This case study summarizes the philosophies, organizational changes, and information systems that DuPont Pharmaceutical Company and SAK Logistics implemented to achieve manufacturing excellence.

Editor’s Note: The DuPont Pharmaceutical Company was acquired by Bristol-Myers Squibb Company on October 1, 2001.

Improving Performance and Reducing Cycle Time Using Flow Path Management: A Case Study

by Glenn Gerecke and Tom Knight

Introduction

Pharmaceutical companies are facing increasing pressure to improve the performance of manufacturing operations. Plants must increase shipments, lower costs, and improve profitability while maintaining consistently high quality and delivery performance. The result: manufacturing excellence is a strategic advantage in the pharmaceutical industry.1

Traditional methods for improving operating performance are often based on out-dated organizational structures, performance metrics, and information.2 For example, many pharmaceutical plants still use Enterprise Resource Planning (ERP) or Materials Requirements Planning (MRP) systems for detailed planning and scheduling, despite the numerous limitations of this approach.3,4 Their performance often plateaus: inventory is too high, shipments take too long, and people are often working on outdated plans and objectives.

This case study describes how one pharmaceutical plant, the ‘DuPont Pharmaceutical Company’ operation in Garden City, New York, broke out of these limitations to reach dramatically better performance. Over the last three years, the men and women at the site, together with some key strategic partners, have reshaped their organization and their systems to pursue...
manufacturing excellence. The following measurable improvements have taken place throughout the operation without the significant addition of capital assets or human resources:

- Units shipped are up approximately 23% over a two-year period.
- Cycle time has been cut by 50% for high volume, high value products.
- Inventory is $10 million lower for critical materials.
- On-time delivery performance has been dramatically improved and is now nearly perfect.

This article summarizes the philosophies, organizational changes, and information systems that were implemented in order to achieve manufacturing excellence. It concentrates on the planning and scheduling improvements and flow path management techniques that have cut cycle time and streamlined product flow. The article describes the following two phases:

- Phase One: Developing the Planning and Scheduling Infrastructure
- Phase Two: Flow Path Management to Improve Performance and Cut Cycle Time

### Plant Mission

DuPont’s 370 employees produce a total of 150 product Stock-Keeping Units (SKUs) ranging from tablets and capsules to syrups. A wide variety of processing technology is employed at the plant including direct compression, wet granulation, roller compaction, fluid bed drying, tray drying, tablet compression, aqueous film coating, and encapsulation. The site packages a large number of bottle configurations and also blisters. The facility was built in 1963 and has grown in a series of expansions to a total of 142,000 square feet.

The process flows for oral solids at Garden City are typical for the industry. Raw materials are received, sampled, and tested. The materials are then weighed and blended into powder, which is either compressed into tablets or encapsulated. Most tablets are coated and tested prior to packaging. Finished products are packed and tested prior to final shipment.

The plant has a two-fold mission:

1. Partner with R&D to rapidly scale-up and launch new pharmaceutical products. The plant is involved in 10-12 product development projects per year. Some of these products are later transferred to a sister location in Manati, Puerto Rico.

2. Supply existing products to the market in a high-quality, economical fashion. The plant produces about 40 different commercial products and 150 SKUs.

The business challenges are clearly different for each part of the mission. New products have relatively unpredictable demand curves and require care and feeding as the organization climbs its learning curve. High volume products, on the other hand, must be produced with consistent on-time delivery and efficient operational costs.

### Starting Point: The Need for Improvements

Three years ago, the site operated in a fashion that was somewhat typical for the pharmaceutical industry:

- The organizational structure was functionally oriented. Each department used stand-alone systems and performance metrics.
- Individual departments maintained “hot lists” based on their knowledge of required customer ship dates.
- There was limited product flow. Material typically spent 90% or more of the time waiting for the next operation. This resulted in long product cycle times, excessive inventory, and costly material storage and handling.
- Systems were not integrated. The ERP system and the MRP module within ERP was used only to manage inventory and do financial reporting. Inventory transactions were one to three weeks behind.

