Pharmaceutical Manufacturing: Structuring Organizational Learning Through "Benchmarking"

by

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Submitted to the Sloan School of Management in Partial Fulfillment of the Requirements of the Degree of Master of Science in Management
at the
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ABSTRACT

The central theme of this project was to develop a framework for the MIT Pharmaceutical Manufacturing Benchmarking Study that would promote organizational learning through a process of "benchmarking". This involved structuring relationships with a number of pharmaceutical companies and developing qualitative and quantitative performance measures to measure the performance of pharmaceutical manufacturing.

We argue that pharmaceutical manufacturing will play an increasingly strategic role in the pharmaceutical industry of the future. Using manufacturing as a source of competitive advantage, however, will require fundamental change within the pharmcaceutical manufacturing organization. To be able to manage this change, pharmaceutical companies must focus on the defining their "current state" and their "desired future state". Defining these states requires the use of performance measures that are relevant for the company. Pharmaceutical companies can use benchmarking as a means to "learn" not only from other plants but also from their own prior performance.

In this thesis, we summarize important results obtained from benchmarking 12 different pharmaceutical plants over multiple years. The results provide valuable insights into quality operations, inventory management, organizational learning and best-practice.

Thesis Supervisor: Professor Charles Cooney
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ACKNOWLEDGEMENTS

First, and more than anyone else, I acknowledge the help of my advisor, mentor and friend Professor Charles L. Cooney. Over the last six years that I have worked with him he has encouraged me every step of the way and provided me with an environment where I could both be creative but also work on issues that were tremendously relevant to the pharmaceutical industry. I have learned many lessons for life from his example.

I would very much like to acknowledge the help of the individuals (who will remain unnamed for reasons of confidentiality) from the many different pharmaceutical plants who were involved in this benchmarking project. Benchmarking can be a time consuming and involved process.

Last and certainly not least, I would like to acknowledge the help of Nanjamma. Her many years of selfless sacrifice helped me though all of high school.

DEDICATION

This thesis is dedicated to my wife Lavanya, my parents, my sisters Vishala and Nirmala, their husbands Ramesh and Shankar and their little ones Divya, Sandhya and Abhinav. They are my purpose for living and have given me everything I have. I believe that all that I have been able to accomplish in my life has been because of their constant and selfless love and encouragement.

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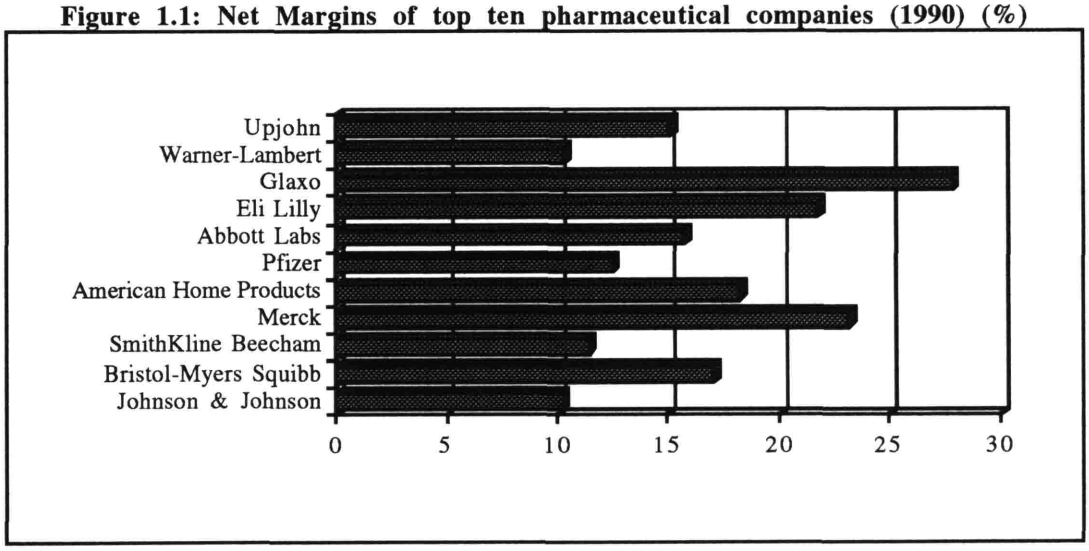
Chapter 1

The Pharmaceutical Industry used to be highly successful

1.1 Profitability

Over the years, the global pharmaceutical business has been quite profitable. Analyzing the pharmaceutical industry as recently as 1990 would have shown it to be more profitable than any other industry in the U.S. As shown in Figure 1.1, net margins for the top ten pharmaceutical companies were substantially higher than the S&P Industrials

Figure 1.1: Net Margins of top ten pharmaceutical companies (1990) (%)

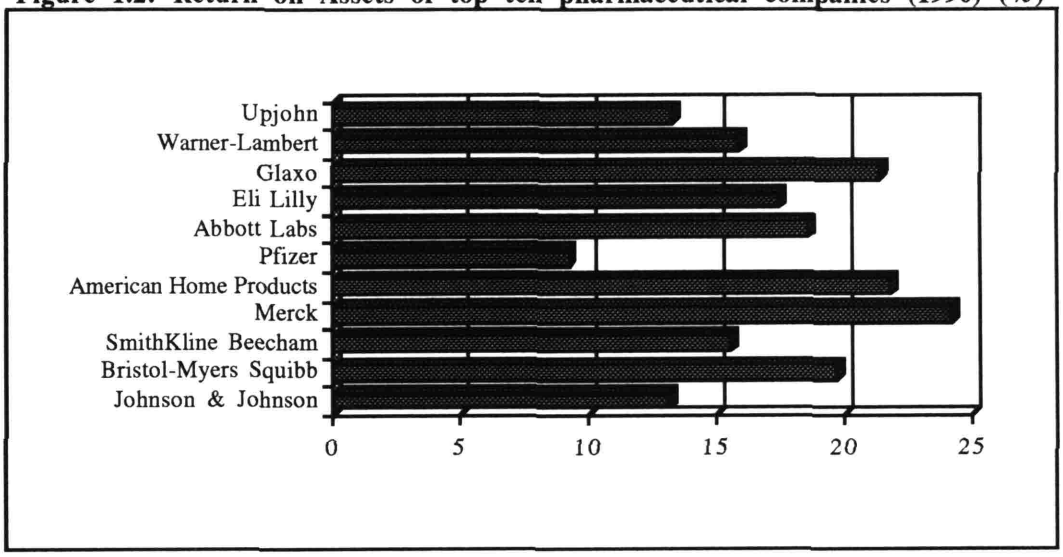


average of about 5%. They had been rising steadily . Figure 1.2 summarizes the return on assets for the same group of global companies. Clearly, the industry was highly profitable.

As a result of this profitability, pharmaceutical companies had rewarded shareholders with returns on equity 50% higher that the median for Fortune 500 industrial

companies. The industry had benefited from healthy sales and earnings growth rates; earnings growth had outpaced sales growth in almost every case.

Figure 1.2: Return on Assets of top ten pharmaceutical companies (1990) (%)



The basis for this profitability could be understood by analyzing the elements of the pharmaceutical industry structure as shown in figure 1.3. This analysis can be broken down into an analysis of the industry competitors, the entry barriers, the buyers, the substitutes and the suppliers.

1.2 Industry Structure

- **Large fixed costs**

The pharmaceutical industry is global with annual worldwide sales growing by more than four fold from 1976 to 1990, when it reached $174 billion worldwide. As shown in figure 1.4, the European market continued to be the largest regional market, and the U.S. market was the largest single market for pharmaceuticals, accounting for 27% of the world market in 1990. The Japanese market is the second largest with 18% of the world market. Japanese pharmaceutical firms are generally small and tend to serve their domestic needs, thus contributing to a pharmaceutical trade deficit in Japan of $1.9 billion in 1989.

