EVALUATING THE INTEGRATION OF CONTRACT MANUFACTURERS IN AN ADVANCED S&OP PROCESS

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ABSTRACT

Avocent Asia Pacific Pte Ltd is an IT product manufacturer. In 2012, the company integrated a key supplier as a collaborative partner in an Advanced S&OP initiative. The results from a 4-month pilot study were highly promising, with mean inventory levels reduced by 30.4%. Forecast accuracy improved significantly, which was reflected in a 52.1% reduction of mean absolute imbalance between inbound and outbound shipments at the regional distribution centre.

Keywords: S&OP, forecasting, supply chain collaboration

1. INTRODUCTION

Avocent Asia Pacific Pte Ltd provides a wide range of software, hardware and embedded technologies for the data centre industry. It is a subsidiary of Avocent Corporation and part of Emerson's Network Power Division. Avocent's customers are mainly enterprise-level IT organizations, who use these products to monitor, control, and manage their geographically dispersed IT infrastructure more efficiently. Avocent sells products under its own brands and also manufactures on behalf of OEM customers. Its Asia Pacific hub is based in Singapore, from which the rest of Asia is served from a regional distribution centre (RDC).

In 2010, Avocent adopted a form of Sales and Operations Planning (S&OP) process within the organization. Two years later, it decided to further introduce an advanced version of S&OP that integrates a key supplier into its collaborative production process.

This paper describes Avocent's experience with the adoption of the Advanced S&OP model and how it is different from the traditional planning process. Finally, a set of results from a pilot study of the Advanced S&OP process is presented.

2. LITERATURE REVIEW

2.1. Sales and Operations Planning (S&OP)

S&OP is a tactical planning process that is conducted in a monthly cycle, pioneered in the 1980s. It has "evolved from what was once known as production planning to a company-wide management process….A properly implemented S&OP process routinely reviews customer demand and supply resources and 're-plans' quantitatively across an agreed-upon rolling horizon (typically 18 to 24 months)."[2]

The S&OP concept focuses on a 5-step monthly process that is participated by key stakeholders within the organization, such as the Sales, Marketing, Operations, Production and Finance departments. The benefits of implementing S&OP include inventory reduction, higher service level and better teamwork between departments.

The 5 steps as shown in Figure 1 are:

- New product introduction review
- Demand review
- Supply review
- Financial reconciliation review
- Management evaluation and analysis

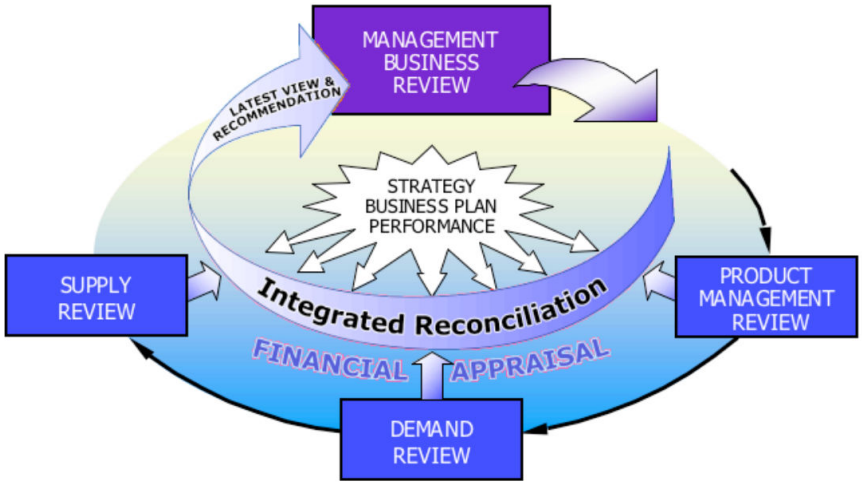

Figure 1: Five-Step S&OP Process [2]

The main benefit of S&OP is the ability to strike a balance in the supply chain [5]. A balanced supply chain is one that has a "seamless flow of materials starting from a supplier's supplier down to a customer's customer supported by transportation elements. In a perfect scenario, this would imply moving the right goods, with the right quantity, in a right quality to the right destination in the right time." An example of striking a balance is in forecast management. If forecasts are too low, they can cause stock-outs and force plants into a scramble and result in

unplanned overtime. On the other hand, if forecasts are too high, inventories can build up and carrying costs would rise.