- Planning and scheduling activities were shortsighted and manual-intensive. The planning horizon was one month at most. Schedules were manually maintained using spreadsheets - hard copies were circulated weekly, often with handwritten notes. Planners tracked work center activities using telephone calls and safety shoe leather. Despite the extra effort, the schedules often had to be re-issued several times each week to track changes. Moreover, several important functions such as Quality Control and Quality Assurance were excluded from the initial scheduling process because of limited planning staff.

- Strategic capacity planning for capital and human resources was not formalized.

<table>
<thead>
<tr>
<th>Factory</th>
<th>Resource and Equipment Priority</th>
<th>Goal</th>
<th>Detailed Scheduling Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Development, validation, and launch</td>
<td>Top Priority</td>
<td>Speed-to-market for new products</td>
<td>Manual review and control</td>
</tr>
<tr>
<td>2. High volume, high cost products</td>
<td>Dedicated equipment where possible, high priority allocation of people and equipment</td>
<td>Low inventory, fast cycle times</td>
<td>Pull Scheduling using CONWIP</td>
</tr>
<tr>
<td>3. Low volume, low cost products</td>
<td>Shared equipment, lower priority for resource allocation</td>
<td>No stock-outs</td>
<td>Push ERP/MRP scheduling with generous lead times - use finished product safety stock as a buffer</td>
</tr>
</tbody>
</table>

Table A. Business objectives for each Focused Factory and Flow Path.
Flow Path Management

To address these shortfalls, the objective was defined to improve planning and manufacturing performance. The improvements were performed in two phases: Phase One built the information systems and planning and scheduling infrastructure to support improved performance. Phase Two built on this foundation by splitting the operation into several distinct product Flow Paths, and then redesigning the organization structure, performance metrics, equipment capabilities, and planning and scheduling tools to meet the needs of each flow path. Detailed performance objectives for the organization also were introduced as part of Phase Two.

The following sections describe each phase in detail.

**Phase One of Change: Developing the Planning and Scheduling Infrastructure**

The change process began by strengthening the information systems and planning and scheduling tools. This positioned the information systems to function as a true ERP system, rather than just an inventory management and financial reporting system.

An operation management system was built, one piece at a time, starting with the ERP backbone. Figure 1 shows the major planning and scheduling activities improved in Phase One. Figure 2 shows the activities improved in Phase Two.

**ERP Data Collection and Analysis**

A basic first step was to populate the ERP system with accurate routings and work center data. This involved a joint effort between the site Planning organization and the Manufacturing and Packaging work groups. The pertinent data fields were populated and validated for accuracy over a six-month period. The ERP system was designed with a tremendous amount of detailed data - this investment paid handsomely in Phase Two.

Having the ERP data in place, the goal was to consolidate operating and decision making information within ERP. The goal was to track inventory and production transactions real-time.

**Inventory and Production Tracking**

Our inventory tracking practices were state of the art for 1965: manual keypunching of inventory transactions into the ERP system by a few trained individuals. This caused long delays, large errors, excessive inventory, and, as a result, material shortages and line shutdowns.

How would up to 450 inventory movement, consumption, and production reporting transactions per day be performed while maintaining up-to-the-minute accuracy? Commercially available technology would allow barcode scanning of materials as actual physical activities took place, followed by a database upload to the ERP system from the handheld scanning devices. But this would delay ERP updates by the frequency of uploads. Not wanting to be limited by aged data, a proprietary technology called Radio-frequency Order Picking and Inventory Control System (ROPICS) was selected. This system uses wireless handheld barcode scanning devices to instantly transmit data to and from the ERP system.

Everyone who touches materials was trained to perform...
ROPICS transactions as part of any given operation they perform. As a way to ensure ROPICS transaction discipline, cycle count accuracy was measured and actively managed to be at least 95% on a consistent basis. All “misses” are investigated and corrective actions implemented.

What was the result? Inventory accuracy improved from 70% to 95+% within six months of implementing the new approach. This ensures cGMP compliance when accounting for critical materials. In addition, very significant quantities of raw materials have been removed from inventory, reducing working capital by more than $10 million and cutting cycle times for high volume products by 50%. This is directly related to inventory record accuracy within ERP - when you know exactly what you have at any given point in time, you don’t need any “padding.”