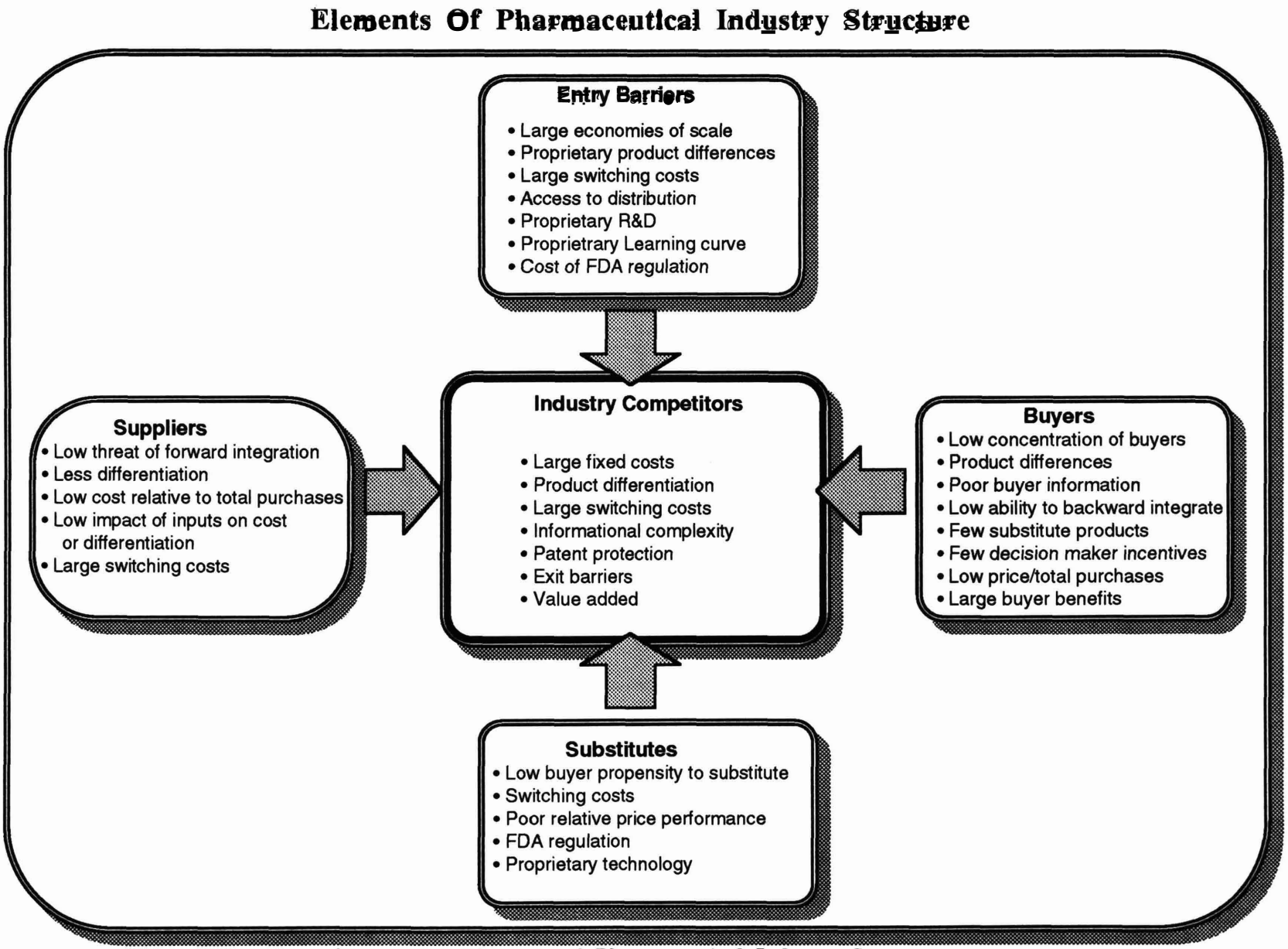
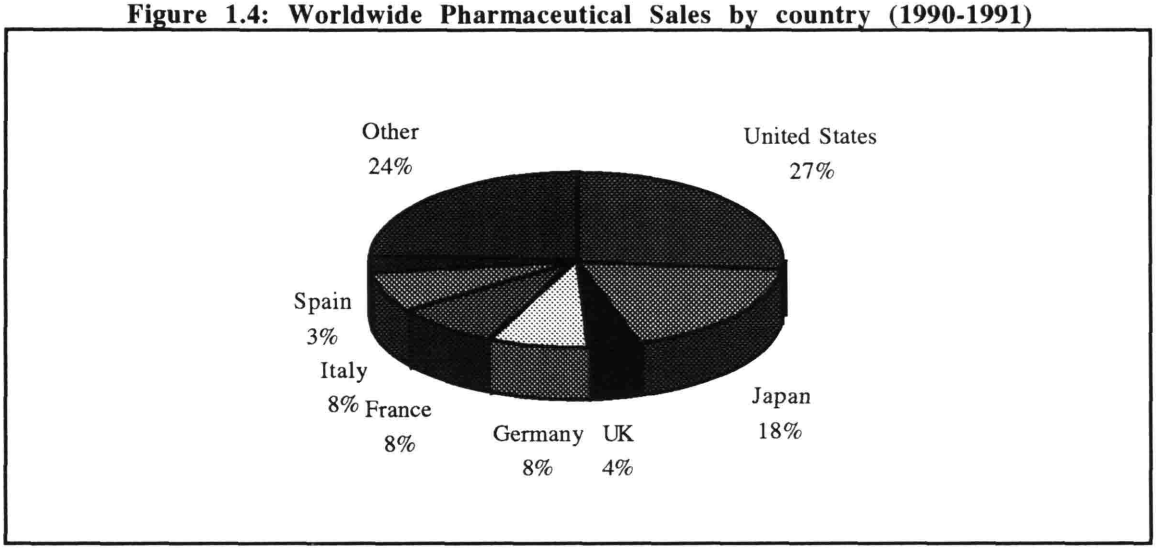


Figure 2.3: Elements of Pharmaceutical Industry Structure

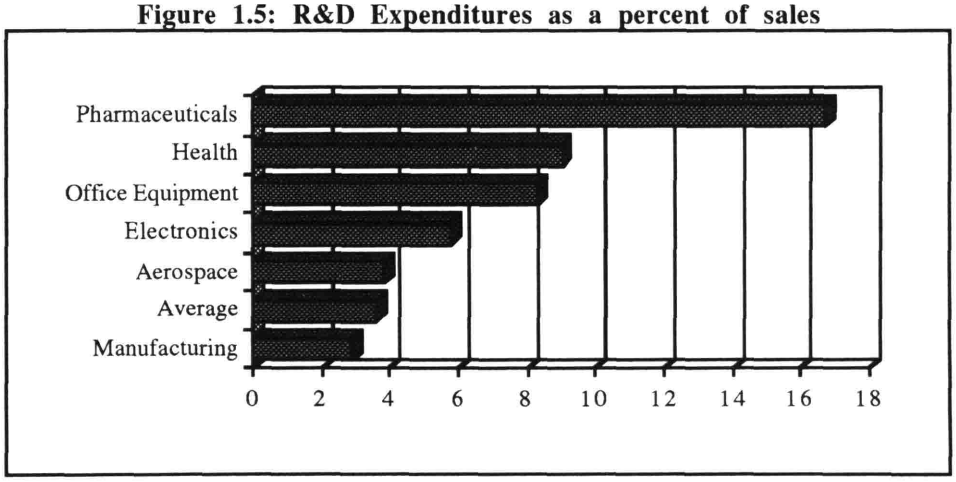
In Europe, Germany was the largest market and was also a dominant exporter to other European countries.

Figure 1.4: Worldwide Pharmaceutical Sales by country (1990-1991)



The pharmaceutical industry has large fixed costs. One of the biggest costs is the investment in R&D. As shown in figure 1.5, compared with other major U.S. industries,

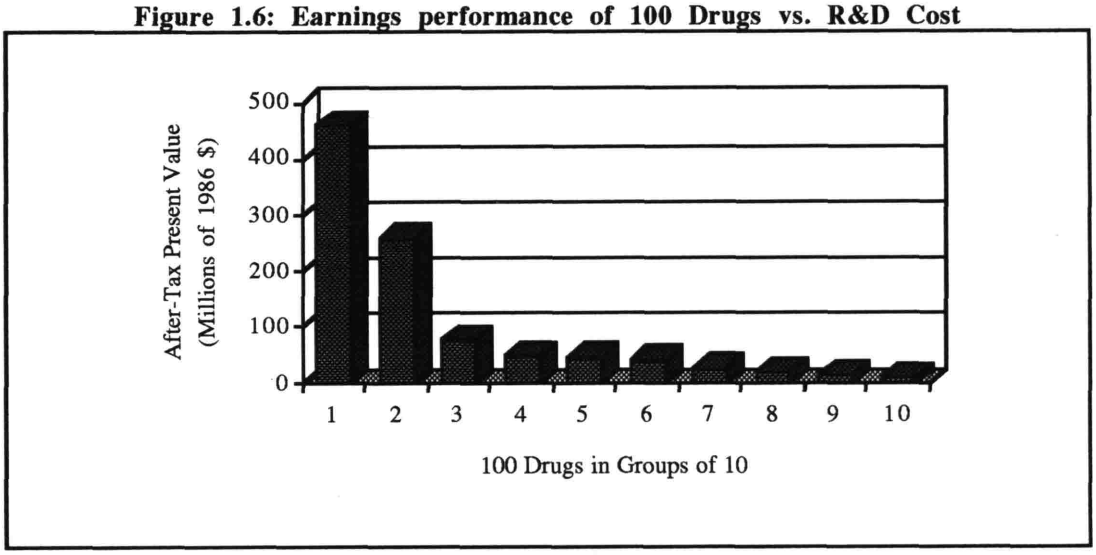
Figure 1.5: R&D Expenditures as a percent of sales



the pharmaceutical industry devotes a higher percentage of its sales revenues to research and development.

