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# A New Framework for Production Planning in the Process Industries

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> Imagine...two computers conversing with each other over a period of time. They are then asked by a human being what they are talking about, and in the time he takes to pose the question, the two computers have exchanged more words than the sum total of all the words exchanged by human beings since Homo Sapiens first appeared on the earth 2 or 3 million years ago. (Simons, p. 165)

We are living in an age when time itself has become the greatest natural resource of business. Within the process industries, we build models that collapse time into increasingly smaller increments. For example, ten years ago most written communication took place by mail. Now, information moves across complex communication networks in a matter of seconds. This change casts a new vision of production planning systems as the year 2000 AD approaches.

In the remaining years before 2000 AD, words such as systems dynamics, optimal control and finite production planning will represent ideas essential to success in the process industries. These concepts build upon the importance of time as a competitive weapon.

For many years, logisticians have recognized the role of time in moving goods from plants and warehouses to the customer (Coyle, Bardi and Langley, p. 40). Products must be available when customers want them. Logisticians call this "temporal utility," the value of having goods available at the right time. Production planning systems are an important link in creating temporal utility. However, production planning systems are only one part of a larger system. To achieve the greatest overall effectiveness, production planning systems must communicate with the entire logistics pipeline.

Information technology has caused a shift in the traditional view of temporal utility. Before rapid communication by computer, humans moved information. Computers now move information at a rate much greater than human response time, creating a world exclusive of humans.This new world brings a fresh perspective to temporal utility. A noted author on the study of time writes:

> The artificial time worlds we have constructed have been accompanied by a radical new temporal value: efficiency. To be efficient is to minimize the time in which a task is completed or a product produced and to maximize the yield, expending the minimum amount of energy, labor, or capital in the process. (Rifkin, p. 103)

In the new nanosecond world of rapid information exchange, two themes will dominate the design of production planning systems in the process industries: 1) production planning systems are part of a much larger logistics system and 2) production planning systems comprise a multi-level decision process termed a hierarchy. These two themes summarize the direction of applied research undertaken during the past several years by the Center for Process Manufacturing located at Penn State Erie, The Behrend College. The Center is a unique partnership between Penn State, APICS and industry, dedicated to the practical application of management science to solve real world problems in the process industries.

## THE ALBATROSS OF MRP II

Many in the process industries who currently have Manufacturing Resource Planning (MRP II) systems will heed the words of Coleridge:

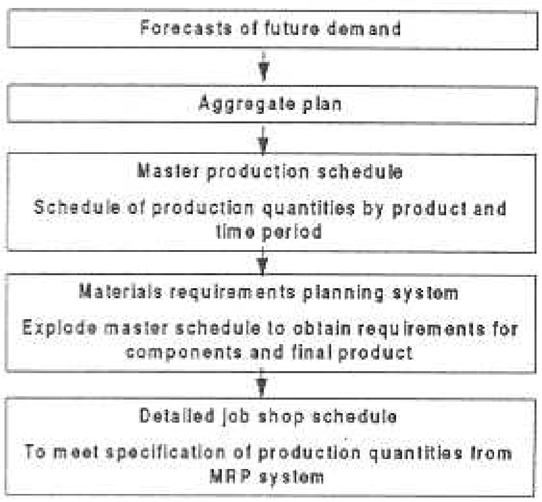
> Instead of the cross, the Albatross
> About my neck was hung.

MRP II (Figure 1) is a trial and error system. In the most traditional form, MRP II assumes infinite capacity and requires manual re-checking to insure feasibility at all levels. Essentially, MRP II users must question due date, capacity, and material feasibility at each level based on judgment gained through experience. This requires large amounts of time to accomplish. In the world of rapid information exchange, traditional MRP II will be much too slow to keep up with changing developments in the marketplace. Because of the manual work involved, MRP II production plans do not keep pace with new information. Besides, "creating new production plans does not help if the supply chain has been filled based on the old one." (Fisher, Hammond, Obermeyer and Raman, p. 83)

These inertial forces severely limit the ability to react to the changing needs of customers. To compensate for inertia, process-oriented firms build extra capacity and buffer inventory levels on raw materials. This results in increased cost and greater risk of obsolescence.

Beyond the question of generating feasible plans, MRP II relies on an in-house forecast to begin the planning process. Never accurate, internal forecasts take the brunt of criticism concerning

**Figure 1. Hierarchy of Production Systems**



the effectiveness of MRP II (Fisher, Hammond, Obermeyer and Raman, p. 93). With rapid information exchange between trading partners, forecasting takes on a much different role.