Grimson & Pkye [1] proposed a framework that identifies 5 stages of maturity in S&OP integration. This framework grades firms across five dimensions, comprising business processes (meeting and collaboration, organization and performance measurements) and information processes (information technology and S&OP plan integration). Stage 1 of the framework is the most basic, in which S&OP is not adopted. Stage 2 ("Reactive S&OP") involves senior management in discussing sales and operations issues. However this is mainly in the context of financial goals, rather than for the purpose of integrating plans or centralizing information, as is the case in Stage 3 ("Standard S&OP"). In Stage 4 ("Advanced S&OP"), suppliers and customers participate in scheduled meetings as part of a formal S&OP team. Planning is concurrent rather than sequential and performance is measured for new product introductions. Finally, in the most mature form of S&OP (Stage 5 "Proactive S&OP"), meetings become event-driven and there is full integration of plans and between ERP, accounting and forecasting systems. A key finding of Grimson and Pyke's investigation is that none of the 15 manufacturing firms that they studied were judged to have fully reached stage 4 or stage 5 maturity in the adoption of S&OP.

2.2. Collaborative Planning, Forecasting and Replenishment (CPFR)

The concept of supply chain collaboration is not new, especially between manufacturers and retailers.

CPFR is a collaborative program aiming at improving forecasts. The process steps for CPFR (as shown in Figure 2) are developed by Voluntary Inter-Industry Commerce Standards (VICS) [3]. CPFR "combines the collaborative intelligence of multiple trading partners in the planning and fulfillment of customer demand." It also "links sales and marketing best practices, such as category management, to supply chain planning and execution processes to increase availability while reducing inventory, transportation and logistics costs."

For example, VICS reported that Lowe's and Whirlpool's CPFR program [3] resulted in a 12% increase in unit sales between 2007 to 2010 while overall inventory costs decreased by 5%. From a customer service perspective, on-time shipments improved by three percentage points.

Another CPFR pilot between Wal-Mart and Sara Lee for 23 apparel items distributed across 2,400 stores also resulted in significant supply chain improvements [4]. After 24 weeks of implementation, Wal-Mart realized a 2% improvement in retail store in-stock, a reduction of 14% in store-level inventory compared to a 32% increase in sales, and an increase of 17% in retail turns on the pilot items.

Figure 2: VICS CPFR Model [3]

The key difference between S&OP and CPFR is that S&OP is a "strategic business management process that aligns centers of functional excellence in a coordinated internal collaborative process, while CPFR is a strategic business management process that aligns the complementary capabilities of trading partners in a coordinated external collaborative process" [2]

The CPFR process has however been developed mainly with the manufacturer-retailer relationship in mind. Even though the model is also applicable to upstream buyer and seller relationships, there are few actual examples of CPFR programs between manufacturers and their contract manufacturing partners, each of whom may still maintain their own individual S&OP processes.

3. TOWARDS A COLLABORATIVE MANUFACTURING MODEL

Traditionally, Avocent's planning process starts when forecasts from its customers are received during the first week of each month. Both the Sales and Operations departments will use these forecasts to formulate a master schedule against historical sales trend. The finalized master schedule will be uploaded into the SAP ERP system, whereby a supply chain forecast known as the Contract Manufacturing Shipment Schedule (CMSS) will be generated and provided to the contract manufacturer (CM). The CM will then review the CMSS and existing open purchase orders (PO) and commit on the actual deliveries according to the CMSS/PO requirement. There is thus an absence of a feedback or joint forecasting process between Avocent and its CM.

Figure 3 shows the key parties along the supply chain for a typical product carried by Avocent, which is manufactured by a contract manufacturer and delivered to Avocent's regional distribution centre (RDC).

