on S&OP solutions; for example, constraints reflecting acceptable customer service levels, minimal manufacturing production levels at selected plants, and the sole sourcing of markets.

In a recent survey of 180 companies in North America [6], ease of use and integration with ERP systems were judged to be the two most important criteria for acquiring S&OP tools. As discussed in [4], both these criteria can be met by advanced analytics that are imbedded in a business intelligence system to: (1) facilitate efficient extraction, transformation and loading of inputs from ERP systems to the S&OP decision database; and (2) report metrics and other results from the descriptive and SCNO models in easy to use dashboards with drill down capabilities. The merger of business intelligence systems with advanced analytics is the critical technological development needed to facilitate and promote the next generation of S&OP tools and practices.

Case Study: Beer Manufacturer

Figure 2 provides an overview of the network underlying an SCNO model constructed for a large beer manufacturer in a country in the southern hemisphere. The model was implemented to plan for peak domestic demands during the summer season that includes the Christmas holiday. As shown, the company's five plants manufacture and package approximately 100 products that are transported through the distribution network to the markets. The company's distribution centers (DCs) are organized in three levels: plant DCs, regional DCs, and local DCs. In addition, the company has arrangements with third-party warehouses to handle surge inventories for peak demand. These DCs are designated with an S in Figure 2.

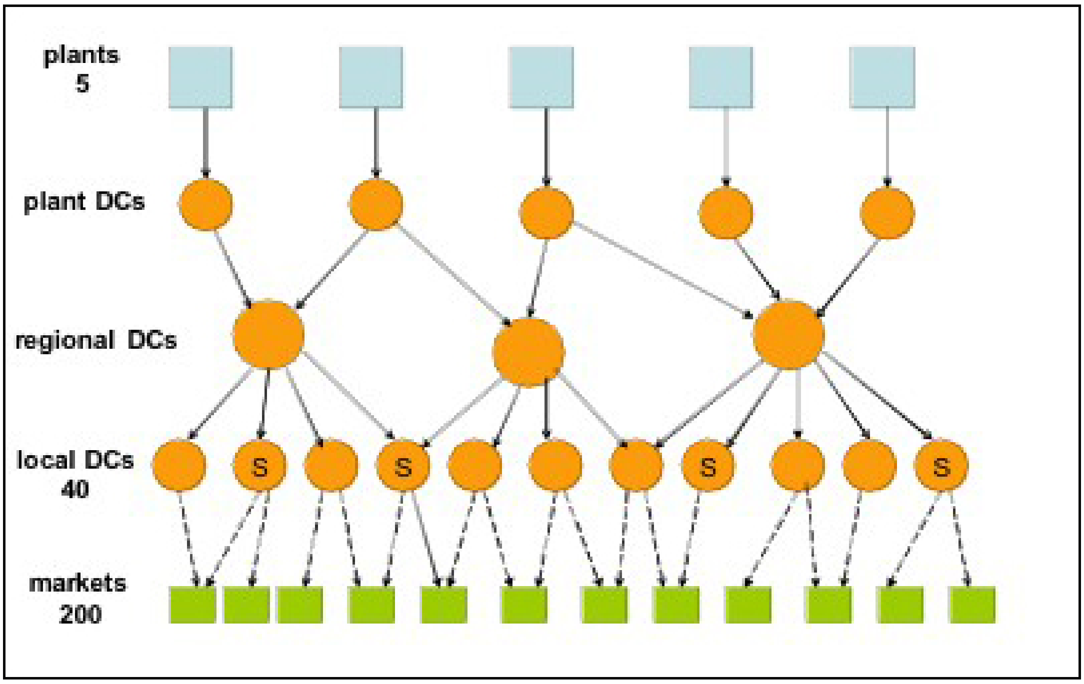

Figure 2: S&OP network of a large beer manufacturer.

The optimization model was constructed by merging 12 monthly sub-models based on the network in Figure 2 plus inventory balance equations linking consecutive months. Forecasted market demand was backed up to demand profiles for the local DCs; hence the dotted lines in the figure. This construction assumed that the customers and markets to be efficiently served by each DC were known. The resulting LP model had approximately 50,000 rows and 125,000 columns and could be generated and optimized in just a few minutes on a high-end PC.

Starting early in each calendar year, the S&OP model was run every month using updated data about inventories, forecasted demands, manufacturing capacities and other parameters. The objective function was to minimize the total supply costs of meeting forecasted demand. It provided S&OP solutions that significantly lowered these costs compared to earlier years before the advanced analytics were used.

