An Optimized and Integrated Supply Chain Planning Architecture for Paper and Film Manufacturers

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ABSTRACT

Over the past years supply chain complexity for paper and film manufacturers has increased as a result of increased possibilities to produce products at different manufacturing locations (including off-shore manufacturing), supplying products from different warehouses, larger product variety, smaller and customer specific lot-sizes and frequently changing demand patterns.

Additionally during the past years, film and paper companies have experienced pressure on margins, often because of competition in low wage countries like China, India…

To meet the increased supply chain complexity and margin pressure an optimized and integrated supply chain planning architecture is required. An optimized and integrated supply chain planning architecture uses a total supply chain concept supported by best practice planning processes and best-of-breed software applications. It allows companies not only to avoid cost increases but also to lower the current cost of operations.

The complete optimized and integrated supply chain planning architecture covers the optimization and integration of:
• The Network and policy design process
• The Forecasting process
• The Sales and Operations (S&OP) / Master Planning process
• The Order Promising / Allocation process
• The Cutting optimization process
• The Order scheduling process

Most companies have been looking at improving above processes but often efforts have been limited to improve planning processes isolated from the other processes. Also when improving the processes, best practice and best-of-breed supporting software applications were not applied.

In this document we will focus on four of the six planning processes: the S&OP / Master planning process, the Order promising process, the Cutting optimization process and finally the Order scheduling process (Figure 1)
The content of each planning process is covered as well as its support by best-of-breed technology and its integration with the other planning processes.

Part 1: Integrated supply chain planning architecture
Part 2: Multi-site S&OP / Master Planning
Part 3: Order Promising
Part 4: Cutting Optimization
Part 5: Order Scheduling

1 INTEGRATED SUPPLY CHAIN PLANNING ARCHITECTURE

1.1 Supply Chain Performance

An optimized and integrated supply chain planning architecture tries to reflect a company’s supply chain strategy and performance goals.

In the paper and film industry short customer lead times, product availability for standard products, capacity availability for non-standard products and quality are important elements of the supply chain strategy. Providing these elements at a lowest cost possible is critical.

Amongst the processes that have a direct impact on the manufacturer’s internal and external supply chain performance and costs are Multi-site S&OP / Master Planning, Order Promising, Cutting Optimization and Order Scheduling.

1.2 S&OP / Master Planning

Multi-site S&OP / Master Planning determine at product or aggregated product level, how much and when production and distribution resources will be used to satisfy forecasted demand. Using optimization techniques, products of the different product groups and volumes are allocated to different manufacturing facilities and distribution centers.
This tentative allocation of production and distribution resources is important information to allow the company to prepare well in advance for the execution of orders in the supply chain (order fulfillment process) and for guaranteeing minimal cost across the supply chain. In line with the company’s supply chain strategy, decisions of product group allocation are made; either allocating product groups to different locations or only to one location. This highly complex calculation needs to be supported by powerful optimization engines.

Another important element guaranteeing minimal cost in the paper and film industry is production campaigns and production cycles. With production campaigns and cycles product groups only get produced with a large minimum batch size (=campaigns) or with a preference in sequence between product groups (=cycles) because of the high cost of setting up machines to manufacture the products or because of quality reasons (for example color contamination). By defining campaigns or cycles, paper and film type companies avoid high set-up costs and safeguard manufacturing processes to run at minimal costs. A best practice S&OP / Master Planning process should calculate the number and lengths of product (line) campaigns and cycles, reducing these set-ups and thus minimizing the total supply chain cost. Again here a powerful optimization engine is required to calculate the campaigns and cycles.

1.3 Order Promising and Allocation

When orders are finally received one uses the S&OP / Master Plan results, to allocate sales orders to the sales plan and the supply plan to give the customer a promise date. Promise dates express when the order will be executed and arrive at the customer.

In order to provide a promise date thus the order is linked to supply (material or capacity) calculated by the S&OP / Master Plan level. Linking the order to supply also allocates the order to the internal supply chain. But additionally orders can also be allocated to the sales plan generated by the S&OP process, in order to manage demand priority; for example to verify if the sales order does not exceed the sales region’s quota.

In the order promising and allocation process best supply chain performance (service and cost) is guaranteed, as promising and allocation is done based on prior verified resources (material or capacity) in the S&OP / Master Plan.

The S&OP / Master Plan focuses on minimizing costs, respecting business strategies and satisfying forecasted demand. Often however the order book is not in line with forecasted demand and also the supply side can have evolved: raw materials have not been supplied in time, production is different than planned or production costs have changed, resulting in a situation that the prior verified resources and estimate costs are no longer valid.

