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PRODUCTION SCHEDULING VALIDITY IN HIGH LEVEL SUPPLY CHAIN MODELS

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ABSTRACT

Although they focus on the big picture, high level supply chain models cannot gloss over the capacity of production nodes to meet production allocations. Capacity is not simply a reflection of equipment production rates. Short runs drive down utilization by increasing total time lost to changeovers. Multistage plants require coordination of capacities at the several production stages. In short, production capacity is crucially affected by the way production runs are scheduled through plants. Modeling actual scheduling practice is often unrealistic, since methods vary from plant to plant, and involve a blend between planned schedules and on-the-fly adjustments. This paper suggests that there is a range of approaches to modeling production scheduling. In the modeling of supply chains, modeling alternatives must be assessed in terms of cost of development and implementation versus validity.

1 INTRODUCTION

Although industrial processes have been successfully modeled at different levels of detail, from chemical reactions to global trade, vertically integrating models is often viewed as fools gold, with time management alone trapping the modeler at one scale or another. However, we have found that putting a one or more production plant into its supply chain context can provide essential information about their interaction that modeling either system without the other cannot provide. Many interactions which are not “programmed” into the simulation, but occur “naturally” can be observed that would otherwise be missed.

2 CONCEPTUAL FRAMEWORK

In order to explore this topic we will adopt the conceptual framework underlying Supply Chain Builder.

2.1 Elements

The basic elements that define a supply chain are locations, inventories, orders and shipments. Items exist in inventories or between inventories in shipments. Inventories exist at locations.

A supply chain link consists of two inventories between which items flow. Each link has a supplier end and a customer end, as shown in Figure 1.

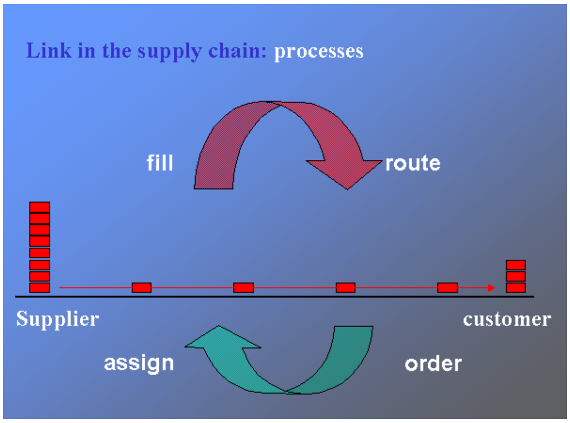

Figure 1: Prototype link

2.2 Structure

Supply chain structure is defined by the supplier/customer relationships that connect raw material supplies at the upstream end of the supply chain to the consumption points at the downstream end.

2.3 Processes

A four-step process controls the flow of items from supplier to customer:

- **Order**: orders are generated based on re-ordering rules.

- **Assign**: Orders are assigned to a supplier.
- **Fill**: Orders are filled by removing items from the supplier inventory and putting them into a shipment.
- **Route**: The shipment is routed from the supplier to the customer, where it is put into stock.

2.4 Demand

Typically, demand depletes inventories at the downstream end of the supply chain, triggering movement of materials within each link. Each inventory in the supply chain may be the supplier of one or more downstream inventories, and the customer for one or more upstream inventories.

2.5 Types of Locations

In this scheme, there are four types of locations: suppliers, customers, warehouses and plants.

- **Suppliers:** Suppliers have unlimited supplies of raw materials; they define upstream nodes in the supply chain structure.
- **Customers:** Customers are points where materials are consumed; they define the downstream nodes in the supply chain.
- **Warehouses:** Warehouses receive, store and ship materials. The same items come in that go out, and are not transformed.
- **Plants:** Plants, by definition, transform materials. There must be a bill of materials that defines the inputs and the outputs of the transformation. Even if a product is only being repackaged, the quantities before and after the repackaging must be tracked, as well as the packaging materials themselves. Only the repackaged product is available to meet downstream demand. Only the unpackaged product is ordered from upstream.

2.6 Production As a Supply Chain Link

Production operations can be viewed as moving material from raw materials inventories to finished goods inventories. The elements and processes involved are completely analogous to links in a supply chain. Raw materials are the supplier inventories; finished goods inventories are the customers. Production orders are generated, assigned, filled, and routed, just as between supply chain locations. (Assignment could be the decision on whether to make or buy a product.)

The policies that determine when production orders are placed, and production order amounts may be very similar to policies for reordering at a warehouse or customer distribution center. Economies of scale, available storage space, cycle times, order processing costs are basic parameters in both cases.