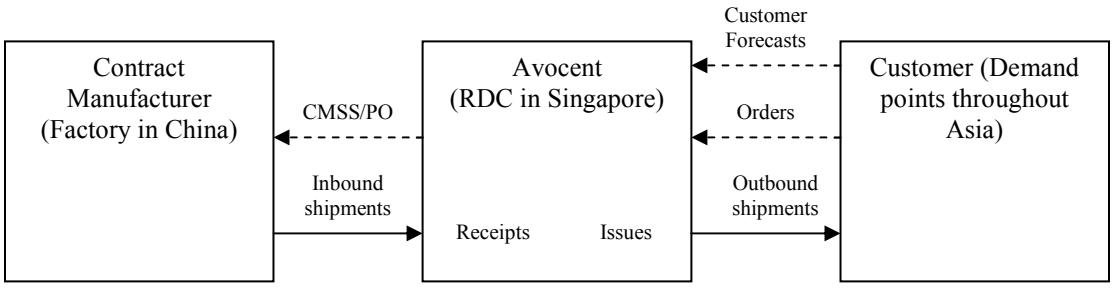

Figure 3: Simplified Supply Chain for a Typical Avocent OEM Product

Two years after implementing S&OP on a limited scale, Avocent has managed to meet customer demand with a lower level of inventory and achieved a higher level of customer satisfaction for their branded business. Inter-department collaboration has also improved as all stakeholders are geared towards common goals.

Despite the success of the S&OP process, buyers still find it necessary to constantly monitor inventory levels against actual demand and often make changes to the PO via pull/push outs or changes in product models. These corrective actions have caused bull whip effects on the supply chain and put strains on the relationships with suppliers, especially towards the end of financial periods.

With the past success in S&OP implementation, a management decision was made to embark on a new mode of collaboration with Avocent's key supplier in China. The collaboration requires both Avocent and the contract manufacturer (CM) to work together as a virtually-integrated team in an Advanced S&OP model, similar to the Stage 4 model under Grimson & Pkye's framework but with elements of CPFR.

3.1. Implementing the Advanced S&OP Process

The Advanced S&OP process as envisioned by Avocent can be viewed as a hybrid of the S&OP and CPFR frameworks. Information (such as forecasts from the customer, reorder points and master production schedules) is shared by Avocent with its contract manufacturing partner (who in turn analyses its own supply chain for constraints). Based on the feedback from the contract manufacturing partner, Avocent determines the level of expedites, rebalancing and adjustments needed to fulfill its customers' demand.

Below are the 5 main stages of Avocent's new process with its contract manufacturer.

Stage 1 - Sales forecasting

- Customer forecast is collected by Avocent and distributed to CM for joint analysis against past trends and budgets.

Stage 2 - Demand Planning

- Forecasted production quantity is determined by validating inventory level, and checked for any variation of forecast that needs adjustment.
- Reorder Point (ROP) levels are computed based on customer historical trend or forecast average over the next 10 weeks. This ROP also takes into consideration production lead-time of 5 days with the default transportation mode transit-time (which depends on the customer's location).
- The Master Production Schedule (MPS) is presented in weekly buckets and is adjusted according to customer pull trends. For example, certain customers have a tendency to pull up to 50% of their monthly demand during the last week of the month.

Stage 3 - Supply Planning

- Based on the required MPS quantity, the CM determines whether there are any supply, material or capacity constraints in meeting the required demand. This information is presented in the weekly committed MPS to Avocent.

Stage 4 - Reconciliation of plans

- At this stage, the CM will report if there is any expediting cost expected. Otherwise alternative plans such as site balancing or product priority adjustment will be considered.

Stage 5 - Finalized S&OP Plan and execute

- Once consensus is reached by both parties, a master production schedule will be produced by the CM and loaded into their production planning system. Avocent will then issue a Blanket PO that provides production coverage for up to 5 weeks.
- From this point onwards, the team starts to monitor inventory levels against ROP levels. When the ROP is breached, CM initiates production based on pre-agreed quantities and schedules to ship products to the respective hubs.

During the planning stage the following information is shared between both parties.

1. Customer raw forecast
2. Warehouse inventory and safety stock levels
3. Historical shipments to end customers
4. Reorder Point (ROP) calculations based on statistical analysis
5. Master Production Schedule (MPS)
6. Raw material constraints
7. Production capacity constraints

During the execution stage, daily communications are conducted between operations, buyers and the CM planners. These sessions help to reconcile any outstanding issues such as sudden increases in demand/forecast or changes in inventory due to abnormal transactions such as returns.

3.2. Differences between the Traditional and Advanced S&OP processes

As shown in Figure 4, the key feature in the new Advanced S&OP process is that the Contract Manufacturer has direct access to the sales forecast provided by Avocent's customer. Production is triggered by a Reorder Point (ROP) that is jointly established with Avocent, who issues a blanket PO upfront (instead of having to review each PO as is the case traditionally).