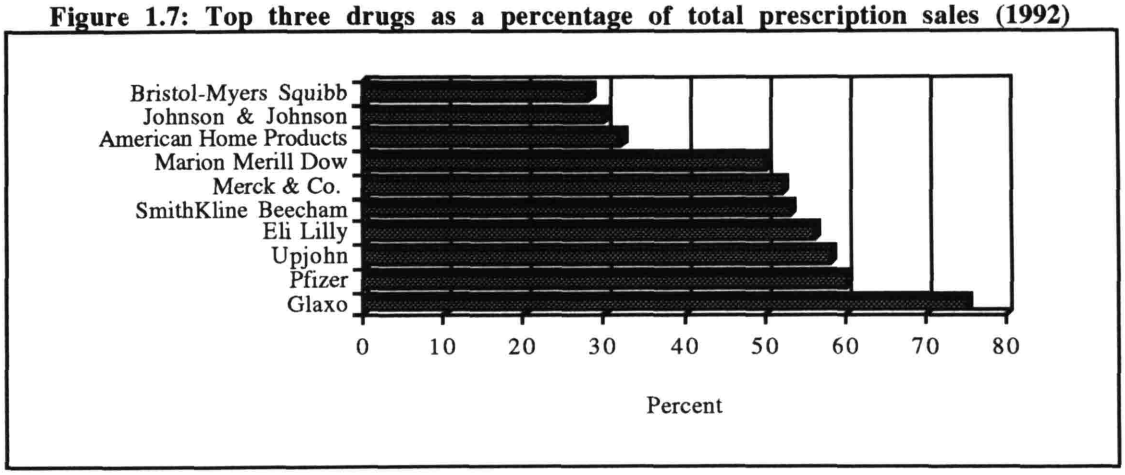
There are significant economies of scale and scope in pharmaceutical drug development. While the cost of developing a new drug (average R&D cost per drug) was as high as $80 million between 1970 and 1979, as shown in Figure 1.6, only 3 out of every 10 drugs introduced between 1970 and 1979 subsequently recovered their R&D costs.

Figure 1.6: Earnings performance of 100 Drugs vs. R&D Cost



Hence, most companies had a few blockbuster drugs which paid off for all the failed attempts. This is shown in figure 1.7 which shows that the top three drugs were a

Figure 1.7: Top three drugs as a percentage of total prescription sales (1992)

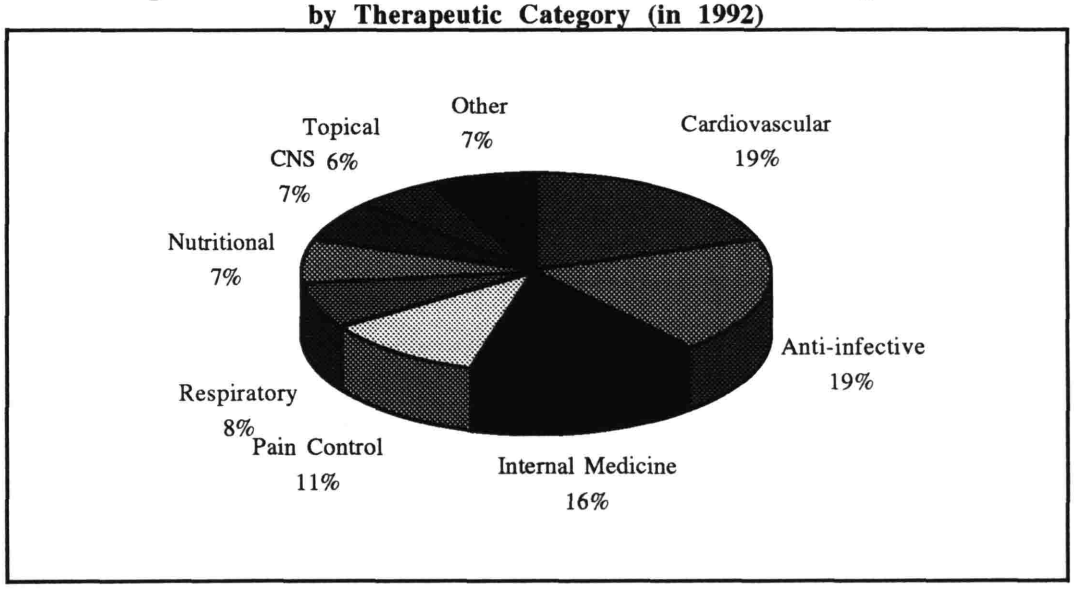


sizable fraction of each of the top ten companies total prescription sales in 1992.

- **Product differentiation**

The market for pharmaceuticals is highly differentiated by therapeutic category as shown in Figure 1.8. As a result, the pharmaceutical industry is also highly fragmented. The share of total sales held by the 20 largest firms accounts for 75% of industry sales; all other firms account for 25% of the market. None of the major companies holds more than a 7.5% share of the market.

Figure 1.8: Distribution of Worldwide Prescription Drug Sales by Therapeutic Category (in 1992)



The industry benefits from significant patent protection. This enables it to derive value from its large fixed costs by excluding others from benefiting from the innovation for a period of time (patents typically last 17 years).

- **Entry Barriers**

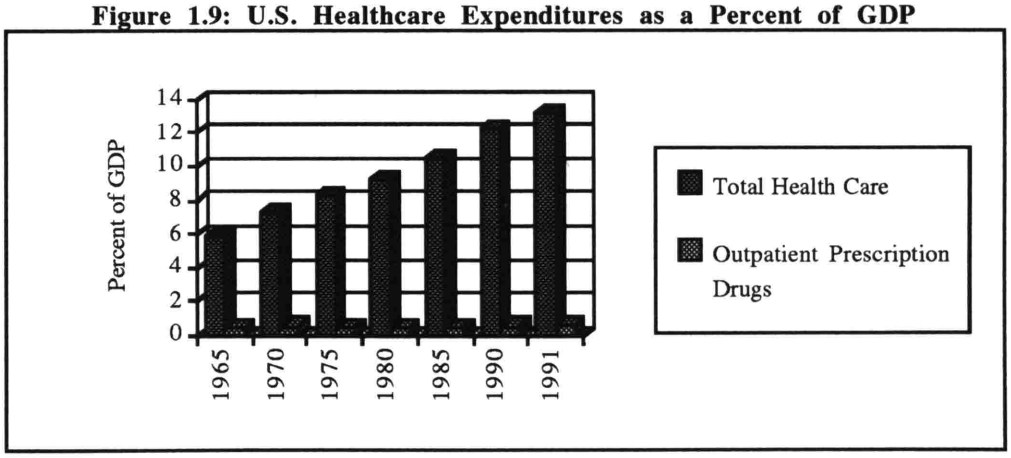
As shown in figure 1.3, there are significant entry barriers to getting into the pharmaceutical industry. This has to do with the large fixed costs reflected in economies of

scale, the proprietary product differences, large switching costs due to the some degree of brand loyalty among doctors and patients, the lack of access to distribution channels, proprietary nature of R&D, proprietary learning curves and the huge cost of compliance with FDA regulation.

- **Buyers**

The pharmaceutical industry has had a unique relationship with the buyer. There has been very little buyer power due to the low concentration of buyers as each one often makes decision individually. There is also significant product differences and extremely poor buyer information. The buyer has no ability to backward integrate into pharmaceutical manufacturing and has few substitute products. Interestingly, the actual decision maker has traditionally been the doctor who have little or no incentive to be price sensitive. In addition, pharmaceuticals are typically viewed as being a low price relative to the other associated purchases of health care as shown in figure 1.9.

Figure 1.9: U.S. Healthcare Expenditures as a Percent of GDP



- **Substitutes**

Pharmaceuticals (brand name or generic or biotechnology based) have often been quite cost-effective with few, if any, effective substitutes for them. The lack of buyer information leads to large switching costs. Most substitute have typically had poor price performance relative to the pharmaceutical drugs. FDA regulation and the proprietary nature of the technology also make it difficult for substitutes to take hold.

- **Suppliers**

The proprietary nature of the technology, associated with the asset specificity and large fixed costs make the suppliers a low threat for forward integration. The suppliers are typically less differentiated and hence have less bargaining power. The costs of material supplies is typically low when compared to the total purchases of the pharmaceutical industry and the inputs have a low impact on cost and differentiation. There are however, large switching costs associated with suppliers to the pharmaceutical industry mainly due to FDA regulation and compliance. This can sometimes determine the nature of relationships with suppliers.

