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Bridging the Aggregation Gap:

Supplementing Sales and Operations Planning with Inventory Profile Analysis

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Abstract

Sales and Operations Planning, S&OP, is used by many organizations to coordinate sales, production, and inventory. Rather than reviewing each stockkeeping unit, SKU, items are aggregated into product families. Actual sales, production, and inventory are then compared to forecasted sales, planned production, and planned inventory at the product family level.

The problem with produce family aggregation, which is not unique to S&OP, is that overages of some items will mask shortages of other items within the product family. The traditional S&OP report format recommended by most authors does not provide information regarding the mix, or balance of SKUs within the product family.

Inventory Profile Analysis, IPA, is an aggregation technique that does provide mix information. The addition of IPA data to the traditional S&OP template can result in a significant improvement in the quality of the information, resulting in a more efficient S&OP meeting and an improved decision-making process.

Introduction

This paper will present an aggregation technique that has been used successfully to supplement the information found in the traditional sales and operations planning (S&OP) report. A hypothetical, but probably not unusual, S&OP executive meeting will be described. Following a brief review of S&OP, the traditional spreadsheet-based S&OP report will be presented. The use of stockkeeping (SKU) data aggregated at the product family level will be discussed, followed by a description of the aggregation problem. Inventory profile analysis (IPA) will then be introduced and IPA calculations will be explained. A revised S&OP report, incorporating the IPA data will then be provided. Finally, two anecdotal examples of improved decision making resulting from the inclusion of IPA in the S&OP report will be offered. Questions are encouraged following the presentation.

A Hypothetical S&OP Meeting

"I don't understand this thing," the Chief Executive Officer says, referring to the sales and operations planning report. "Why are sales and fill rates below target when we have too much inventory in virtually every product family?" The Vice President of Sales and the Vice President of Manufacturing look at each other. Finally, the VP of Sales says, "We do have a lot of inventory, but we don't always have the product the customer wants. Manufacturing needs to make the right mix of products." To which, the VP of Manufacturing replies, "We produce to the forecast. Sales needs to forecast the right product mix."

"Then if mix is the problem," the CEO points out, "why isn't product mix included on the S&OP report? I don't mean SKU details, just some sort of summary statistic. I want the two of you to look into inventory aggregation techniques and see what's available."

Sales and Operations Planning

APICS, the association for operations management, (www.apics.org) defines sales and operations planning as "a process to develop tactical plans that provides management the ability to strategically direct its business … by integrating customer-focused marketing plans … with the management of the supply chain…. It is performed at least once a month and is reviewed by management at the aggregate (product family) level" (Blackstone & Cox).

"Sales and operations planning is carried out at the aggregate level… product groupings or families rather than individual products or items" (Ling & Goddard). Product families are mutually agreed upon by sales and manufacturing during the implementation of S&OP (Palmatier & Crum). They can be based on a market perspective, a production process perspective, or some combination of the two (Thomas). Once the product families have been defined, finished goods items are assigned to specific product families. There can be several hundred, or even several thousand SKU's in a product family. In the S&OP process, each product family is considered an entity, and reported in total units, or in some organizations, in total costs (Palmatier & Crum).

Both Oracle (www.oracle.com) and SAP (www.sap.com) offer S&OP modules for their enterprise resource planning (ERP) products, and other ERP companies will probably provide

some S&OP functionality if they are not already doing so. The minimum S&OP requirement from an ERP system would be the ability to aggregate products into product families and then to print S&OP reports by product family. Though some ERP systems offer real-time "dashboards" and drill-down capability in their S&OP modules, an ERP system is not required for S&OP. Many companies use downloads and a spreadsheet to produce their S&OP reports (Thomas). Spreadsheets also provide a degree of flexibility not found in most ERP products.

Spreadsheet templates described by Ling and Goddard and by Wallace have been used by many companies use when implementing S&OP. The templates differ somewhat for make-to-stock and make-to-order companies. This discussion will focus on make-to-stock, which relies on forecasts and inventory to link customer orders with production, rather than make-to-order where production is directly linked to specific customer orders. Intuitively, the inventory mix problem should be more challenging for make-to-stock companies than for make-to-order companies.