Our manufacturing and information technology staff has recently leveraged the ROPICS technology for managing the shop floor weigh-up and charge-in processes. This has greatly enhanced the ability to perform these critical operations in an error-free fashion by eliminating manual calculations and by guiding batch formulation real-time using a validated system. New ways will continue to be explored to use this technology for shop floor operations.

Since improving inventory accuracy, the materials requirement plan from ERP has been made much more meaningful by having the rough-cut schedule and real time inventory both resident in ERP. We just don’t run out of materials anymore.

**Shop Floor Control, Sequencing, and Scheduling**

Custom reports were developed to show a weekly rough-cut schedule and equipment capacity utilization for each of the 75 Manufacturing and Packaging work centers - all based on ERP shop orders. These reports replaced the spreadsheets and are now the primary means for communicating the rough-cut schedule.

Quality Control and Quality Assurance were initially left out of the ERP scope. This was a mistake. Since the initial project, a program was launched and completed to add these work centers to the routings so that they are integrated with the Manufacturing and Packaging operations. The addition of QA and QC to the implementation scope was critical for reducing cycle times, since products interface with these work centers up to five times during each cycle.

**Capacity/Facility Planning**

With the tactical elements in place, we were able to lengthen the planning horizon to the strategic time frame. Equipment capacity utilization can now be predicted for each work center throughout the forecasting horizon (two years in this case).
This is done using the ERP capacity planning modules with little customization. The same techniques are used to calculate labor requirements for each work center, knowing only the labor rates and product demand stored in ERP.

The Directors of Engineering, Manufacturing and Packaging, Technical Operations, Human Resources, Finance, Information Resources, and Planning now meet monthly to review the capacity plan for the upcoming two years. All capital equipment and staffing plans are formulated from these meetings and incorporated into the budgetary process. Having sufficient but not excessive equipment capacity and labor available at the proper times makes the best use of the company’s cash and provides the necessary conditions for reduced cycle time. The site’s financial budgets and long-range operating plan also are developed from the ERP database.

**Phase II of Change: Flow Path Management**

**Defining Flow Paths using Pareto Analysis**

Performance soon peaked following these initial successes. Relying on ERP and the traditional performance metrics was reducing efficiency, increasing inventory, and lengthening cycle time. The duality of the plant’s mission statement, the complexity of the manufacturing operation, and the limited equipment flexibility, we needed to focus on specific product groups and tailor the management systems for each product group.

Flow Path Management is a management technique that organizes manufacturing systems into process-based flow paths. These flow paths simplify planning and scheduling, support organization structures aligned to process flow, and enable cycle time reductions and other performance improvements. Management can tailor the business processes in each of the following four areas:

1. **Performance Metrics**
2. **Organization Structure and Development**
3. **Planning and Scheduling**
4. **Process Control and Equipment Flexibility**

To identify the major flow paths, Pareto analysis was used. The analysis showed that the bulk of inventory dollars were invested in two products. We decided to focus on reducing cycle times for these two high volume, high value products. The actual Garden City flow paths along with their associated volumes are shown in Figure 3.

The operation was divided into three distinct factories within the overall operation, called “factories within the factory.” Development products were assigned to the first factory. The second factory, for high volume products, held two flow paths: one for each of the two high volume products. The remaining low volume products were assigned to the third factory. The strategy to accomplish the entire mission involved the scheduling rules shown in Table A.

After defining the major flow paths, the business processes were tailored within each flow path to best fit the needs of that business.

**Performance Metrics and Feedback Information**

To track progress and to motivate and reward improvement, a set of performance measures for each flow path was designed and implemented.

The vision was to automatically generate these metrics on a daily basis and to give individual work center owners the ability to view them on that frequency. To implement this vision, a data warehouse was developed containing all the ERP data and inventory transactions described above. We call this our Cycle Time Information System (CTIS). Using CTIS, work center owners are able to quickly visualize, on a daily basis, their own area’s performance for each flow path and make any necessary adjustments. Figure 4 shows how the data is automatically transferred from the ROPICS guns into the data warehouse, and then analyzed on our intranet web server for displaying the performance for a given flow path. Every person at the plant (and in the company at other locations) can view the metrics using the corporate intranet site. Figure 5 shows an example of CTIS output, displaying the location and on-time status of open orders in a flow path.