Chapter 2

The pharmaceutical industry in a state of transition

There has been a very significant change in the structure of the pharmaceutical industry in recent years. Figure 2.1, shows the global pharmaceutical industry coming

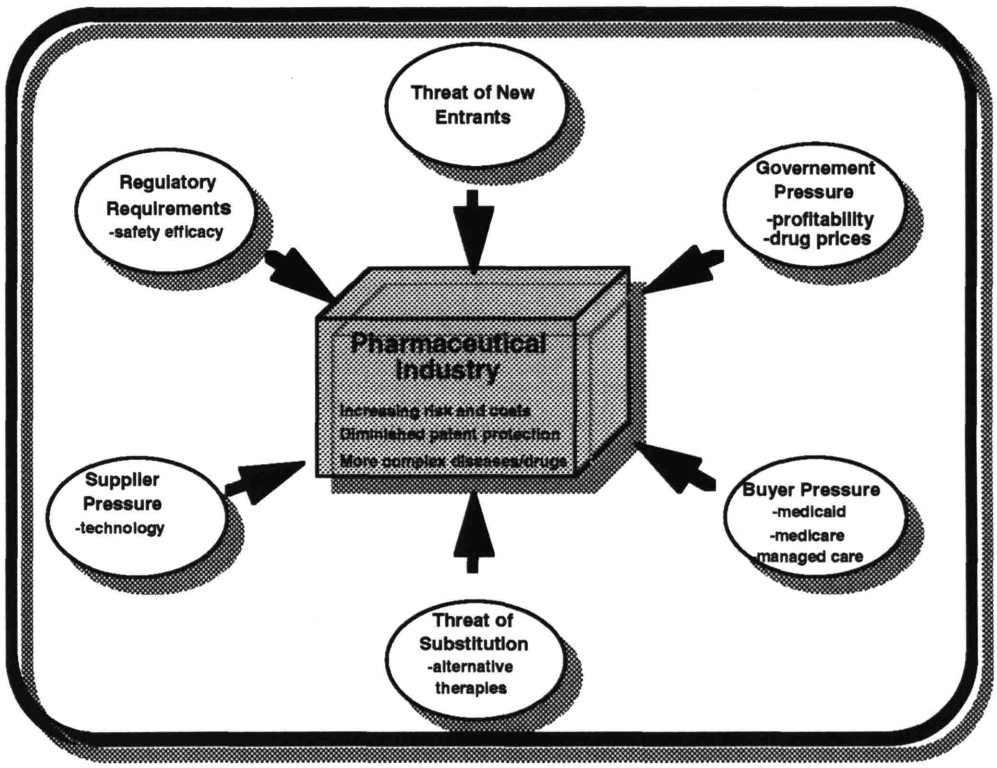


Figure 2.1: Increasing pressure on the pharmaceutical industry

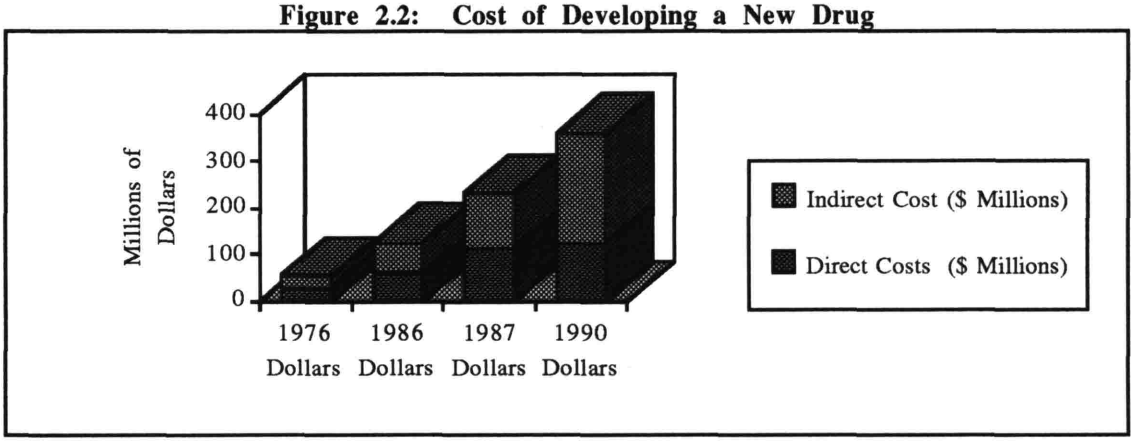
under increasing pressure. These include government pressure on prices and profitability, increased bargaining power on the side of the buyer, increased threat of therapeutic and generic substitution, stringent regulatory requirements, rapidly changing technology and the threat of new entrants within the context of longer product development time scales, more complex drugs and the increasing costs of research and regulatory compliance. In

this squeeze, the industry needs to assess the efficacy and effectiveness of its research, manufacturing and marketing operations. Given these competitive pressures it is becoming increasingly apparent that pharmaceutical industry profits will almost certainly decline in the next few years.

2.1 Increased competition between firms

Pharmaceutical R&D is increasingly risky and costly. As shown in figure 2.2, on average, it costed $359 million in 1990 to bring a new drug through discovery, clinical

Figure 2.2: Cost of Developing a New Drug



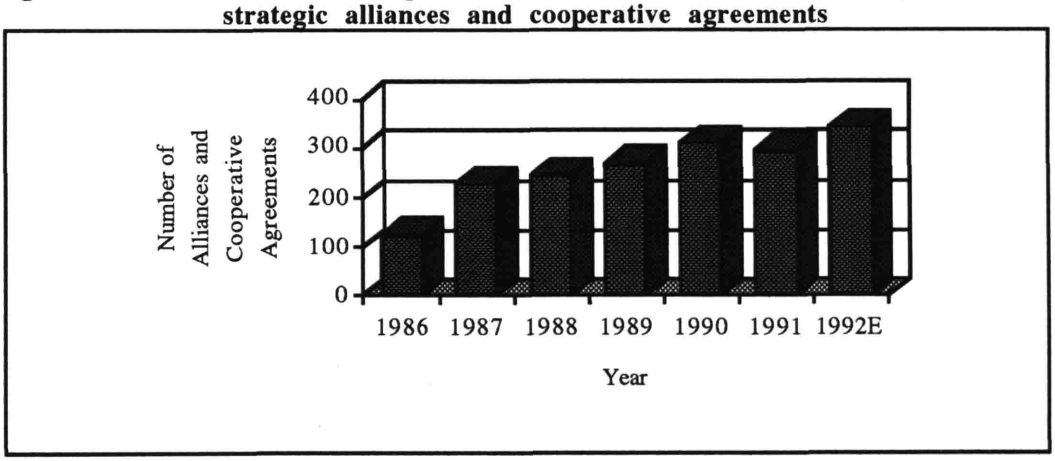
testing, development and FDA approval to begin marketing. This cost had increased sharply in recent years. Major contributions to the increased cost include the intricate nature of modern research, failed products and regulatory hurdles. In addition, the focus has shifter toward chronic and degenerative diseases; complicated and extensive clinical testing is often necessary to prove efficacy of new medicines.

The nature of the pharmaceutical industry is changing. Presently, an important dimension in the rivalry between pharmaceutical firms is the race to gain a foothold in the generics market. The U.S. market is by far the most susceptible to generic substitution. It is estimated that the U.S. market is about 25 percent generic, while Japan is close to 19 percent and most European markets are less than 10 percent generic-substituted. This is having a profound effect on U.S. ethical drugs companies who rely heavily on their

domestic market. The product life of most brand name pharmaceuticals has now effectively been reduced significantly by the success of generics. The strengths of these companies will erode if they are not hedged against the onslaught of generic substitutes. Hence increasingly pharmaceutical companies are focusing on manufacturing and reducing manufacturing costs.

The increased fixed cost of research and the higher risks together with the reduced revenues are also leading to a rapid consolidation within the industry as pharmaceutical companies enter into an increasing number of alliances and competitive agreements as shown in figure 2.3.

Figure 2.3: Pharmaceutical companies have entered into an increasing number of strategic alliances and cooperative agreements



2.2 Increased government pressure

The relentless rise in U.S. health care expenditures has resulted in health care costs exceeding $800 billion per year (14% of the U.S. Gross National Product). As shown in figure 2.4, health care expenditures have been doubling or tripling every decade. This has resulted in government pressure on pharmaceutical prices and profitability.

As national healthcare expenditures continue to rise, figure 2.5 shows that drugs as a percentage of national health expenditures declined from 1965 to 1980, and have

Figure 2.4: National Health Care Expenditures (Billions of Dollars)

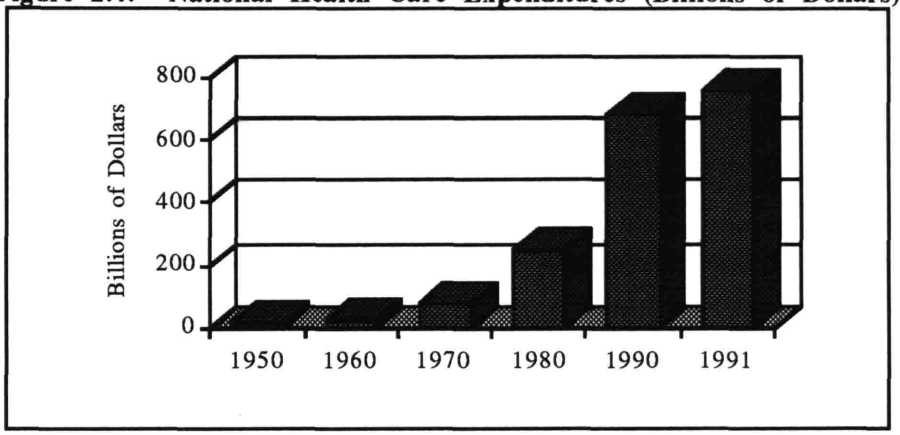
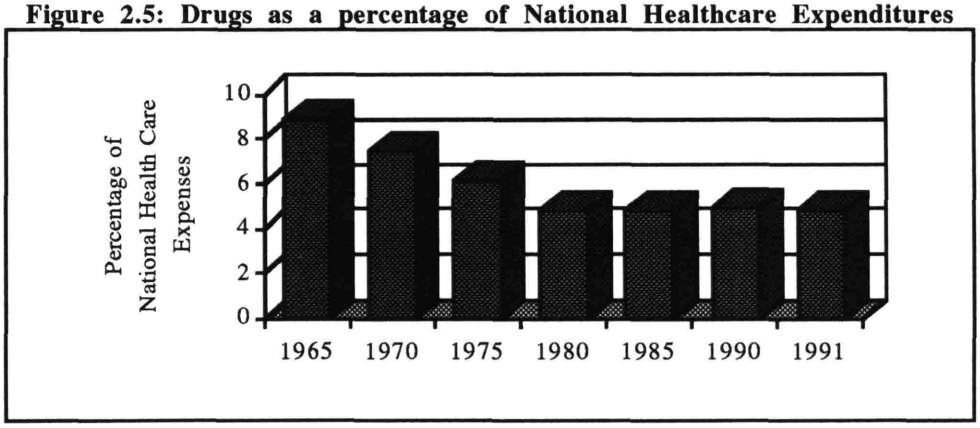