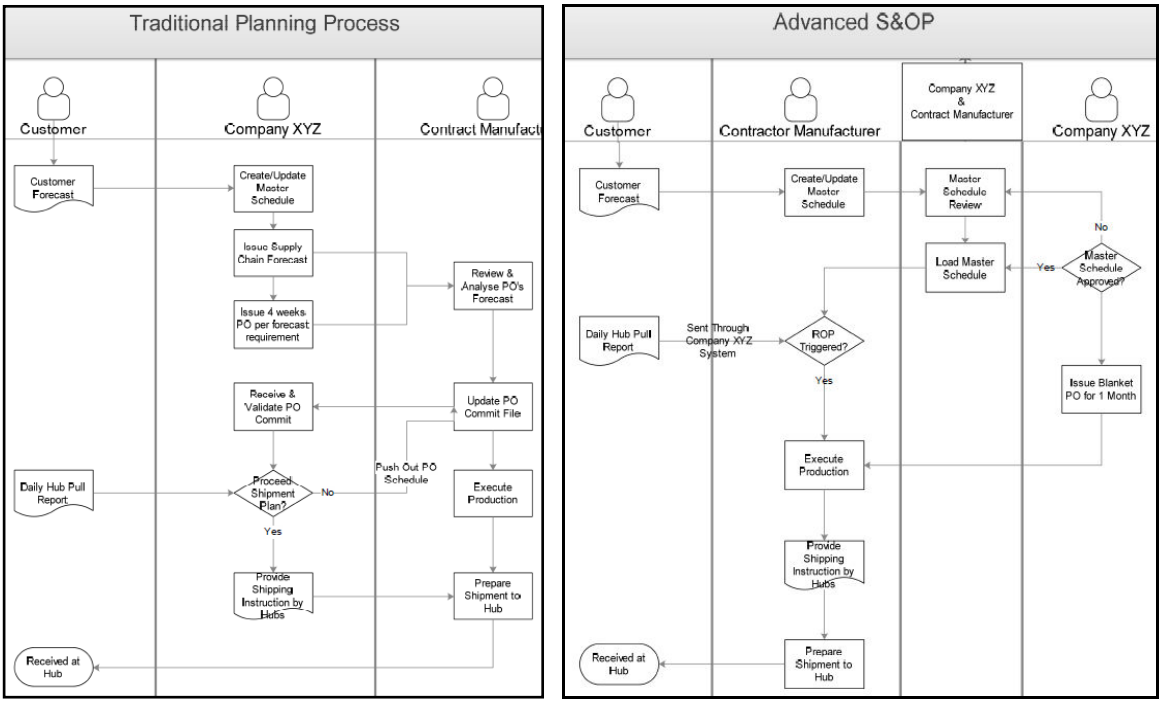

Figure 4: Flowcharts for Traditional Planning versus Advanced S&OP

Table 1 highlights other key differences between the 2 processes, in terms of the planning cycle, purchase orders, delivery triggers and changes in demand or supply.

Table 1: Traditional Planning versus Advanced S&OP

	Traditional Method	Advanced S&OP
Planning Cycle/ MPS/ CMSS Report	• Avocent plans its MPS and uploads it into SAP system. • SAP calculates required orders based on current inventory, open POs, demand and part master setting such as transit lead-time to generate a CMSS report • Buyers review and adjust the CMMS report before forwarding the forecast plan to CM to plan for its own MPS • MPS is reviewed every month, while	• Avocent and CM share the same agreed MPS for each part number in a common planning platform and load the MPS into its system at the same time • Both Avocent and CM conduct joint MPS reviews every two weeks. • During mid-month review, weekly MPS and MPS Commit

	Traditional Method	Advanced S&OP
	CMSS is reviewed every two weeks • Errors may occur in CMSS report when the part master settings such as transit lead-time are set wrongly in Avocent's SAP	are changed to match customer demand
Purchase Orders (PO)	• Each buyer places multiple purchase orders within a defined approval limit (Average 30~50 POs for each buyer)	• Buyers place the reviewed parts and quantity into a single Master Scheduling Agreement (MSA or also known as Blanket PO) for management approval
Trigger Point for Delivery	• Safety stock level breached • PO scheduled date due	• ROP level triggered
PO Management (Customer changes in demand/ suppliers changes in commit)	• SAP system recommends suitable actions for each PO/ Purchase requisition (PR) line after MRP run • Buyers review the system data and check with CM on adjustment for the PO dates in order to maintain the desired inventory level	• System auto-generates purchase requisition (PR) based on MSA. • System calculates the necessary changes and adjusts the dates on PR lines. • Buyers will convert the PR into single PO for delivery when ROP is triggered