The Traditional S&OP report

The traditional S&OP report consists of one page per product family with six major fields per page. Two columns present data for the past and the future, and three rows present data for sales, operations, and inventory. Within each of the three historical sections are the planned and actual aggregate totals, and the deviation from plan. The three future sections, of course, present only the planned totals. A hypothetical S&OP report is shown in Figure 1.

S&OP Report						April 2007
Garden Machines	Jan	Feb	Mar	April	May	Jun
SALES						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	3,600	2,800	2,800			
Difference	-400	-1,200	-1,200			
Cum Diff	-400	-1,600	-2,800			
OPERATIONS						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	4,000	4,000	4,000			
Difference	0	0	0			
Cum Diff	0	0	0			
INVENTORY (EOM)						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	3,900	5,100	6,300			
Difference	-100	1,100	2,300			
Days on Hand	1.08	1.82	2.25			
Fill Rate	0.88	0.79	0.74			

Figure 1 – Traditional S&OP Report

The objective of S&OP is to learn from the past and make short-term adjustments in sales or manufacturing activities to achieve the long-term objectives of the organization. In Figure 1, performance data for the "Garden Machines" product family is presented for January, February, and March. The S&OP team is meeting to discuss actions to be taken in April, May, or June to resolve the problem. The problem, in this example, is that inventory is increasing, with March inventory considerably over the planned quantity, yet the fill rate, the percent of new orders filled from stock, is decreasing and sales are significantly below plan.

Inventory is the result of production minus sales. As such, actions cannot be taken directly with inventory, but must be taken by way of changes in sales and/or operations. For example, price reductions or other marketing actions could be implemented to increase sales and reduce inventory, or production could be cut back or eliminated to reduce inventory. The difficulty in this example is that the fill rate is decreasing, and this is generally a sign of too little, not too

much, inventory. Stimulating demand or reducing production might make the fill rate problem even worse than it is now.

The root problem in the example will be discussed later. First, the problem of aggregation needs to be understood.

The Agony of Aggregation

The assumption, in product family aggregation, is that all stockkeeping units in the family are represented in static proportions. For example, if item "A" constitutes 10% of the product family, item "A" will always account for 10% of the sales, 10% of the production, and 10% of the inventory. This is rarely, if ever, the case in the real world. Another implied assumption in product family aggregation is that an excess of one SKU will compensate for a shortage of another SKU. This assumption cannot be supported.

The garden machines product family shown in Figure 1 is comprised of four stockkeeping units, lawn mowers, chipper shredders, leaf blowers, and snow blowers. Each is produced on the same assembly line, and each accounts for 25% of the annual sales for the product family. The traditional S&OP report illustrated in Figure 1 presents the product family data with the assumption of a balanced proportion of all four SKU's. The actual mix of SKU's is not displayed for any of the 27 aggregate totals on the report.

Inventory Profile Analysis

Returning to the opening scenario, two executives have been charged with investigating inventory aggregation techniques. They find a paper on inventory profile analysis (Robison) published by APICS in the March 2001 issue of the Production and Inventory Management Journal, and winner of Romey Everdell award (APICS) for the best article of the year.

Inventory profile analysis (IPA) recognizes that an excess of one SKU cannot compensate for a shortage of another, even within the same product family. IPA uses historical data to create a proportional distribution of each SKU in the family. The aggregate plan is then disaggregated into proportional SKU targets, and each actual SKU quantity is compared to its target. In inventory profile analysis, three values are obtained, coverage, shortage, and excess. Coverage is the actual quantity up to, but not exceeding the target for each SKU. Shortage is the difference, if any, between coverage and the target, and excess is any amount over the target. Figure 2 illustrates the IPA calculations for finished goods inventory in the garden machines product family for March 2007.