Figure 2.5: Drugs as a percentage of National Healthcare Expenditures



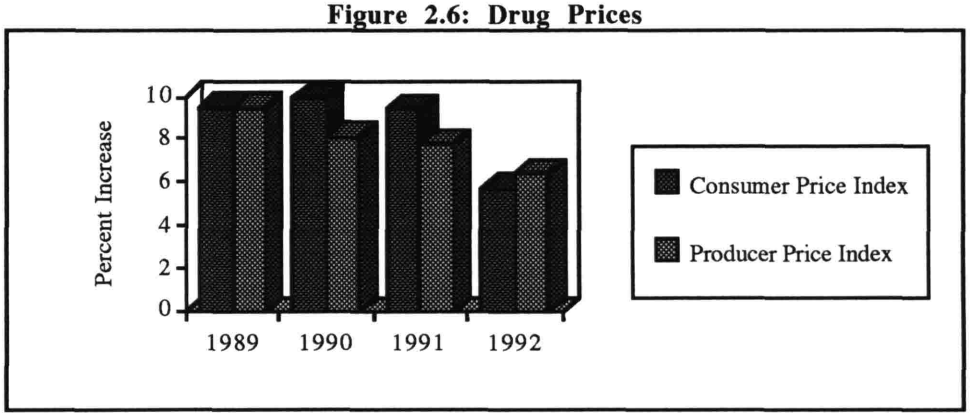
remained steady at a modest level since then. Outpatient drugs account for only five percent of each health care dollar. All drugs account for only about seven percent. However, although pharmaceutical costs as a percentage of total health care expenditures are small and decreasing, profitable drug companies are easier targets for cost reduction than hospitals or physician services.

2.3 Increased buyer pressure

Historically, drug companies have profited from their unique relationship with their customers. Insurance companies, not the user (patient) often pay for prescription drugs. In addition, the prescriber (physician) had little incentive to choose a lower priced drug in favor of a higher priced drug. However, this situation is changing. The buyers (insurance companies and HMOs) have begun to join forces to increase their bargaining power and hence force the pharmaceutical companies to lower their prices.

Figure 2.6 shows the effect of this change. As seen in the figure, the rate of

Figure 2.6: Drug Prices



increase in pharmaceutical drugs prices has begun to fall under increased government and buyer pressure.

2.4 Increased threat of substitution

The monopoly of the pharmaceutical company is usually protected in the form of a patent. However, prescription drugs are increasingly coming under the threat of therapeutic substitution (during the patent life) and generic substitution (immediately after the patent has expired). Figure 2.7 shows the expected dramatic growth in generics in the 1990s. It was estimated that 200 drugs will come off patent by the year 2000.

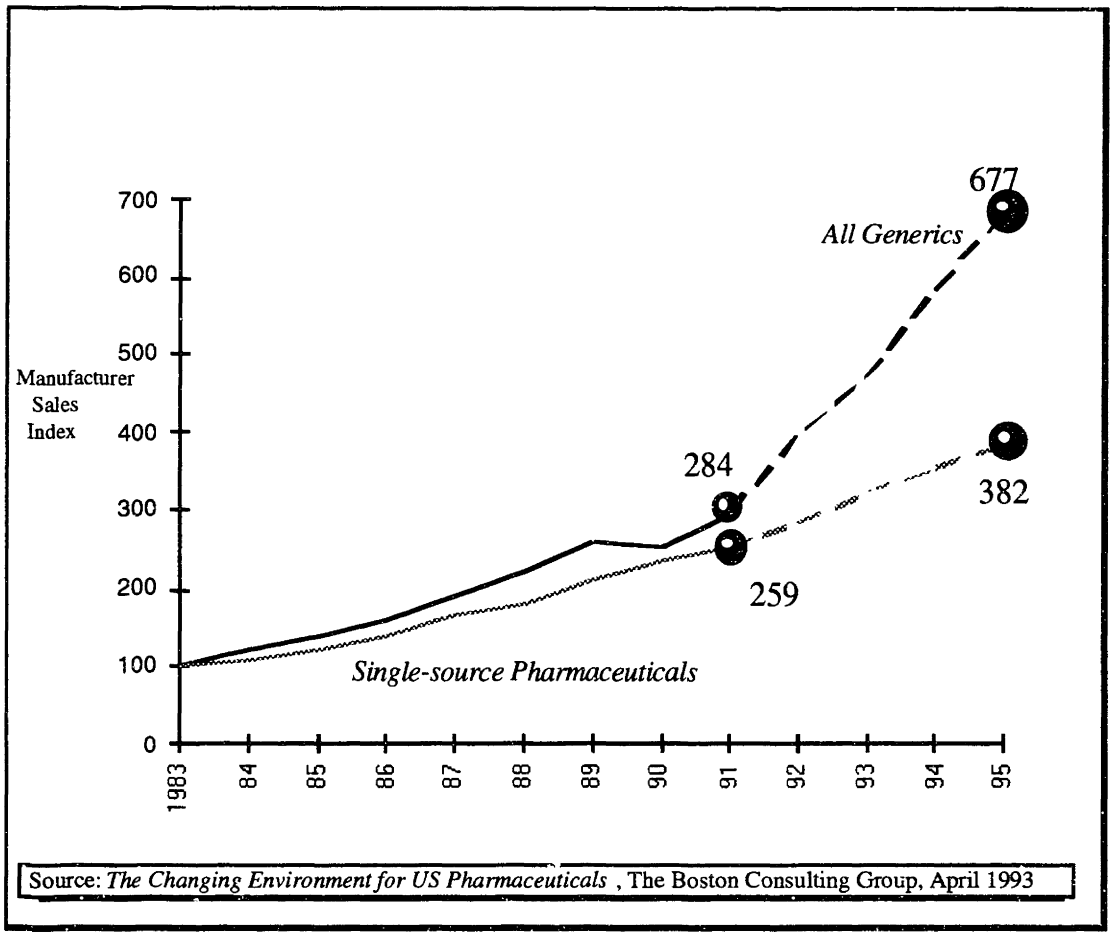


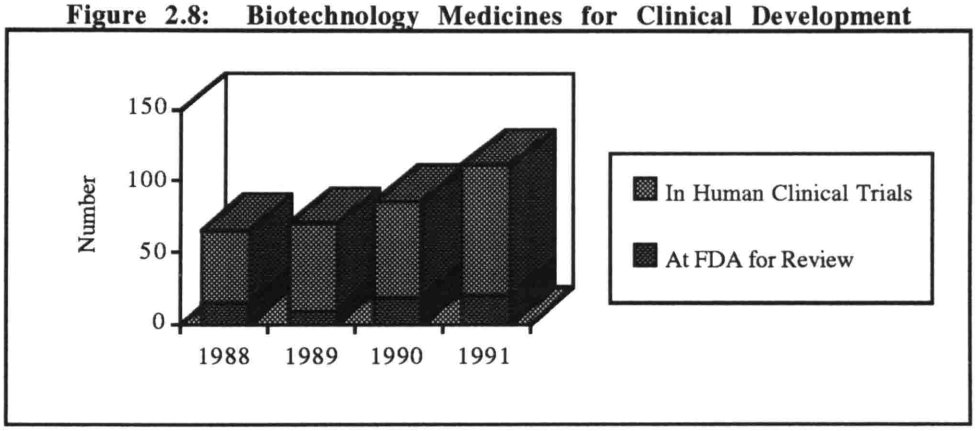
Figure 2.7: Growth of Generics

Similarly, biotechnology is beginning to play a large role in therapeutic substitution as biotechnology products begin to become therapeutic alternatives for some conventional pharmaceutical drugs. At the end of 1991, 21 biotechnology medicines had been approved by the Food and Drug Administration. Meanwhile, as shown in figure 2.8, there are mounting number of genetically engineered drugs and vaccines in clinical trials and at the FDA for review.