Cost Minimization Vs. Product Minimization

At this stage in the development of advanced analytics for S&OP, an unresolved issue when constructing an SCNO model is: Should a company use an objective function that

- minimizes the total cost over the planning horizon of meeting sales which are treated as fixed and given,

or

- maximizes the net profit over the planning horizon from sales — some of which are treated as discretionary and may incur avoidable marketing, sales, product customization or non-standard service costs?

The total cost minimization approach is easier because it is simpler and directly extends current and past modeling practices regarding supply chain management. Demand management may be handled by manipulation of inventory balance equations for each product (or product family) in the SCNO model. For each product and at each location where the product may be held, this familiar equation is

Ending inventory = beginning inventory + product received or made — product shipped or sold

Cost minimization analysis may implicitly evaluate net profits by flexibility built into the model regarding if and when certain intermediate or finished products are shipped or by running multiple scenarios with varying demand profiles for finished products.

The net profit maximization approach provides more explicit modeling of integrated supply chain and demand management decisions and therefore provides more comprehensive S&OP analysis. It is more challenging to construct these models and to use them once they have been validated.

It is important to recognize that demand management modeling depends heavily on the industry. For example, companies that manufacture commodities such as chemicals or building materials often face decisions about requests from customers for customized versions of their products. The company must decide how much to charge for customized products, where the products will be made and when the products can be delivered. Typically, the company faces a portfolio of such requests and should employ integrated decision-making methods that simultaneously evaluate all such requests received over a meaningful period of time. By “discretizing” the possible selling price range for each customized order, zero-one decision variables in an SCNO model can select if, where and when each order might be manufactured and at what net profit.

Consumer package goods companies are candidates for S&OP models that integrate supply chain plans with marketing and sales plans for the coming months. Market response models that predict market share and market volume as functions of product prices, advertising, promotion and sales force effort can be linked to supply chain models that determine the costs of supplying the demand generated by the marketing plans. The objective of the integrated optimization model is to

maximize net profits = gross profits from product sales

— marketing and sales costs — supply chain costs

See [2] for details about market response models; see [3] for mathematical programming methods that integrate market response models with supply chain optimization models.

The S&OP Decision Database

Although the form and content of the S&OP decision database will depend on the nature of the company's business and on the software they acquire or implement to support decision-making, some general principles have emerged as the result of successful SCNO applications. The input data for the SCNO model is typically partitioned into *master data* files describing the structure of the company's supply chain and *scenario data* files containing numerical values for relevant costs, activities, resource constraints and final product demands. The master data files are permanent or semi-permanent with changes made infrequently. By contrast, multiple scenario data files are created and analyzed as part of each month's planning process. Outputs from SCNO model optimization of each scenario are stored in extensions of the scenario data files.

Master data files list the names of the company's suppliers, facilities (plants and DCs), and markets and their geographical coordinates. They list the names of the raw materials, work-inprocess and finished products that flow through the network, along with their units of measure. They also list the names of: the processes at each facility; the bills-of-materials used there to transform products; and resources that are consumed in carrying out these transformations. Geographical connections are provided by lists of the links in the in-bound (suppliers to facilities), inter-facility (facilities to facilities), and out-bound networks (facilities to markets). Finally, the master data files list other structural data such as available transportation modes and the number of time periods in the SCNO model.

The scenario data files provide numerical parameter values for each period in the planning horizon including:

- raw material capacities and costs for each supplier,
- facility indirect costs,
- process, product transformation, and resource capacities and costs at each facility,

- inventory throughput and safety-stock costs and capacities, and
- transportation costs and capacities.

For multi-national networks, the costs may be specified in multiple currencies with a currency exchange table for each period. The scenario data may also include managerial constraints on the shape of the S&OP solution such as the number of plants where a product may be made. Finally, numerical data describing demand forecasts by product and time period are also specified. These data may be expanded to incorporate net profit maximization options such as product pricing.

Dismantling Decision-making Silos

Managerial decision-making in Figure 1 refers to integrated decision-making among supply chain and marketing and sales managers. Advanced analytics and supporting processes serve to dismantle decision-making silos that are still present in many companies. The SCNO model provides the inspiration, or the abstract representation, for analyzing the company's S&OP problems in an integrated manner. The perspiration, or hard work, for implementing the advanced analytics is creating, validating and updating the decision database that feeds the SCNO model.

Additional effort is needed to develop and maintain S&OP processes that exploit insights provided by advanced analytics about integrated decisions.

For this purpose, the company needs to create an S&OP Coordination Committee and an S&OP Analysis Team. A typical S&OP Coordination Committee will be comprised of the VP for Supply Chain Management, key managers from procurement, manufacturing, distribution, marketing and sales, plus the head of the S&OP Analysis Team. The S&OP Analysis Team will be comprised of knowledge engineers who know the company's business and, depending on the nature of that business, have relevant, in-depth knowledge about analytics for demand forecasting, data mining, supply chain management, managerial accounting, mathematical programming and marketing science.