Garden Machines	Historical Proportion	Target Inventory	Actual Inventory	Coverage	Shortage	Excess
Lawn Mower	0.25	1,000	2,200	1,000	0	1,200
Chipper Schredder	0.25	1,000	1,800	1,000	0	800
Leaf Blower	0.25	1,000	2,300	1,000	0	1,300
Snow Blower	0.25	1,000	0	0	1,000	0
Totals	1.00	4,000	6,300	3,000	1,000	3,300
Percent*				75.0%	25.0%	52.4%

* Coverage & Shortage are % of Target. Excess is % of Actual.

Figure 2 – IPA Coverage, Shortage, and Excess for March Ending Inventory

Coverage

Coverage is the lessor of target or actual for each SKU. Although 6,300 total units are in inventory, only 3,000 units, or 75% of the target, are actually available to "cover" the expected demand. Unless corrective action is takes, a fill rate of about 0.75 could be expected. The actual fill rate will be slightly higher due to the "excess effect" explained later. The ideal coverage would be an amount equal to the aggregate target for the product family.

Shortage

Shortage is the complement of coverage, the difference between coverage and target, the difference between "what we have" and "what we wish we had." Mathematically, shortage is the greater of target less actual or zero. In the example, the shortage is 1000 units, or 25% of the target. Obviously, the ideal shortage value would be zero.

To summarize, coverage (3,000) plus shortage (1,000) equals target (4,000) and the coverage percent (75%) plus the shortage percent (25%) will always equal one hundred percent.

Excess

Excess is the greater of actual less target or zero. In the example, there are 3,300 excess units in inventory. Coverage (3,000) plus excess (3,300) equals actual (6,300). Since excess is a function of the actual inventory, rather than the target, the excess percent is calculated by dividing the excess quantity by the actual inventory. In this example, 52.4 percent of the total inventory is excess.

The Excess Effect

Excess inventory will increase fill rate slightly, but the effect will be less than if the same quantity were used to improve coverage of another SKU, assuming the target includes safety stock. This can be illustrated using standard deviations. Assume a normal distribution of demand and two standard deviations of safety stock. The expected fill rate would be 97.7%. An excess quantity equal to one standard deviation will only increase the fill rate by about 2.2 percentage points (99.9 – 97.7 = 2.2) while a shortage of one standard deviation will reduce the fill rate by about 13.6 points (97.7 – 84.1 = 13.6). This incremental increase in fill rate resulting from excess inventory is known as the excess effect. The excess effect of 2.2 points in this example can hardly justify the loss of 13.6 points in the same product family. If this were a two-SKU product family, an excess of one standard deviation in one SKU and a shortage of an equal amount in the other SKU will result in a fill rate of about 86% (97.7 + 2.20 – 13.6 = 86.3). In summary, excess inventory is a very inefficient use of resources because the same resources could have been used to increase coverage and reduce shortage.

Supplementing S&OP with IPA

It is important that S&OP decision makers can easily see and understand the inventory mix previously hidden in the aggregate totals. Though they may share a common root cause, the short term remedies for inventory shortage are completely different than for excess inventory.

The excess quantity or percent should be included in the S&OP report, however there is no reason to include both coverage and shortage in the S&OP report as they are really two perspectives of a single event. Since the ideal excess value is zero, it is usually logical to use

shortage rather than coverage, as shortage also has an ideal value of zero. This provides a simple "exception report" where any value other then zero is a problem, and the bigger the value, the bigger the problem. Either quantities or percents could be used, depending upon the preferences of the users. Quantities will be displayed in the examples that follow.

Figure 3 is the original S&OP report shown in figure 1, with the addition of shortage and excess quantities in the inventory section of the report. This information should alert the users that the declining sales and fill rates, and the increasing inventory could be related to a problem with the inventory mix. Note that for each period, the actual inventory is equal to the planned inventory, plus the excess and minus the shortage.