Few would favor use of an internal forecasting tool, such as time series analysis, over live demand information from the customer (Nahmias, p. 51). Until recently, detailed information from customers did not exist. However, the age of rapid information exchange allows much greater communication between trading partners. It is common to see forecasts based on customer's information about demand rather than internal estimates of aggregate demand. This greatly changes the role of manufacturing planning and control (MP&C) systems. Current demand information from the customer is useless unless an MP&C system can quickly turn the information into a feasible, low cost production plan.

### Compensating for the Albatross

Just as the ancient mariner fought the weight of the albatross about his neck, process-oriented firms are compensating for the shortfalls of MRP II. With much fanfare, many process-oriented manufacturers replaced their infinite capacity, master planning systems with finite planing and scheduling systems. Most of the new finite planning and scheduling systems depend on a rule-based approach. In highly stable demand situations, rule-based approaches will work reasonably well. However, in dynamic situations where demand is constantly changing, rule-based systems require a great degree of manual intervention to obtain a feasible schedule.

Consider the following example to visualize the limitations of rule-based systems. Suppose you are driving on a busy highway in a large city. The intersection of each cross street marks a city block. Stoplights are at each intersection. Occasionally, you must stop at an intersection because of a red light. You accept the rule that red means stop, and green means go.

Now suppose one day that the rules changed. Red now means go and green means stop. Depending on the time of day, you may witness a tremendous accident at the first intersection. Eventually, after witnessing several accidents, you would learn that the rules had changed. You would adapt to the new set of rules.

With MP&C systems the consequences are seldom as great as those mentioned in the above example. When the rules change, there is no massive automobile accident, rather customer service suffers and costs increase. Finite planning and scheduling with rule-based systems is an improvement compared to infinite capacity planning. However, these systems serve as a transition to more flexible treatments of the finite capacity problem that are able to deal with dynamic demand.

The new framework for production planning in the process industries builds on the twin themes of systems modeling and hierarchy. The emerging framework only slightly resembles the structure of traditional MRP II. Beyond question, the new framework will depend on increasing computing power along with the prudent application of operations research. We now turn our attention to a discussion of the new framework.

## SYSTEMS MODELING AND THE BEER GAME

Modeling distribution networks to determine cost impacts have received much attention by several practitioners within APICS (Canella & Schuster, 1987; Schuster & Canella, 1990; Schuster, 1987, 1990).

With basic knowledge of logistics systems assumed, let's look at a simple game to highlight the behavior of a logistics system. This game originated at the Systems Dynamics Laboratory of MIT. It is a common classroom exercise for students studying the behavior of systems.

Imagine a simple system for production and distribution of beer. Customers purchase cases of beer from a wholesale distributor who in turn receives shipments directly from the beer manufacturer. The beer manufacturer receives shipments of empty bottles from a glass company. Both the beer manufacturer and the glass company have finite capacity and fixed lead-times. They do not receive direct demand information from the customer. Rather, they see demand as orders for truckloads of beer (from the distributor) and orders for truck loads of empty bottles (from the manufacturer).

To begin the game, customers purchase beer at a fixed rate. Both the beer manufacturer and the glass supplier are able to match their production rates to the consumption rate even though they do not have first hand knowledge of the rate of consumption. The matching of production rates results from consistent orders for truckloads of beer and empty glass.

At some point in the game, students increase their consumption of beer, then hold at the new consumption rate. This represents a single step in demand.

The effect of this single jump in demand is quite dramatic. The beer manufacturer quickly senses that demand is increasing. Wishing not to lose any sales, production increases to cover surging demand. Meanwhile, the glass company must react to the increased production of beer, and produces slightly more empty glass than the beer manufacturer actually needs. There is an amplification in the production rates at both the manufacturer and the glass company.

Eventually, the beer manufacturer becomes alarmed as inventory levels of finished goods begin to rise. The beer manufacturer has over-anticipated the amount of beer consumed because of the rapid jump in demand. Bottling production rates are cut so that inventory will decrease. This has a great effect on the glass company which has not anticipated the decrease in demand for empty bottles.

As the game continues, students find that incomplete information concerning customer demand causes highly irregular demand patterns (this is represented in Figure 2). This lumpy demand proves disastrous to both the beer manufacturer and glass company.