4. RESULTS AND ANALYSIS

Prior to a roll-out on a larger scale, a four-month pilot study was conducted on the SKUs demanded by a major customer of Avocent. The fulfillment of this customer's demand before and after the implementation of the Advanced S&OP process is investigated, in particular

- the inventory per unit sales used to meet demand and
- forecast accuracy, which can be indirectly measured by the weekly imbalance between inbound and outbound shipments at its regional distribution centre in Singapore.

Selected data for 45 weeks before and 19 weeks after the commencement of the new process are available for analysis. During this period, there were no external events (e.g. major natural disasters) or other internal activities (such as the large scale introduction of new products) that could have contributed to major shocks in the supply chain. Such factors would be more difficult to control over a prolonged study period.

4.1 Normalized Average Inventory

Higher sales generally require higher levels of inventories. Hence, in this analysis, the level of inventory normalized against demand is computed, such that:

$$\textit{Normalized Weekly Inventory} = \textit{Average Weekly Inventory/ Average Past 4 Weeks of Sales} \quad (1)$$

A low level of normalized inventory typically indicates superior performance in inventory control. The below chart is the plot of an index of normalized inventory, before and after the Advanced S&OP process was introduced.

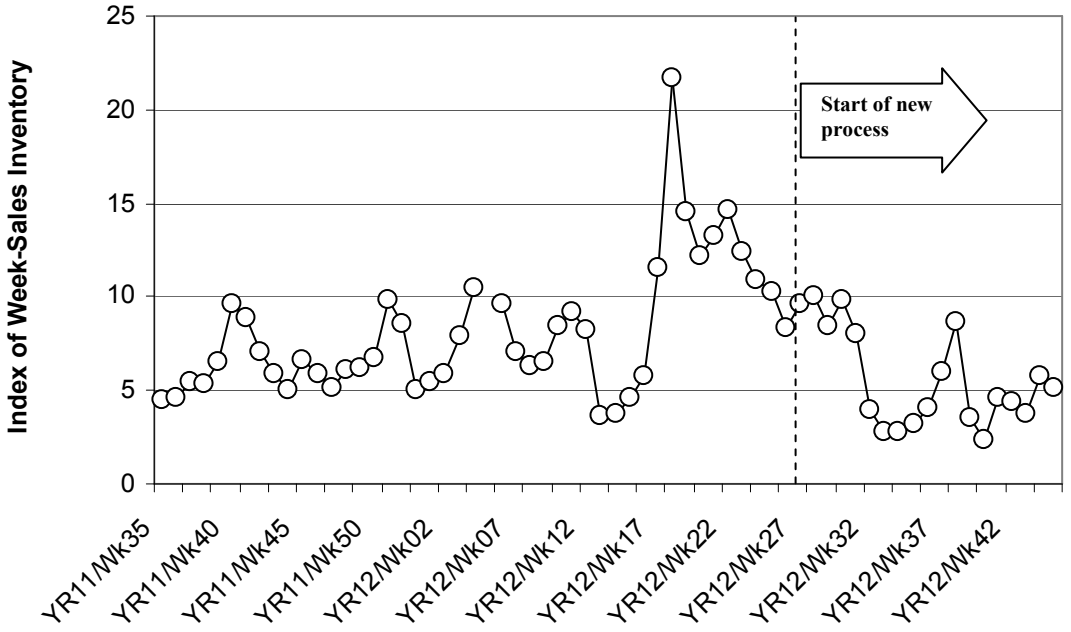

Figure 5: Normalized Inventory Before and After Advanced S&OP

(Note: The normalized inventory level for YR12/Wk05 (with a high value of 50) was identified as an outliner and removed from the data set during analysis. This outliner was the result of extremely low sales in January 2012, even though average inventory level remained relatively stable.)

The results of the analysis show that there was a 30.4% reduction in inventory levels in the weeks after the new process was introduced. However, due to the limited scale of the pilot study and the large fluctuations in inventories (which is a characteristic of the IT industry), a *t-test* was also conducted to ascertain the significance of the impact of the Advanced S&OP process.