These metrics are reviewed at the daily operations meeting to make operating decisions and monitor status for each flow path. The purpose of this meeting is to establish a common
understanding of the three factories’ status each day and to provide a vehicle for communication among the work center owners. Hundreds of active shop orders are managed (by exception) cross-functionally in a daily 15-minute meeting. Issues are identified early and resolved.

CTIS is used as an early warning system so that flow path bottlenecks are identified and resolved quickly. Three Flow Path Metrics are monitored daily:

- **Health of the Flow Path**: Displays the location of open orders within each flow path (dynamic bottleneck identification) and whether the orders are on time, behind schedule, or late. Figure 5 shows this graph.

- **Cycle Time vs. Goal**: Measures elapsed time from raw material (active ingredient) receipt to shipping of finished product for each flow path. Provides overall measure of operational effectiveness and motivates cycle time reduction efforts.\(^{10-14}\)

- **Inventory vs. Goal**: Determines when to pull work into the flow path. This pull scheduling tool controls work in progress inventory and cycle time.\(^ {15}\)

Distribution of the information through CTIS provides a constant source of performance feedback. Using CTIS, we are able to break flow path cycle time into its individual components and encourage continuous improvement from each work center owner.

Site operating objectives are built around flow path performance for each of the three flow paths. Stretch goals are set with aggressive improvement. Every functional group has its own objectives that are based on the whole organization’s objectives. All 370 people in the organization can articulate what role they play in achieving these objectives, since the objectives are an element of each person’s performance appraisal.

A portion of each person’s compensation is determined by the success of the organization in meeting site operational objectives. The performance management process is carefully monitored at the highest levels of the site organization to ensure that the compensation process is used effectively to drive manufacturing excellence. The site leadership team is responsible to ensure that each objective is approached in a synergistic fashion. This reinforces the site objectives and motivates individual contributions and team performance.\(^ {16,17}\)

**Organization Design: Aligning People and Skills**

The plant took several steps so that the organization reaches stretch objectives:

- Additional training was offered to help employees expand their skills. The training included an on-site workshop in Factory Physics techniques to expose everyone to the opportunities for cycle time reductions and other improvements. Factory Physics is a systematic description of the underlying behavior of manufacturing systems. These analysis techniques are used to identify opportunities for improvement and target specific improvement projects.\(^3\) The total site training budget has been approximately $250,000 per year over the last three years. In addition, job-specific training is managed as part of the normal course of business.

- Strategic partners were hired to speed implementation and complement the skills of internal staff members. DuPont Pharmaceuticals retained the services of SAK Logistics to support the implementation of the Cycle Time Information System and the cycle time reduction projects.

- Additional people were dedicated to process improvement and cost savings. As part of a corporate Six Sigma process improvement initiative, two DuPont Pharmaceuticals employees were appointed to serve as full-time Six Sigma Black Belts.

- People were assigned to specific flow paths. By focusing on the needs of just one flow path, the employees can customize their work and improve cycle time through their area.

- People within a flow path were cross-trained so that they are able to move to the flow path bottleneck and relieve the congestion. As an example, suppose the tablet coating operation experienced downtime causing uncoated tablet cores to accumulate in front of that operation. The flow path health metrics would quickly highlight the bottleneck. Cross training allows people from the weigh-up operation to move to coating and increase production of coated tablets until the bottleneck is relieved.

- Staff groups were redeployed to support flow path success. Technical and QA resources were made available to the...
operating areas 24/7 for consulting and problem solving. Material is not permitted to move from one operation to the next without complete satisfaction that all work was performed correctly. Focusing on problems as they occur increases visibility, drives more participation in the problem-solving process, and creates more ownership for the quality of the product. This minimizes cycle time variability.