The best way to deal with this changed environment is to re-run the S&OP / Master Plan using the updated supply and demand information. A customer order for example not receiving a promise date because of lack of anticipated resources or material should be included in the master planning calculation. After optimization the order receives new or changed resources (material and capacity) and can still get a promise date.

This process of promising and re-promising can be highly complex, but needs to be managed properly as it highly contributes to the final cost and service performance of the company. A company’s supply chain strategy typically is translated into strategies or business rules used in the order promising or re-promising process. Examples of strategies are “a promise is a promise” or “promise at lowest supply chain cost”. Depending on these strategies, changes in the supply chain or order book are reflected in changes of costs (we want to keep the promise date but a new set-up will be required or promise dates (we want to keep the supply chain cost minimal).

Once the order is allocated and promised it will be either fed back to the S&OP / Master Plan process to have a production order generated for it and sent to the cutting optimization and order scheduling processes, or directly used in the cutting optimization and order scheduling processes.

1.4 Cutting Optimization

In the film and paper industry often the cutting optimization process is a very important process as it guarantees a minimization of material waste. A non-optimal cutting optimization process will result in higher waste of material and result in a higher total supply chain cost.
Cutting optimization covers more than trim optimization. Next to trim optimization it looks at minimizing costs triggered by set-ups in between two cutting programs, production throughput optimization and customer service and cost considerations related to partial, optional or full orders.

Sets of orders that may be fulfilled together are grouped based on order characteristics (material, width, due dates …), machine characteristics (speed, number of knives…) and other characteristics (customer priority…) and used in a cutting optimization calculation.

The outcome is a slitting/cutting program containing different orders to be fulfilled together and guaranteeing lowest execution costs and respecting other external or internal strategies.

1.5 Order Scheduling

Finally the slitting/cutting programs get visualized on scheduling boards, where the interactions with the primary production programs (film extruders, paper machines, coating installations…) are shown and can be acted upon. Also interactions with downstream installation like printers, palletizers, wrappers up to truck loading can be added to the scheduling board.

Again different strategies can be used on how to schedule the primary production orders and secondary slitting/cutting programs across the different installations in a plant: respecting order due dates, verifying material availability, maximizing output, minimizing WIP levels, minimizing set-ups on extruders, coaters… The scheduling strategies should always be chosen in line with the company supply chain strategies; for example reflecting that meeting due dates is more important than minimizing set-ups.

Best practice scheduling requires not only optimization of the primary and secondary production schedules using best-of-breed scheduling technology, but also (message based) integration of status feedback of the shop floor installations. On-line or very frequent (every minute…) feedback guarantees an always up-to-date schedule to support scheduling performance goals of maximizing output on bottleneck machines as well as respecting customer order promise dates.

Although in this document we have separated cutting optimization and order scheduling in two different processes today’s technology allows having both processes fully integrated, where often the cutting optimization process is called from within the order scheduling process. This is especially valuable if the cutting optimization also decides on the sequence of the cutting programs, thus minimizing set-ups.

1.6 Division versus Plant

With the availability of high speed networks, terminal services and internet technology the location of hardware or database(s) is less an issue compared to the past. These technologies allow separation of the execution location of the planning process from the location of the server with its planning application and database.

The important factor in the architecture is more related to who executes the different elements of the planning processes.

The S&OP/Master Planning process and Order promising process are often processes that are executed at division or company level. The Cutting optimization process and the order scheduling process are often executed at the factory level.

Providing an integration reflecting the responsibility levels between the different planning processes is critical. Integration is either done on-line via messages or via batch controlled publishing of results to the other processes.
A set-up of the processes in a multi-site environment could typically be done as pictured below. The S&OP/Master Planning process and Order promising process in the division headquarters and the cutting optimization and order scheduling processes at the plant level (Figure 2)

![Figure 2: Division versus Plant planning processes]

2 S&OP / MASTER PLANNING

2.1 S&OP versus Master Planning

One of the main differences between running an S&OP and master planning process is the decision to allocate the customer or sales region forecasted demand to the manufacturing locations. If this decision still needs to be taken we will typically execute an S&OP process first. If the decision has been taken a Master Planning process could suffice.