2.5 Increased Regulatory Requirements

The Food and Drug Administration (FDA) continues to have stringent requirements for safety and efficacy. The large number and increasing complexity of New Drug

Figure 2.8: Biotechnology Medicines for Clinical Development



Applications (NDAs), in turn, have led to a backlog at the FDA. This adds to the time and cost involved in drug development.

2.6 Rapidly changing technology and threat of new entrants

The level of sophistication and the volume of available data in fields relevant to traditional pharmaceutical research like chemistry, physiology, and pharmacokinetics are increasing rapidly. Biotechnology is a fast-growing and research-intensive technology that poses a great threat to traditional pharmaceutical products. Figure 2.9 shows the percent of total projects that are biotechnology related. With the advent of biotechnology, smaller companies are now able to develop drugs that rival (or even surpass) those of the established pharmaceutical companies. This has increased the threat of new entrants.

2.7 What is an appropriate response?

It is clear that the pharmaceutical industry is in a state of transition. What is not so clear is how the brand name pharmaceutical, generic and biotechnology companies are going to respond to this increasingly hostile environment. Typical responses over the last 2-3 years has been to decrease marketing and manufacturing costs, increase R&D productivity and form alliances both vertically along the value chain and horizontally between companies with complimentary products or competencies (Porter, 1985).

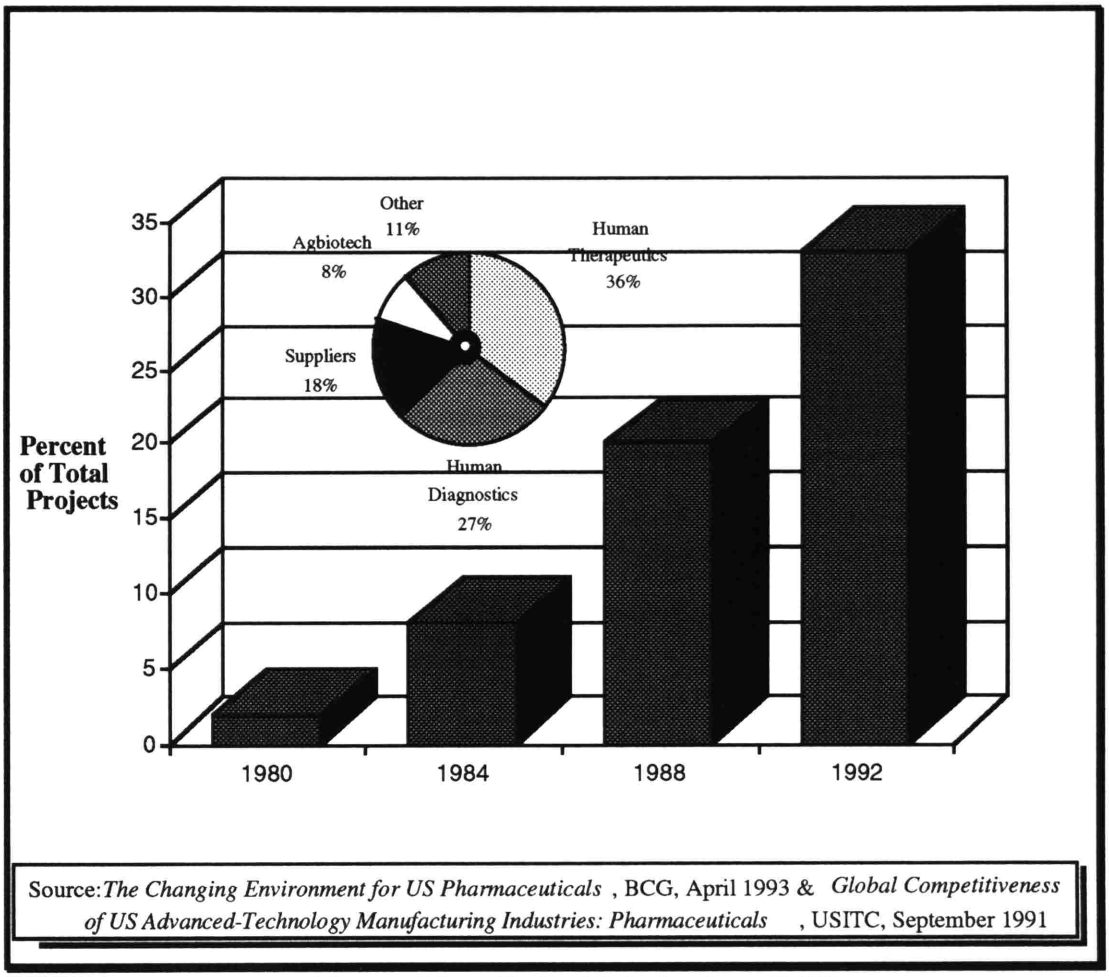


Figure 2.9: U. S. Biotechnology R&D

This thesis will focus on understanding the role that manufacturing may be able to play to help pharmaceutical companies compete in this more difficult environment.

Chapter 3

Project Goals

3.1 Pharmaceutical Manufacturing Benchmarking Project:

The research described in this thesis is part of a larger study being conducted at MIT under the auspices of the MIT Program on the pharmaceutical industry. The MIT Program on the Pharmaceutical industry is a large interdisciplinary and on-going industry study at MIT that attempts to understand the key determinants of competitiveness within the global pharmaceutical industry. Some of the projects that are currently underway within the program are investigating issues of R&D productivity, project management, cost of capital, manufacturing and drug pricing.

This project describes work that was done as part of the focus on pharmaceutical manufacturing. The purpose of this project was to understand the role of manufacturing in determining competitiveness within the pharmaceutical industry and to become a catalyst in improving the performance of pharmaceutical manufacturing. An important prerequisite to being able to do so is to develop a means to measure pharmaceutical manufacturing performance. "Benchmarking" was determined to be a useful tool to do so and led to the initiation of the Pharmaceutical Manufacturing Benchmarking Project.

The pharmaceutical manufacturing benchmarking project is a large on-going and multi-year study that attempts to provide answers to the following questions:

- How important is manufacturing in the pharmaceutical industry?
- How can manufacturing performance be measured?
- How well do pharmaceutical companies do at manufacturing?

- How do pharmaceutical companies compare with other industries?
- How do pharmaceutical plants compare when compared across
    - different sectors of the industry
    - different countries/geographical area
    - different technologies
- How much better can pharmaceutical companies be at manufacturing?
- How much money can be gained from continuing improvement in operations?
- How good are the best pharmaceutical plants at manufacturing?
- What are the important leverage points to focus on to maximize improvement?

These questions provide the basis for formulating a mission. The mission of the Pharmaceutical Manufacturing Benchmarking Project is to:

a. Elucidate the role of manufacturing in the pharmaceutical industry.

b. Develop a set of metrics that can be used to determine performance.

c. Develop a framework that allows companies to compare performance across plants/processes.

d. Compare performance at the plant/process level.

e. Quantify the opportunity for improvement by establishing best practices.

f. Provide a means for companies to continuously improve their performance.

3.2 Thesis Project Goals:

This thesis project combines work I have done over the years as part of my Ph.D. research in the department of chemical engineering and the research I was involved in as the project coordinator of the MIT Pharmaceutical Manufacturing Benchmarking Project.

My specific goals in this project were to:

- Characterize the current state of pharmaceutical industry.
- Elucidate the strategic role of manufacturing within the industry.
- Develop a approach to structuring relationships between MIT and pharmaceutical companies involved in the benchmarking study.
- Test traditional functional metrics on companies.
- Develop a framework for benchmarking manufacturing performance.
- Develop a set of performance metrics for measuring pharmaceutical plant/process performance
- Test framework and metrics on companies.
- Describe and compare performance based on results obtained.

The central theme of this project were to structure an appropriate framework for the MIT Pharmaceutical Manufacturing Benchmarking Study that would promote organizational learning through the process of benchmarking pharmaceutical manufacturing.

Chapter 4

Structuring organizational learning through "benchmarking"

4.1 "Benchmarking"

4.1.1 Definition

Over the years, there have been many definitions of benchmarking. The Figure 4.1 shown below summarizes a compilation of these definitions done by Michael Spendolini (Spendolini, 1992). Any of the definitions from this palette is a reasonably good summary of the idea of benchmarking.