In real life, situations similar to the beer game occur many times per day. Process-oriented firms must carry additional capacity and inventory to buffer against wild swings in demand caused by the non-linear nature of dynamic systems (Fisher, Hammond, Obermeyer and Raman, p. 85). Until underling system dynamics are well understood, process-oriented firms will continue to experience boom-bust cycles that increase cost. A member of the System Dynamics Laboratory at MIT summarizes this feeling with the following passage:

> Structures of which we are unaware hold us prisoner. Conversely, learning to see the structures within which we operate begins the process of freeing ourselves from previously unseen forces and ultimately mastering the ability to work within them and change them. (Senge)

### The Continuous Replenishment Solution to the Systems Dynamics Problem

The key to solving the vexing problem of lumpy demand patterns lies in adapting appropriately to changes in demand. During the past ten years, systems designers made several attempts to smooth out irregular demand patterns by using improved planning systems. For example, the original promise of Distribution Requirements Planning (DRP) involved the potential to smooth out irregular shipments between plants and forward warehouses by adapting Material Requirements Planning (MRP) logic to distribution planning. Though partially successful, DRP fell prey to the old enemy, forecast error.

Process-oriented firms proved largely unsuccessful in forecasting shipments from forward warehouses. This reduced the effectiveness of DRP.

In the early 1990's, systems designers tried a different approach to deal with irregular demand patterns. They applied DRP logic to individual customers and used improved data communication technology to take advantage of live demand and inventory data obtained directly from customer's inventory systems (see figure 3). Customers began to experiment with allowing manufacturers to determine the size and timing of shipments to their distribution centers. This process became known as Continuous Replenishment (CR).

Under CR, rapid communication of true customer demand patterns gives manufacturers the opportunity to balance supply with demand. Accurate knowledge of production capability (finite production planning), combined with CR provides a powerful system to smooth out lumpy demand patterns. In this view, the manufacturing plant is a link in the chain beginning with raw material purchase and ending with consumers purchasing finished product. If manufacturing plant systems are not able to react quickly, a bottleneck will develop with dire consequences. This raises questions concerning the speed with which MRP II can determine production and raw material requirements and its ability to deal with capacity constraints.

## THE POST MRP II ERA

Among the practitioner, academic and consulting communities, little disagreement exists concerning the potential of finite planning and scheduling to reduce cost. Process-oriented firms must plan within capacity constraints in order to remain profitable and deliver high levels of service to customers. With flat bills of material and short lead times, material planning is relatively simple compared to complex capacity planning decisions.

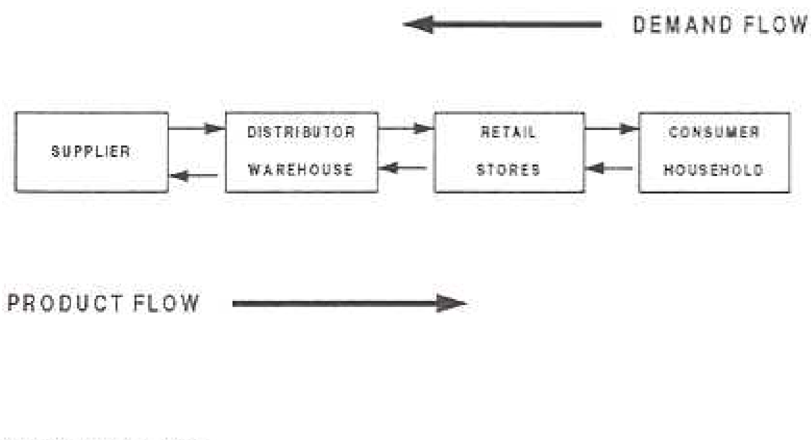
Process-oriented firms have several options concerning finite planning and scheduling. As mentioned previously, most current applications utilize rule-based approaches that accomplish the minimum goals of finite planning and scheduling, but lack the flexibility to deal with dynamic demand. A smaller group of software vendors uses deterministic simulation to perform "what-if" analysis (for an example, see Schuster and Finch, 1990). Finally, a very small group of software vendors employs optimal based approaches that require mathematical programming.