Taking a decision on allocating the demand volumes to the different manufacturing facilities will highlight if the forecasted demand is higher or lower than the available manufacturing capacity. In case of insufficient capacity, the S&OP process will tell how much the forecast per region (and product family) needs to be reduced to meet the capacity. This reduced forecast is then considered as a sales plan. If the capacity is sufficient to meet all forecasted demand the forecasted demand automatically becomes the sales plan.

Other possible differences between S&OP and Master Planning relate to the horizon and the aggregation level:

- An S&OP process typically runs on a horizon of at least one year and on aggregated product level. Master planning typically runs on at least 13 weeks and on SKU (Stock Keeping Unit) level.

Note: As the paper and film business also contains a lot of Make-to-Order products, SKU level planning means also planning on Planning Materials grouping a number of Sales units (=Make-to-Order products).

- Also in case of Master planning actual customer orders are often combined with forecasted demand to generate the requirements for the master plan.

- The responsibilities of people involved in the process between the two planning processes may also differ, as an S&OP process may involve deciding on investments or disinvestments.
2.2 Typical Plans

In the figure below one sees the result of a calculation in the two planning processes. In the S&OP process we calculated how much of three planning materials (paper or film) will be produced in a certain month on a certain machine. In the Master Planning process we have broken down the plan by week and decided on volumes for SKUs (example: A1, A2…) as well as remaining Planning material volumes still to be assigned to customer orders.

The above example shows a CYCLE between product family or planning material A, B and C. It also assumes that product family or planning material C is only produced two times a month, while A and B are produced every week.

Once optimal volumes by SKU and by week are calculated, in the Master Planning process, they can be translated in production orders. These production orders are used to be scheduled in the Order scheduling process.

Not only allocation of products and volumes to plants are calculated in the S&OP / Master Planning process, also production campaigns and cycles are determined. With this information all components are available to support the order promising process.

2.3 Planning Views in the S&OP / Master Planning Process

Three planning views with information decided in the S&OP / Master planning process are shown below:

- A sales planning view
- A production planning view
- A purchasing requirement planning view

2.3.1 Sales Plan

In the S&OP process, in case of capacity shortage, sales plans can be converted into sales quota, for example per sales region, to be used in the order promising and allocation process.
Figure 4: Example of a Sales Plan

In the above figure 4 we see the data for a product family for a certain sales region (18Mxxxx/EUR). The independent requirement line (“Tot. Indep Req.”) shows the forecasted demand. The total plan line (“Tot. Plan”) shows how much actually can be sold given the current capacity in the supply chain. If no changes can be made to the capacity or outsourcing can be used the volumes on the plan line will be considered as the sales plan.

One can drill down on the total plan line and see which plants currently are satisfying the forecasted demand. On the detail picture below we see the volume is satisfied by two outsourced manufacturers. Outsourcer 1 satisfies 7,473 pounds and outsourcer 2 satisfies 14,711 pounds out of the total of 22,184.

Figure 5: Details of a Sales Plan

2.3.2 Production Plan

The production plan is sales region neutral and expresses when and how much of each product (family) is going to be produced at the plant, independent of which sales regions it is going to be shipped to.

If outsourced manufacturers are used the production plan will show how much volume each of outsourced manufacturers need to produce.
Above figure shows an example of two products being produced. The bottom product also shows how much production actually has already been committed (“Scheduler Plan” line).

2.3.3 Purchasing Requirements Plan

Using the production plan and bill of material information, a purchasing requirement plan for each raw material and each supplier can be calculated. In case the same material can be purchased from different suppliers the purchase plan may consider purchase price, transport cost of the material and available stock or capacity at each supplier to decide where to buy the product.

The volume on the ATP line shows the total volume per product that needs to be purchased for the planning horizon, while the dependent requirement line (“Tot. Dep. Req.”) shows the required volumes by period and the Inventory line (“Tot. Inventory”) shows what is needed until a certain period. Adding the information of what has already been purchased (purchase orders) would show what has to be ordered additionally.
3 ORDER PROMISING AND ALLOCATION

When entering an order in the order entry system an ATP (Available to Promise) date or CTP (Capable to Promise) date is calculated. The inventory and supply (material and capacity) plans of the S&OP / Master Planning / Order scheduling processes serve as input.

3.1 Sales Quota

If a sales plan exists per customer or sales region, one can verify prior to calculating the promise date for the customer order, if the quantity of the customer order is in line with the sales plan generated for the customer or sales region the customer belongs to.

This process of verifying the sales quota can be a very important process, when capacity shortage (thus sales plan lower than originally forecasted demand) risks having customer orders of non-premium customers or non-premium products taking away volumes or capacity reserved for premium customers and products.