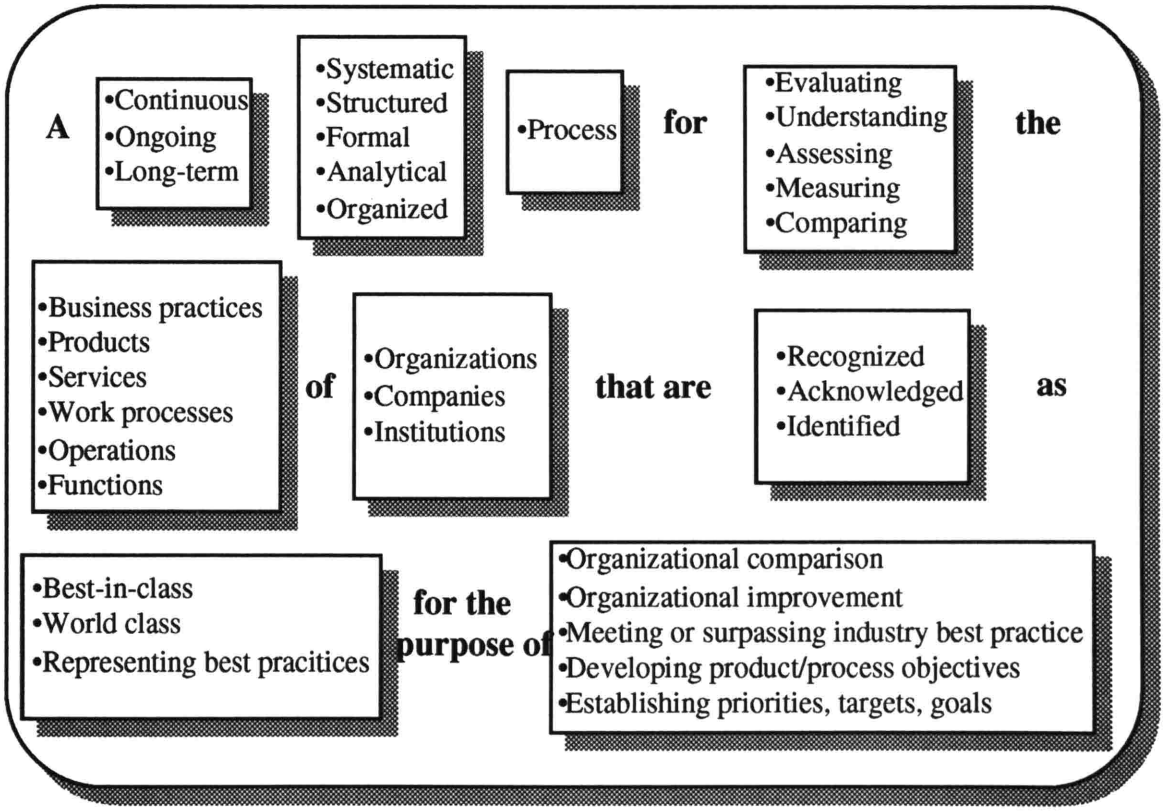


Figure 4.1: Palette of definitions for "benchmarking"

It is important to understand that there are four key attributes to benchmarking. The first is that it is never over. Benchmarking is an continuous and on-going process. The

second is that it is a structured means to assess the business practices. The third is that it usually implies a comparison for the purpose of improvement. And finally, benchmarking often involves some notion of "best practice".

4.1.2 When, Why, Whom, What, Where and How?

Any benchmarking study involves choices to be made regarding the when, why, whom, what, where and how of benchmarking (McNair et al., 1992).

- **When to benchmark?**

Benchmarking can be performed at any time. However, it is most effective when the company feels the need for it. This need can be quite specific and be triggered by some crisis or initiative within the company. This need can also be quite general and have to do with the company's desire to improve itself in a proactive manner.

- **Why benchmark?**

A company should benchmark because it wants to improve its performance. It is important that benchmarking be viewed as a tool for improvement rather than a tool to assign blame to certain people or certain parts of the organization.

- **Whom to benchmark?**

Benchmarking can be done at different levels. As shown in Table 4.1 a company can practice internal, competitive, industry or "best-in-class" benchmarking. Each of these has its own set of advantages or disadvantages.

- **What to benchmark?**

There is a need to determine whether the benchmarking with focus on specific processes, activities, or functions. It is also important to decide on the depth of the

Table 4.1: Types of benchmarking

Type	Description	Advantages	Disadvantages
Internal	Analysis of practices within various division/plants in same organization	• Data are often easy to collect • Data are easier to interpret	• Limited focus • Internal bias
Competitive	Looks outward to identify how other direct competitors are performing	• Identifies strengths & weaknesses of competition • Helps to level the playing field • Information is very relevant	• Data collection difficulties • Ethical issues • Antagonistic attitudes
Industry	Extends to all other companies within the same industry.	• Relevant information • Allows for identification of trends	• Seldom leads to performance leaps or breakthroughs
"Best-in-class"	Look across multiple industries in search of "best-practices" independant of source.	• Supports quantum leaps in performance. • Stimulating results	• Time consuming • Difficulty transferring practices into different environment.

analysis to be performed. Benchmarking can focus on specific departments or functions (vertical benchmarking) or they can focus on a specific process or activity (horizontal benchmarking).

- **Where to get benchmarking information?**

Benchmarking typically builds on existing sources of information. An initial focus is to be able to use any published or already publicly available information. This involved accessing previous benchmarking studies, annual reports of companies and use of public data bases. Benchmarking also typically involves getting confidential information from within the companies and requires their cooperation.

- **How to benchmark?**

There are many ways to do benchmarking. The process of benchmarking was broken down into 3 stages: *Measurement*, *Analysis* and *Change*.

Measurement: This first stage identifying the scope of the benchmarking study, identifying appropriate drivers and performance drivers and identifying the organizations to benchmark.

Analysis: Analysis involves actual interviewing, developing a questionnaire, gathering information from companies, analyzing the data and reporting the results. This is then followed by an analysis of the data that is obtained.

Change: Actually implementing change involves communicating results, establishing goals and developing action plans and monitoring progress.

Clearly, this is an on-going process as change is followed by another round of measurement, analysis and change and so on. Benchmarking is an on-going process.

4.1.3 Benefits of benchmarking

As described in Table 4.2, benchmarking provides a company with a number of

Table 4.2: Benefits of benchmarking

Rigor	• Making sure targets are set high enough.
Overcoming disbelief	• Convincing ourselves that we can do better.
Accountability	• An ongoing process for measuring performance and ensuring improvement.
Culture change	• An outward looking company rather than one that is internally focused.

important benefits. The primary benefits are the rigor that is associated with benchmarking, a means to overcome disbelief about being able to do better, a means to provide accountability and a culture change to an outward looking company.

Benchmarking provides a means to knowing thyself. Each company can use benchmarking as a means to understanding its own strengths and weaknesses. A clear

understanding of oneself and an appropriate target desired state are the critical prerequisites for organizational change.

4.2 Performance metrics

A primary step in benchmarking is to develop a set of performance metrics. The goal was to choose metrics that appropriately captured both the current state and provided a means to set a target or goal state. *A critical requirement for success is that the firm needs to know where it wants to go and have a means to measure its progress towards that goal.* Only with defined goals and metrics of performance can one propose a path towards success and measure progress towards that goal. But what were these performance metrics? Which ones are most relevant? There were no clear answers to these questions either within pharmaceutical organizations or within academia. Hence our first task was to define what the desired characteristics of these new performance measures would and then identify the major classes of such performance measures.

4.2.1 Desired characteristics in performance metrics

- **Must be directly related to manufacturing strategy**

An important attribute of a performance measure is that it must be related to the operations or manufacturing strategy (Maskell, 1991). Performance measures must provide a means to know well an organization is achieving the goals laid out in its strategy. This is particularly important because people concentrate on whatever is measured. The manufacturing strategy, in turn, must be congruent with the overall corporate or business strategy.

There are six key elements around which a manufacturing strategy can be built. They are quality, cost, delivery reliability, lead time, flexibility, and employee relationships

(Maskell, 1991). The amount of emphasis on each of these areas defines the manufacturing strategy.

- **Are simple and easy to use**

It is important a performance measure is simple and easy to use. Otherwise it will simply not be used.

- **Provide fast feedback to operators and managers**

A performance metric must be a means to provide fast feedback to operators and managers. The faster the feedback the stronger the impact on performance.

- **Intended to foster improvement rather than just monitor**

A performance metric must be used to foster improvement in a positive way rather than be a means to monitor or control. Otherwise the metric will not serve its purpose in the long run.

- **Primarily non financial in nature**

While financial measures are important to be able to measure performance on a common basis of money, they do not provide an easy way for shop floor level focus on operational improvements. Hence we argue, that most performance metrics should be non-financial in nature.

- **Vary between locations**

The relevance of a particular performance measure varies between locations. A performance measure that is relevant in one plant may not be as relevant in another plant.

- **Change over time as needs change**

The relevance of a particular performance measure also varies over time. The importance of a particular performance measure changes as needs change.

4.2.2 Major classes of performance measures:

Similar to manufacturing strategy, there are six key components of manufacturing performance. They are quality, cost, delivery reliability, lead time, flexibility, and employee relationships (Maskell, 1991).

4.2.2.1 Quality:

Table 4.3 depicts the important issues that related to quality that need to be measured and relevant component of these issues. While measuring quality performance within a manufacturing organization it is important to understand the definition of quality, the vendor quality performance, the production quality performance, the accuracy of data, the amount of preventative maintenance and the cost of quality (PMA Measuring Quality Performance Committee, 94).

Table 4.3: Important issues to consider relating to quality metrics

ISSUES	Important components to address
Definition of Quality	• Form, fit, function, reliability, consistency
Vendor Quality Performance	• Delivery performance and quality performance • Number of vendors • Concerned about value added vs. non-value added activities • Inspection is non value added • Vendor certification vendor's use of SPC • Measuring incoming quality
Production Quality	• Need methods to measure variances SPC • SPC and Continuous improvement • Percentage of repeat sales • Works first time • Time between service calls
Data Accuracy	• Inventory Accuracy Simplified counting • Bill of Materials and Routing Accuracy • Forecast accuracy
Preventative Maintenance	• Reactive vs. Proactive
Cost of Quality	• External, internal, prevention and appraisal costs.