Each month, the S&OP Analysis Team updates the S&OP decision database and, working with the S&OP Coordination Committee, optimizes multiple scenarios describing supply and demand management plans for the coming months. These scenarios are created in response to feedback from S&OP managers to the Coordination Committee regarding the desirability and feasibility of plans suggested by earlier scenarios. Although discussion about each month's revised S&OP solutions for the coming months should be encouraged, the Coordination Committee must be given authority to impose decisions if and when the discussion becomes prolonged and counterproductive. One can expect, or at least hope, that contentious S&OP problem solving will occur infrequently as the result of monthly planning exercises that look out many months in anticipating problems and finding effective resolutions. Conflicts in team decision-making can also be reduced by creating and applying managerial incentive plans that promote integrated S&OP.

Hierarchical Planning With Advanced Analytics

Hierarchical planning refers to the identification and application of consistent and effective strategic, tactical and operational plans. The discussion thus far has addressed the use of advanced analytics in a company to support tactical S&OP over the coming months. These analytics can be transformed into and/ or linked to similar analytics that address strategic and operational planning.

Tactical S&OP analysis will often reveal the need to strategically re-design the company's supply chain network over the coming years. Related decisions regarding the company's portfolio of products or the acquisition of a complementary company may also require such analysis. A tactical SCNO model can be expanded to address strategic design options by re-defining the time periods and associated data in the model and expanding the decision database to describe the new strategic options. Conversely, a strategic network design model can be readily converted to a tactical S&OP model by fixing the design decisions and re-defining the time periods and associated data.

When moving from tactical to operational analysis, the challenge is to translate aggregate and holistic tactical plans to detailed operational ones. Detailed models for inventory control, production scheduling, personnel scheduling, vehicle routing, etc. are available for examining operational plans. An S&OP optimization model can set goals and constraints for these models over the coming days and weeks that reflect efficient tactical plans for the coming months.

Case Study: Perdigao

Perdigao, a Brazilian food manufacturer with more than $6 billion in yearly revenue, produces poultry, pork, beef and processed dairy products. Its products are sold in Brazil and in 110 countries around the world.

As discussed in [5], starting in 2003, Perdigao began developing S&OP processes to deal with many supply chain challenges including:

- long lead times up to 18 months for acquiring raw materials,
- tight constraints on slaughtering and freezing capacity,
- shelf-life constraints on finished products,
- no formal sales forecasting process or analytics, and
- a push rather than a demand-driven system for replenishing distribution centers.

Perdigao's installed SAP system contained the transactional data needed to generate and apply advanced analytics. The first step was the design and implementation of an S&OP process spanning sales, marketing, logistics, production, finance and procurement for both international and domestic markets. The goal of the new process was to extract insights from the sales organization that could later be used in developing analytics for demand forecasting. It also promoted communication and a greater sense of coordination between the sales organization and those in production, logistics and purchasing.

The next step was to leverage Perdigao's ERP system to develop demand forecasts and create a decision database with timely and accurate data describing sales orders, distribution center inventories, manufacturing and logistics constraints appropriate to short-term and tactical planning. Forecasting models were also used to predict market prices for the company's products. The S&OP transformation team then focused on distribution planning processes that would change supply chain planning to one that was demand-driven from the previous one that was push-driven.

After three years transforming their S&OP process, Perdigao took a large next step in implementing a Supply Network Planning Optimizer to address both short-term (three months) and long-term (18 months) issues involving supply chain and demand management decision-making across Brazil. The Optimizer was a large-scale LP model that addressed three suppliers groups, 16 plants, 20 DCs, seven markets, and two exporting ports. The objective function of this model was to maximize profit with constraints on product mix to ensure long-term stability of total product offerings. Constraints capturing shelf-life and inventory balances were also incorporated in the optimizer model.

The company SKUs were modeled directly (not aggregated) and numbered 600 to 1,000. As a result, some versions of the model involved more than one million constraints and several million variables and required several hours to be optimized. Modeling products at the SKU level facilitated the computation of implementable short-term operational plans as well as analysis of intermediate tactical plans. However, the resulting model size inhibited the running of multiple scenarios each month. Planning continuity was reflected in the main scenario run each month by consensus among the S&OP managers in meetings held prior to the run.

Following successful data validation exercises and extensive user training, participants in Perdigao's new S&OP process employing advanced analytics gained widespread user adoption. Representative results [5] include a 40 percent increase in inventory turns in the company's domestic markets, a 4 percent decrease in stockouts, and a 31 percent decrease in shelf-life losses.

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