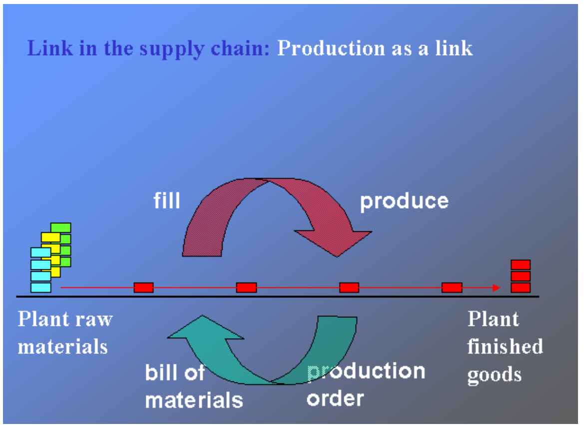

Figure 2: Production as a Link

As illustrated in Figure 2, production is a critical link in determining the length of a supply chain from raw materials suppliers to customers.

3 WHY ARE WE CONCERNED ABOUT PLANT SCHEDULING?

Any factor that affects the time required to fill orders in a supply chain link will impact the overall responsiveness of the supply chain. Production facilities are typically more complex than other links in the way that resources are applied to order filling. We often must go beyond consideration of the capacity of the plant as a whole and define the capacity of production systems within the plant. System capabilities may be overlapping with some systems able to make many products while others can make only one or two. Multiple stages of production put additional stress on plant management. Limited in-process inventories require that production across multiple stages be coordinated. In practice, such scheduling is often considered an art, rather than a science, with continual modification of schedules 'on the fly'.

4 WHAT IS A PRODUCTION SCHEDULE?

A production schedule is a plan for what product will be made at what time utilizing what resource. The function of the plan is to control plant operations. In the reality of plant operations, many factors intervene to take actual plant operations away from the plan. For example, if the plan is to make 1000 cases of Product A starting at 10:00 am, it cannot be certain when that production run will end. The schedule may call for switching to product B at 1:00pm. What if the run of Product A is not completed? What if raw materials for Product A have run out?

If we take the view that a production schedule is a plan that controls production operations, the definition of a schedule must be broadened to include the rules that guide its generation and implementation. In the above example, the rules for when to start a run when a prior run has not been completed would be considered part of the schedule.

Scheduling practices differ widely in the duration of their planning period. In some plants, a tentative schedule is laid out for an entire year, establishing production cycles for each product. The schedule is then varied during the course of the year as inventories exceed or fall short of targets. At the other extreme, some plants are scheduled 'on the fly', with production runs changed only when inventories hit certain trigger points. The predictability of demand is a key factor in dictating the ability to plan out production schedules over longer periods.

Where ever scheduling methods lie on the spectrum from reactive to planned, there are certain factors that all scheduling practices have in common. They must take into account demand for the product being made. This may be done by simply monitoring the levels of inventories of produced items. It may further take into account rate at which these inventories are being depleted. Scheduling must take into account the capacity of productive resources to make the schedule products. A key issue impacting overall capacity is the time required to changeover from making one product to making another.

5 MODELING PRODUCTION SCHEDULES

There are several potential goals in modeling production scheduling. One goal might be to develop scheduling algorithms that can be used to schedule actual production as well as scheduling a model of production. Although this objective is not uncommon, it goes beyond the scope of modeling production scheduling in the context of a high-level supply chain model. Our objective is to validly model the productive capacity of plant nodes in the supply chain. Validity is not an absolute. We must test alternative approaches to modeling production schedules against actual experience to determine their suitability. The cost of a modeling approach can be measured in the time require to develop it; its impact on the execution time of the model; and the complexity of specification of its parameters.

Four methods of modeling production schedules are described below as illustrative of the range of approaches that might be considered. Other approaches are possible, including combinations of planned and reactive methods.

- **Standard Supply Chain Builder Ordering:** production orders are generated by daily review of the inventory levels of finished products. Timing and size of orders are determined by user defined reordering policy parameters. Orders are filled in sequence, with queues for raw materials and production resources.
- **On the Fly:** when manufacturing systems become available for production, inventories are reviewed and the most urgent order that can be produced on the system is placed.
- **Order Limiter:** at weekly or other intervals, production orders are placed which match finished goods requirements with compatible production systems. Orders are processed sequentially rather than being cast in a firm schedule.
- **Schedule Builder:** finished goods requirements are periodically assessed and a production schedule is generated taking into account system production rates, changeover times, and compatibilities.

In Table 1, these four methods are compared with respect to the following issues.

1. How is the initial generation of production orders controlled?
2. How are orders modified to reflect availability of resources?
3. How is the timing of the filling of orders controlled?
4. How are raw material limitations taken into account?