Because of the highly competitive nature of consumer and commodity industries, Process-oriented firms ask a great deal from finite planning and scheduling systems. During the past several years, we developed a list of elements that finite planning and scheduling must handle: 1) customer service levels, 2) forecast bias, 3) manufacturing lead time, 4) capacity, 5)inventory carrying cost, 6) set-up costs and 7) lot sizing. It is doubtful a single model can address all of the issues important to process-oriented manufacturers. If such a model did exist, it would be highly complex and require long solution times.

A more practical approach involves combining several models together in hopes of satisfying all the issues of concern to process-oriented firms. Current research at the *Center for Process Manufacturing* has focused in this direction (Allen and Schuster, 1993, 1994; Schuster and Allen, 1994). Evidence exists that other researchers follow the same line of reasoning (see Gascon, Leachman and DeGuia, 1993). However, an occasional situation arises when a single model works with success (for an example, see Allen, 1990). This attests to the great flexibility of applied operations research in solving practical problems.

The speed of re-planning should become much greater as comprehensive finite planning and scheduling models become available. The time lags associated with MRP II will no longer exist. Because process-oriented firms have flat bills of material, some researchers' hint that MRP may become completely integrated with finite planning and scheduling (see Leachman, 1993). This would come close to the elusive goal of a model that develops feasible capacity, materials and due date plans simultaneously.

**Figure 2. Traditional Replenishment System**




*FROM FOOD ENGINEERING MARCH 1994*

## THE FUTURE PROMISE OF CONTROL THEORY

Beyond the finite planning and scheduling body of knowledge lies the specter of a "guiding hand" that coordinates flow through an entire logistics system. Control theory may assume this role in the age of rapid information exchange.

A brief example provides the best way to understand control theory. When you take a shower, cold and warm water mix together and flow through the shower head. As the water changes temperature, you adapt by adjusting the cold and warm water faucets to get the correct temperature. As time passes, you continue to adjust the facets to maintain the correct temperature. The patterns of adjustments constitute a regulation function. Often the pattern of adjustment is irregular and hard to predict.

Now let's take this analogy one step further. Suppose we wanted to find the unique pattern of adjustments that minimizes the amount of warm water needed to maintain the correct temperature. In some respects, this is much like a trajectory problem in physics. A unique body of mathematics called optimal control exists that will solve this problem. With origins in engineering, optimal control finds many applications in physical systems. It is a way to find optimal solutions to dynamic problems. Researchers are beginning to apply optimal control to solve problems in economics and logistics.

Though mathematically rigorous, optimal control may someday provide the "guiding hand" that minimizes cost in production and logistics systems.

## CONCLUSION

The framework for production planning in the process industries is changing rapidly as new information technology becomes available. The traditional framework of MRP II will not be able to cope with rapid exchange of information between trading partners. Rule-based finite planning and scheduling systems will give way to multiple models that provide near optimal solutions to dynamic problems. Finally, MP&C systems will become part of broader logistics systems.

As these changes unfold, we undertake a great dialogue between industry, academia and consulting during the remainder of this decade. In the words of Coleridge:

> The guests are met, the feast is set:
> May'st hear the merry din.

Figure 3. The ECR System

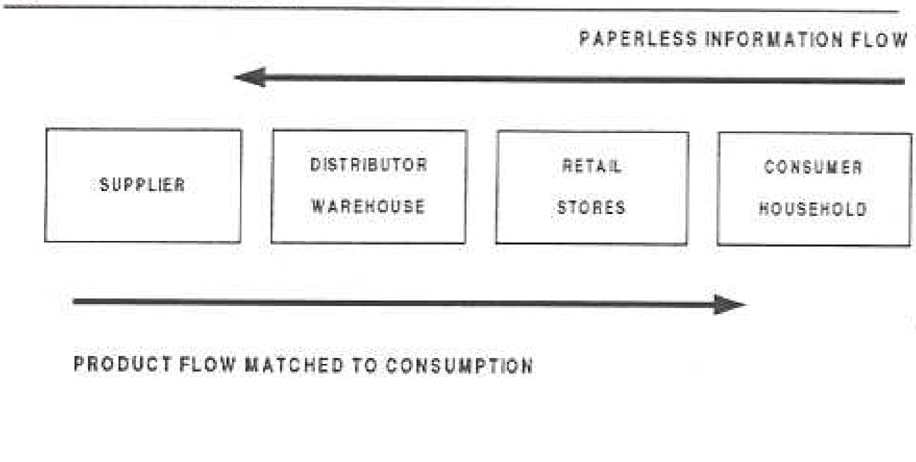



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FIGURE 3

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