The null hypothesis (H_0) and alternate hypothesis (H_1) are:

H_0: $\mu_1 \leq \mu_2$

H_1: $\mu_1 > \mu_2$

Where:

- μ_1 refer to the mean Average Inventory/Average Sales *before* implementing Advanced S&OP
- μ_2 refer to the mean Average Inventory/Average Sales *after* implementing Advanced S&OP

The rejection criteria for H_0 is that t-value is >= critical value (one-tail) i.e.

- if $t > 1.680$, then H_0 can be rejected at the 5% significance level;
- if $t \leq 1.680$, then H_0 cannot be rejected at the 5% significance level

t-Test: Two-Sample Assuming Unequal Variances

Customer A (S&OP Parts)	*Before*	*After*
Mean	8.0690	5.6142
Variance	12.5147	6.9140
Observations	44	19
Hypothesized Mean Difference	0	
df	45	
t Stat	3.0487	
P(T<=t) one-tail	0.0019	
t Critical one-tail	1.6794	
P(T<=t) two-tail	0.0038	
t Critical two-tail	2.0141	

The t-test result shows that the t-value of 3.049 is higher than the critical one-tail t-value of 1.680. Based on this, the null hypothesis H_0 can be rejected.

To account for possible seasonal effects, another test is conducted for a smaller subset of data for 11 weeks (weeks 35 to 45) within the trial period for which data from the corresponding period a year ago is available. In this test, the calculated t-value is 2.262, which also exceeds the critical t-value of 1.726.

It can thus be concluded that the Advanced S&OP process was effective at the 5% significance level in reducing inventory during the pilot study.

4.2. Forecast Accuracy

Since past forecasts are not available for this study, a surrogate set of analysis is conducted by comparing weekly inbound versus outbound shipments at the regional distribution centre (RDC). A positive imbalance (i.e. receipts greater than issues) over a short period indicates that the inventory at the RDC is rising, most probably as a result of forecasted demand being greater than actual demand, vice versa. This is a more rigorous test than analyzing inventory levels, as it also takes into account under-forecasting. Under-forecasting results in low inventories that may appear desirable but are not unsustainable. It can also greatly increase the likelihood of stock-outs.

As receipts are usually put into stock at the RDC for an average of about a week before they are shipped out, an offset of 1 week is applied to outbound data when computing imbalance. To account for delays in ocean shipping (which may cause scheduled receipts to arrive in the

following week), the receipts and issues values are smoothed over two weeks. Therefore, imbalance is computed as follows:

$$\textit{Imbalance} = \textit{Average of receipts (week x and week x+1)} - \textit{Average of issues (week x+1 and week x+2)} \quad (2)$$

Since the objective is to investigate overall forecast accuracy rather than over-forecasting or under-forecasting specifically, the *absolute* imbalance between receipts and issues is calculated and plotted in Figure 6, for the period before and after the Advanced S&OP process was introduced.