Table 1: Comparison Of Scheduling Methods

Issue	Standard SCB	On the fly	Order Limiter	Schedule Builder
Initial orders	Standard ordering options	Message sent by controller to order block	Standard ordering options. Should send message from controller.	Message sent by controller to order block
Resource Limiting	Capacity table	Inherent in control structure and initial order generation	Orders are reduced to fit capacity. If multiple resources, additional orders are generated.	Build schedule and resize orders
Timing of order filling & delivery	Only raw materials will limit order filling. Drop in plant models may limit completion.	Filled immediately after created. Drop in plant determines completion.	Only raw materials will limit order filling. Drop in plant models may limit completion.	Filling & delivery triggered by completion of runs
Raw material limits	Shipments will be limited to available raw materials	Initial order limited to available raw materials.	Shipments will be limited to available raw materials.	Requirements list limited to available raw materials for each planning period.

6 ASSESSMENT OF COST AND VALIDITY

The cost/benefit curve, Figure 3, suggests that there might be a diminishing return from introducing greater complexity into the modeling of plant scheduling.

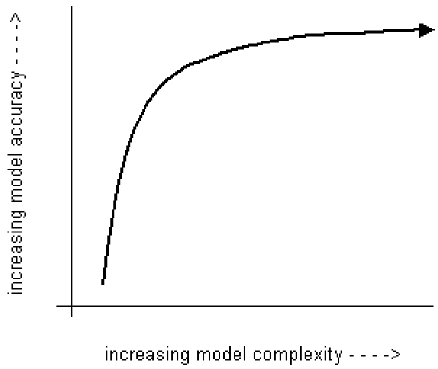

Figure 3: Benefits From Modeling Complexity: 'Diminishing Returns'

The goal is assessing alternatives for modeling scheduling is twofold. First, to determine what are the modeling options that get the greatest advance in accuracy for the least increase in complexity. Second, to determine if the curve is truly shaped as shown in Figure 3. There may be an alternative and less attractive shape as shown in Figure 4. This would imply that we have to develop a lot of complexity before we yield significant benefits in accuracy.

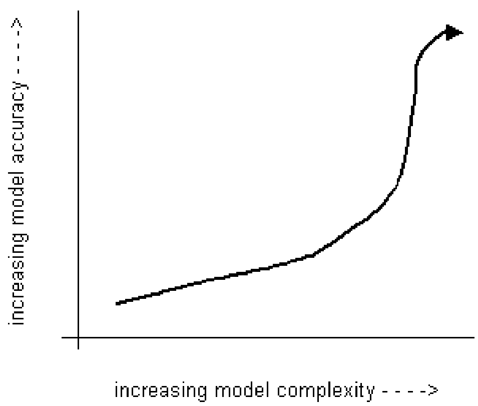

Figure 4: Benefits From Modeling Complexity: 'High Complexity Required'

Cost assessment must include not only model development cost, which may vary widely among modeling methods, but must include assessment of resulting model run time and the utility of scheduling parameters. The usefulness of a model may stem from the ability conduct experiments quickly that require many runs. Supply chain models commonly capture the flow of many thousands of shipments of materials. Complex scheduling logic may slow down model execution not so much as a result of the time to calculate the schedule, but rather as a result of the detailed production model that might be required to carry out the schedule.

Assessment of the validity of production schedule models is challenging. When the goal is not to make the model "look like" the real thing, how do we know how close we are? We need to employ common sense in reviewing simulation results. The goal is to product a valid model of the production throughput of a plant over each time period. We can inspect the results of model test runs, looking at resource utilization, run lengths, overall production output, and out of stock performance. Experienced plant management can assess whether the model results reasonably reflect the productive capacity and responsiveness of real world plants.

We should not be drawn into the illusion that modeled production schedules can be compared to real world "paper" schedules or to actual production experience to determine their validity. Most plants do not implement paper schedules without significant modifications in reaction to unpredicted demand and production realities. Usually these changes are not documented as schedule modifications, leaving the production historian with a fictitious record. Records of actual production experience can be just as deceiving. We may know just what was made on each system each hour of the day and week, but we do not know the underlying causes – shortages, breakdowns, judgment calls of all kinds – that led to that production experience. We can and do model random effects, but by definition, they will not map neatly onto the random events that occurred during historical periods.

So, validation of production schedule modeling techniques must rely on the common sense assessment of experienced people looking at model results. This entails a process of developing confidence over a period of time, rather than a single "validation" step in the model development process.

7 CONCLUSION

High-level supply chain models that incorporate production facilities within their scope should take into account impact of production scheduling on overall supply chain performance. A common sense approach should be taken to assessment of the costs and benefits of alternative modeling techniques.

AUTHOR BIOGRAPHIES

DAVID J. PARSONS is Vice-President of Simulation Dynamics. His experience with simulation began in 1965 with experiments in the use of natural selection algorithms to evolve architectural designs. During the 1980's he designed, built and operated several dairy-processing plants using simulation of key systems as an integral tool for design, value engineering, and troubleshooting. Mr. Parsons received a B. A. from Harvard College and a Master of Architecture degree from the Harvard School of Design. His email and web addresses are `<Parsons@ SimulationDynamics.com>` and `<http://www. SimulationDynamics.com>`.

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