**Pull Scheduling to Cut Cycle Time and Inventory**

With the metrics and organization in place, earlier planning and scheduling improvements were expanded to reach better performance. One primary obstacle to overcome was the weaknesses of Materials Requirements Planning (MRP) as a scheduling tool. While MRP works well in plants with limited complexity and with low utilizations, it begins to fall apart as real-world conditions occur. For example, MRP is not sensitive to capacity constraints. As a result, plants using MRP systems have an incentive to “pad” their lead times just in case variability causes a production problem. These padded lead times increase inventory and cycle times unnecessarily. In addition, since MRP is a “push” system, it will not slow down material releases if there is a production problem in the factory. This causes inventory to build needlessly and increases cycle times further.

To overcome these issues, a pull scheduling system was implemented for high volume flow paths. A Constant Work in Progress (CONWIP) system was adopted. CONWIP works by setting an inventory target for each flow path. When inventory drops below the target, the system sends a signal to the first operation to send more work into the flow path. This pull signal works to always maintain a constant amount of work in progress in the flow path. Planners and work center owners use the pull signal contemporaneously with flow path health information to schedule each factory flow path and monitor daily performance. Using current, accurate, focused flow path data allows optimum communication and coordination.

The CONWIP system has several advantages over MRP. First, it allows inventory and cycle time targets to be reached. Second, it eliminates the motivation to pad MRP lead times. Finally, it requires significantly less data than MRP since only a single number is needed — the total inventory for the flow path each day.

CONWIP also offers several advantages over other pull scheduling methods such as Kanban cards. First, CONWIP works well even if many low volume products are produced on the same flow path; the pull signal authorizes the release of the next order for the flow path, regardless of the specific SKU. Second, CONWIP provides a simple way to move material to the bottleneck for the flow path. As an example, if the tablet coating operation experienced downtime, uncoated tablet cores would accumulate in front of that operation without any changes in the CONWIP target.

**Improving Equipment Flexibility and Reliability to Support Faster Cycle Time**

With pull scheduling, inventory levels can be lowered to any level. However, care must be taken to avoid setting inventory levels so low that bottleneck equipment starves for work. In short, enough inventory must be maintained to handle expected equipment outages, changeovers, and between-lot cleaning. The more variability in equipment uptime or the longer the changeover times, the more inventory that is required.

As part of the change process, several work centers were identified with long outages and/or long changeover times. Teams were formed to improve this equipment. For example, one team was formed at the high speed packaging line to reduce changeover times. This team included operators, mechanics, QA technicians, and support personnel from all three shifts. As shown in Figure 7, the team was able to cut changeover times by more than 50% in 90 days using Single Minute Exchange of Dies (SMED) techniques. By reducing the changeover times, the equipment utilization dropped, reducing cycle time and facilitating reductions in campaign sizes, operating costs, and inventory.

**Results and Lessons Learned**

The Garden City organization has validated tens of millions of dollars in working capital reductions by improving the way inventory is managed. Shipments have reached record high levels, and cycle times continue to set new monthly records. We are confident that this is just the beginning of the benefits that will be realized.

The key lessons learned include:

- ensure that information systems are timely and accurate
- identify product flow paths based on business needs
• establish flow path performance metrics and metric ownership to motivate improvements

• staff each flow path and train its employees so they work together to reach stretch objectives

• utilize external strategic partners to accelerate implementation and complement internal skills

• use pull scheduling to overcome the weaknesses of MRP

• continued improvement requires faster changeovers and smaller campaign sizes

References


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Glenn Gerecke has approximately 20 years of work experience in the chemical processing and pharmaceutical industries. His career is characterized by leadership in the areas of organizational design and development, inventive and implementation of systems, technological innovation, operational quality, and project management. Gerecke is currently Vice President and Site Director, DuPont Pharmaceuticals Company, Garden City, New York. (DuPont was acquired by Bristol-Myers Squibb Company on October 1, 2001.) He is responsible for all aspects of site management and leadership. In this position, Gerecke has built an exceptionally strong and extremely motivated organization, has driven remarkable improvements in first-time-through quality and cycle time reduction, and has implemented leading edge operational systems. He has Master’s degrees in business administration and management from Framingham State College and Worcester Polytechnic Institute, respectively. He holds a BS in chemical engineering from Worcester Polytechnic Institute.

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