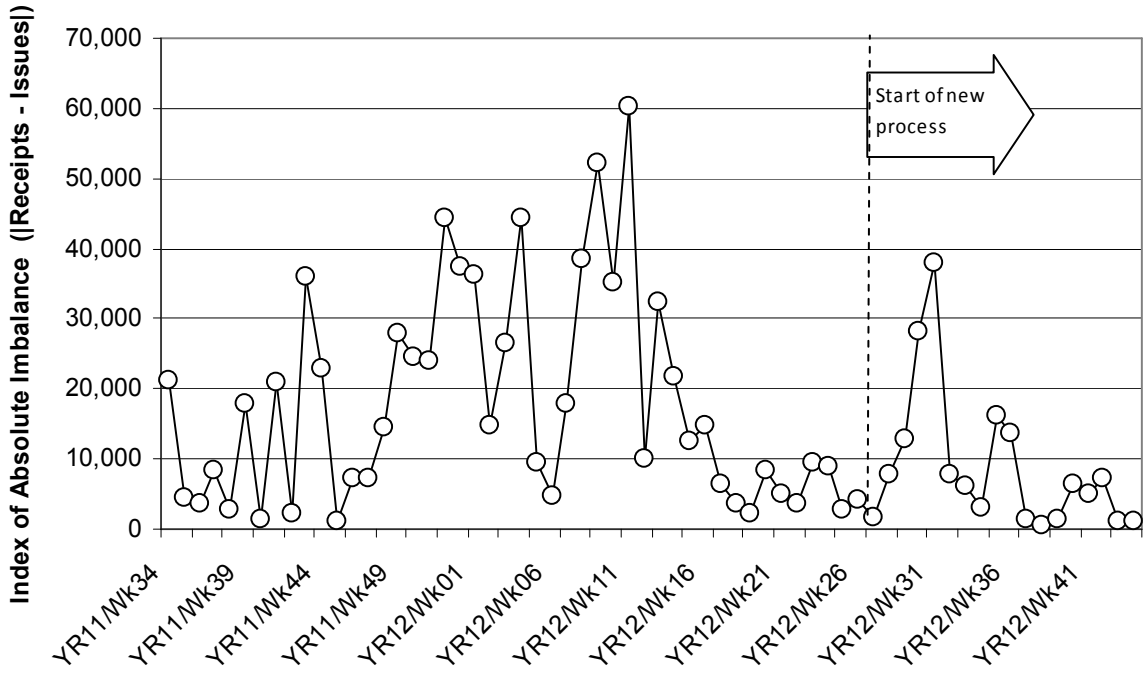

Figure 6: Balance between Inbound and Outbound Shipments

Results from the analysis show that the absolute imbalance of 8,637 (index) after the adoption of Advanced S&OP process is a 52.1% reduction from the 18,035 (index) before.

From Figure 6, it is apparent that prior to introducing the new process, there was a tendency for the absolute imbalance between receipts and issues at the RDC to fluctuate dramatically from week to week, possibly as a result of buyers' efforts to compensate for over and under forecasts in past periods. This effect is noticeably under control during the pilot study.

A t-test is again conducted to determine whether the mean absolute imbalance between receipts and issues after the introduction of the Advanced S&OP process is significantly lower than that before. Seasonal effects are assumed negligible in the absolute imbalance time series since seasonality (if present) would have been accounted for during demand forecasting.

The null hypothesis (H_0) and alternate hypothesis (H_1) are:

H_0: $\mu_1 \leq \mu_2$

H_1: $\mu_1 > \mu_2$

Where:

- μ_1 refers to the mean absolute imbalance between receipts versus issues *before* implementing Advanced S&OP
- μ_2 refers to the mean absolute imbalance between receipts versus issues *after* implementing Advanced S&OP

The rejection criteria for H_0 is that T-value is >= critical value (one-tail), i.e.

- if $t > 1.675$, then H_0 can be rejected at the 5% significance level;
- if $t \leq 1.675$, then H_0 cannot be rejected at the 5% significance level

t-Test: Two-Sample Assuming Unequal Variances

Customer A (S&OP Parts)	*Before*	*After*
Mean	18035	8637
Variance	230868946	97306799
Observations	45	19
Hypothesized Mean Difference	0	
df	51	
t Stat	2.9352	
P(T<=t) one-tail	0.0025	
t Critical one-tail	1.6753	
P(T<=t) two-tail	0.0050	
t Critical two-tail	2.0076	

The result of the t-test shows that the computed t-value of 2.935 is higher than the critical one-tail t-value of 1.674. Hence H_0 can be rejected, which implies that the introduction of the Advanced S&OP process has significantly reduced the imbalance between inbound shipments from the contract manufacturer and outbound shipments to the customer. This is most probably attributable to improved forecast accuracy with the implementation of the Advanced S&OP process.

5. CONCLUSION

The results of the study strongly suggest that after the adoption of the Advanced S&OP process, both inventory level and forecast errors have been reduced during the fulfillment of demand from the customer in the pilot study.

Traditional S&OP does not closely involve suppliers, while CPFR has been designed mainly for collaborations between manufacturers and retailers. This paper fills some of the gaps in the

literature when a supplier is brought into the S&OP process via a framework similar to CPFR, but in the context of a manufacturer and its contract manufacturing partner. While not ground-breaking, Avocent's application of Advanced S&OP (as classified under the Grimson & Pkye framework) is probably one of few of its kind that has been successfully documented so far.

Although the results are based on a pilot study done on a limited scale, initial results are promising, with improvements shown to be statistically significant. The findings from the pilot study thus provide manufacturers with an indication of the potential quantitative benefits when contract manufacturers are integrated into an Advanced S&OP process.

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