S&OP Report						**April 2007**
Garden Machines	Jan	Feb	Mar	April	May	Jun
SALES						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	3,600	2,800	2,800			
Difference	-400	-1,200	-1,200			
Cum Diff	-400	-1,600	-2,800			
OPERATIONS						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	4,000	4,000	4,000			
Difference	0	0	0			
Cum Diff	0	0	0			
INVENTORY (EOM)						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	3,900	5,100	6,300			
Difference	-100	1,100	2,300			
Shortage (Actual < Plan)	1,000	1,000	1,000			
Excess (Actual > Plan)	900	2,100	3,300			
Days on Hand	1.00	1.67	2.60			
Fill Rate	0.88	0.79	0.74			

Figure 3 – S&OP Report with Shortage & Excess Inventory

As stated earlier, inventory is the result of sales and operations – an out-of-balance inventory does not create itself. To continue the investigation, the S&OP team needs visibility of the mix of products being manufactured, compared to the production plan, and the mix of products being sold, or at least demanded, compared to the forecast.

Figure 4 is the IPA calculations for March production. The total production matched the plan, but three items were produced below plan (900 < 1000), and the snow blowers were produced above plan (1300 > 1000). An examination of production records for the month should indicate the reason for these deviations from plan. An example would be a request from Customer Service to expedite orders for snow blowers.

Garden Machines Production	Historical Proportion	Planned Production	Actual Production	Coverage	Shortage	Excess
Lawn Mower	0.25	1,000	900	900	100	0
Chipper Schredder	0.25	1,000	900	900	100	0
Leaf Blower	0.25	1,000	900	900	100	0
Snow Blower	0.25	1,000	1,300	1,000	0	300
Totals	1.00	4,000	4,000	3,700	300	300
Percent*				92.5%	7.5%	7.5%

* Coverage & Shortage are % of Target. Excess is % of Actual.

Figure 4 – IPA Shortage and Excess for March Sales

Figure 5, below, is the IPA calculations for March sales, which were 1,200 below forecast. Three items were considerably below forecast (500 < 1000), but the snow blowers were above forecast (1300 > 1000). Given that only 1300 snow blowers were produced in March (fig. 4), it is possible that the actual demand for snow blowers might have been even greater. An examination of backorders and order cancellations for March should be conducted to determine the true demand for snow blowers.

Garden Machines Sales	Historical Proportion	Forecasted Sales	Actual Sales	Coverage	Shortage	Excess
Lawn Mower	0.25	1,000	500	500	500	0
Chipper Schredder	0.25	1,000	500	500	500	0
Leaf Blower	0.25	1,000	500	500	500	0
Snow Blower	0.25	1,000	1,300	1,000	0	300
Totals	1.00	4,000	2,800	2,500	1,500	300
Percent*				62.5%	37.5%	10.7%

* Coverage & Shortage are % of Target. Excess is % of Actual.

Figure 5 – IPA Coverage, Shortage, and Excess for March Sales

In figure 6, shortage and excess have been added to both the sales and the operations sections of the report.

S&OP Report						April 2007
Garden Machines	Jan	Feb	Mar	April	May	Jun
SALES						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	3,600	2,800	2,800			
Difference	-400	-1,200	-1,200			
Cum Diff	-400	-1,600	-2,800			
Shortage (Actual < Plan)	1,000	1,500	1,500			
Excess (Actual > Plan)	600	300	300			
OPERATIONS						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	4,000	4,000	4,000			
Difference	0	0	0			
Cum Diff	0	0	0			
Shortage (Actual < Plan)	100	300	300			
Excess (Actual > Plan)	100	300	300			
INVENTORY (EOM)						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	3,900	5,100	6,300			
Difference	-100	1,100	2,300			
Shortage (Actual < Plan)	1,000	1,000	1,000			
Excess (Actual > Plan)	900	2,100	3,300			
Days on Hand	1.00	1.67	2.60			
Fill Rate	0.88	0.79	0.74			

Figure 6 – S&OP Report with Shortage & Excess, Sales, Operations, & Inventory

Figure 6 indicates that the primary reason for the inventory problems, in this hypothetical example, is in sales and not operations. Actual production does vary from plan, but only by a few hundred units. Sales, however, is showing considerable shortages between forecast and actual sales. The S&OP report now has the needed mix information to explain the fill rate problem, and can point the appropriate staff in the right direction for the root cause and a solution.