3.2 Order Promising

Once the order has passed the sales quota verification it will be linked to the supply that was calculated in the S&OP / Master Planning / Order scheduling process. Based on the due date of the customer order and the availability of supply a promise date will be generated.

In case there are different sources (distribution centers or direct delivery from the outsourcer’s distribution center) the order promising process generates both the source of supply and the promise date.

On-line order promising gives the advantage that availability of a resource gets immediately reduced after an order has been linked with that resource. Availability for premium customers or premium products can be
safeguarded by using the above mentioned sales quotas or providing separate supply (reservations) for the premium customers or products.

3.3 Keeping Your Promises

The most difficult part of order promising is not so much the first time the order gets promised, but when between the promising event and the final preparation information gets changed frequently, for example triggered by changes to the customer orders (quantity changes, request date changes, product changes…) and the supply (supply is later than foreseen, product failed quality control…), with the latter as the most occurring.

A best-of-breed order promising tool should include the business rules that the business has set forth. Business rules will reflect service or cost prioritization. A business rule set to “Keeping promises” will require throwing away earlier allocations between supply and customer orders and re-allocations to existing supply or new supply (if the S&OP / Master plan / Production schedule has been updated). A powerful order promising engine combined with frequent interaction on the supply side will help keeping promises.

If certain volumes of the products are managed in a VMI (vendor managed inventory) system, the results of the VMI process should be taken into account in the order promising process.

3.4 Capable to promise

In pre-dominantly Make-to-Order businesses sometimes CTP is used. In this case no material plan has to be available to receive a promise date, but machine, tool capacity or component availability is checked instead. After checking the availability in this environment a production order is generated using the ordered SKUs routing and operation information, to safeguard that the promise date can be kept and other orders are not consuming the same resources.

4 CUTTING OPTIMIZATION

With the promising of the customer orders done, one can start calculating a plan for the film or paper cutting process. Reducing cutting waste can account for hundreds of thousands of dollars of material savings per year. Combining the orders in an optimal not only helps saving money but is also an important element to safeguard customer service levels.

The cutting optimization process selects orders that are due in the next days and combines these orders in an optimal combination on the slitters / cutting installations. This can be done for both reels and sheets. The result of an optimization is a grouping of orders in a cutting program, but also the sequence of programs is important as it determines set-ups that need to be done between the programs.
The cost of the solution can be analyzed and the user can decide to add orders due the next week if the yield seems to be insufficient.

Figure 8: Example of a Cutting Program with Details of Orders and Program

Figure 9: Example of a Cutting Program Yield and Cost Report
5 ORDER SCHEDULING

Integrated with the cutting optimization is the order scheduling process.

5.1 Scheduling Secondary and Primary Production

In order to safeguard that the programs are slit/cut in time the scheduling process schedules the programs for the cutting installations (= secondary production) on the schedule board.

In case the Master Planning process did not generate the work orders for the primary production (extrusion, paper machines, coating…), the work orders get created in the order scheduling process. After creation the work orders for the primary production are being scheduled.

Minimizing change-over time, maximizing throughput on the bottleneck machines and respecting intermediate stock levels are amongst the most important goals for the order scheduling process. The availability of optimization engines helps determining a best possible schedule meeting the different objectives. Especially the complex interaction between primary and secondary production will often require powerful scheduling techniques supported by optimization engines.

Additional to an optimization engine the scheduling process can be done more interactively based on conflict highlighting and manual changes. For schedule modifications due to for example later availability of raw materials, or damaged intermediate products in the warehouse manual interactions supported by an advanced GUI (Graphical User Interface), support making the last modifications before publishing the schedule.

Figure 11 contains an example of a production schedule for primary production (orienting, coating) and secondary production (slitting): colors of production orders reflect film types.
The two fine diagonal lines in the above picture show how the slitting program can be traced up the production chain. Even if intermediate stock exists between primary and secondary production, a link should be created to trace the material flow.

5.2 Message Based Shop Floor Feedback

As the order schedule has to be kept up to date a tight integration with the shop floor control system is required. Message based or frequent batch processed shop floor feedback helps guaranteeing an up to date schedule, allowing the scheduler to keep production orders in line with promise dates and previously estimated schedule costs.

After shop floor feedback is received the production schedule adjusts automatically and will generate conflicts for the scheduler to treat. The scheduling process includes re-scheduling the production orders on the planning board and issuing the changed production order times to the shop floor (figure 12).