To complete the story, this hypothetical example contained a deliberate flaw. The forecast for the four SKU's in the garden machines assumed equal demand of 1000 units each, but seasonality caused heavy demand for snow blowers, moderate demand for chipper shredders, and little demand for leaf blowers and lawn mowers. Manufacturing shifted production slightly from lawn mowers to snow blowers, but the failure to include seasonality in the forecast, the root cause of the problem, went undetected.

In figure 6, six lines were added to the traditional S&OP report. After the users are familiar with the new IPA data, they might decide that some of the traditional indicators are no longer necessary. Figure 7 is suggested format for such a report.

S&OP Report						April 2007
Garden Machines	Jan	Feb	Mar	April	May	Jun
SALES						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	3,600	2,800	2,800			
Shortage (Actual < Plan)	1,000	1,500	1,500			
Excess (Actual > Plan)	600	300	300			
OPERATIONS						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	4,000	4,000	4,000			
Shortage (Actual < Plan)	100	300	300			
Excess (Actual > Plan)	100	300	300			
INVENTORY (EOM)						
Plan	4,000	4,000	4,000	4,000	4,000	4,000
Actual	3,900	5,100	6,300			
Shortage (Actual < Plan)	1,000	1,000	1,000			
Excess (Actual > Plan)	900	2,100	3,300			
Fill Rate	0.88	0.79	0.74			

Figure 7 – Revised S&OP Report with IPA Indicators

Completing the opening scenario, the CEO, the VP of Sale and the VP of Manufacturing are back in the executive S&OP meeting, only this time with the IPA enhanced S&OP report. The VP of Manufacturing says, "Inventory is increasing, driven by 3,300 units of excess products. The shortage is entirely snow blowers. We shifted production from the excess products to expedite some orders snow blowers, but apparently not enough. In the future, my people will notify me if any item is expedited more than once a month." The VP of Sales continues, "The problem was that our new forecasting model didn't take into account the seasonality of the products in the garden equipment family. We corrected the model and we are working with manufacturing to get our inventory back in balance." To which the VP of Manufacturing replies, "Yes, we're only making snow blowers now, and we have enough of the other products to see us into May. We learned some lessons this time. We won't be fooled by aggregate totals again."

Antidotal Support

A shoe importer suffered poor fill rates in their flagship product family yet aggregate inventory was above plan. When an inventory profile analysis was conducted, it was discovered that a large school had adopted a particular shoe as part of their official uniform. When the local retailer ran out of the product, the students went on line and ordered all the shoes they could find from across the country.

A manufacturer of lenses for prescription eyewear had four months to produce sufficient inventory to launch a new product. An inventory profile analysis was conducted weekly and soon discovered that problems with some of the molds were preventing a balanced production mix. New molds were obtained, the inventory was balanced, and the product was launched on schedule.

Summary

Traditional sales and operations planning answers the question “Do we have the right quantity?” Inventory profile analysis answers the question “Do we have the right mix?”

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Biography

Jim Robison has over 30 years experience in operations management as director of supply chain, director of production control, materials manager, inventory manager, and purchasing manager. Jim is a Certified Fellow in Production and Inventory Management, CFPIM, and is certified in integrated resource management, CIRM. His has a Bachelor of Science degree is in business and industrial management from San Jose State University, a Master of Business Administration degree from Sonoma State University and is currently pursuing a Doctor of Business Administration degree at Golden Gate University. He is a former APICS chapter president and has presented at three APICS conferences. Jim is a recipient of the Romey Everdell Award for the most outstanding article published in the Production and Inventory Management Journal and winner of the Plossl Award for best doctoral dissertation in operations management. He currently teaches operations management as an adjunct lecturer at Sonoma State University in Rohnert Park, California.