4.2.2.2 Cost:

Table 4.4 depicts the important issues to consider relating to cost metrics.

Table 4.4: Important issues to consider relating to cost metrics

ISSUES	Important components to address
Waste Rate	• The seven wastes - waste of overproduction, waiting, transportation, processing, stocks, motion, making defective products
Inventory turns	• WIP turns • Turns by product, turns by plant • Valuation of cost of goods sold
Value-added analysis	• Value added analysis is related to cycle time • Direct Labor Productivity • Valuing production completions
Cost Productivity	• Cost productivity per unit • Cost of adding value per unit • Cost/output ratio
Overhead efficiency	• Output per unit of overhead
System Complexity	• Transaction per lot • Pages per lot

Important ideas to consider while designing cost metrics are waste rates, inventory turns, value-added analysis, cost productivity, overhead efficiency and system complexity.

4.2.2.3 Delivery reliability:

Table 4.5 depicts the important issues to consider relating to delivery reliability

Table 4.5 : Important issues to consider regarding delivery reliability metrics

ISSUES	Important components to address
Vendor delivery performance	• Certification • Days late: on time vs. late vs early. • Variance • Unpack and put-away
Schedule Adherence	• Is one aspect of quality in production process • Quality implies reduction of variability in product & process • Do operators establish schedules • Product Completions schedule vs completed • Cell completiions schedule vs. completed • Past due products
Order & Schedule changes	• How often is the order or schedule changed
Customer service level	• Delivery performance and quality • FG inventory levels? • Service level • Delivery reliability • Receipt vs dispatch • No. of past due orders
Lost sales	• What is the lost sales due to poor delivery reliability?

metrics. Important ideas to consider while designing delivery reliability metrics are vendor delivery performance, schedule adherence, order & schedule changes, customer service levels and lost sales.

4.2.2.4 Lead time:

Table 4.6 depicts the important issues to consider regarding lead time metrics. It is important to understand that many problems are caused or are related to long cycle times. High cycle times lead to high work-in-process inventory and often require that plants make-to-stock rather than make-to-order. This also make it very difficult to make changes during the process and leads to added complexity in the system and is often associated with uneven loading of work centers. Long lead times make a manufacturing plant inflexible to change. Hence, it is useful for manufacturing plants to focus in shortening cycle times. Reduced lot sizes and synchronized production planning and control lead to reductions in lead times. As shown in Table 4.6, the important issues to address when designing lead time related metrics are the means of measuring cycle time, the D:P ratio, the set-up times, the material availability, the distance of material movement, the machine up time and the customer service time. It is important to understand the

Table 4.6: Important issues to consider regarding lead time metrics

ISSUES	Important components to address
Measuring cycle time	• Detailed recording of cycle times • Analysis of engineering routing
D:P ratio	• Delivery time to production lead time ratio.
Set up times	• Leads to shorter run, smaller lots sizes, less WIP
Material Availability	• How often is production held up for lack of material?
Distance of Material Movement	• How far does material travel?
Machine up time	• Machine utilization levels
Customer Service time	• Easiest measure of overall efficiency of production process

difference between the production lead time and the delivery lead time. Production lead time is the critical path time for purchase and production of material to product. Delivery lead time is the lead time offered to customers

4.2.2.5 Flexibility:

One of the important attributes of a successful manufacturing plant is flexibility. There are different kinds of flexibility. Flexibility can be with respect to changes in production mix, changes in production volumes or an ability to quickly introduce new products. As shown in Table 4.7, the important issues to consider regarding flexibility

Table 4.7: Important issues to consider regarding flexibility metrics

ISSUE	Important components to address
Number of different parts	• The more parts, the greater the complexity of production
Commonality	• Percentage of standard, common and unique parts
Number of different processes	• The more the processes the lower the flexibility
Position of differentiation	• Last minute differentiation • Product enrichment • Measuring the position of differentiation • Number of Levels in the Bills of Materials
New Product Introductions	• Speed of introduction ("time to market") with minor, moderate and major enhancement • Number of new product introduced over a time period
Cross-training	• Cross-trained workers are more flexible
Output compared to capacity	• To be flexible, need more capacity than demand.

metrics are the number of parts or materials, the commonality among them, the number of different processes involved, the position of differentiation, the number of new product introductions, the degree of cross training and the amount of space capacity.

4.2.2.6 Employee relationships:

Another important aspects of designing performance measures is the ability to measure employee relationships. While they are exceedingly important, they are often difficult to measure. Here we are trying to measure the morale, teamwork and involvement

of people, leadership in working environment issues and environment and safety. Some typical measures attempt to capture quality circle involvement, number of suggestions per employee, number of suggestions put into practice, amount of training/education time per employee and the number of skills per person.

Of course, it is important to note that different metrics are important to different companies. This is often related to the difference in their strategies and their critical success factors. Hence, it is more likely that there will be families of different metrics that correspond to certain strategies. These families are likely to focus on the core operational processes in the organization and are likely to cut across functional departments. Benchmarking must begin at the highest organizational level in order to understand the drivers for success, e.g. cost, quality, performance, etc. for each company or situation. For example when comparing multisource vs. brand name pharmaceutical firms, they have different critical success factors and different core competencies; thus, there are different drivers to their performance.

4.3 Organizational learning through "benchmarking"

In our view benchmarking is simply a means for structuring organizational learning. It is not a solution. Rather, it is a process. Benchmarking provides a framework for organizational learning by leading the company to focus on measuring performance and measuring it against prior performance within the plant and outside the plant in a manner that allows the organization to constantly ask itself if it can do better.

It is important to understand that benchmarking is not the same as surveying or business intelligence. The aim of benchmarking is to locate organizations that do something exceptionally well and then to develop a data-sharing relationship with them for the purpose of mutual learning. Benchmarking tries to close the gap between one

organization and the rest of the field. It assumes that having data on how the best organizations perform will be useful in increasing the internal rate of improvement.

Chapter 5

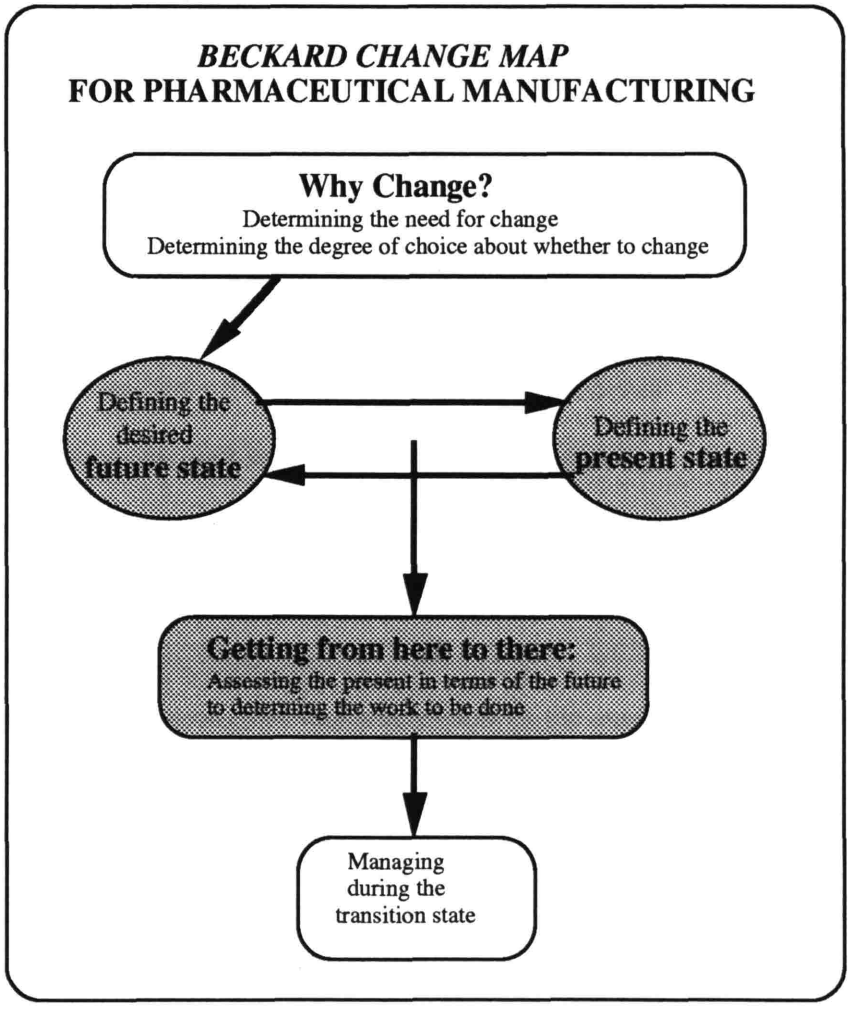
Structuring learning through "lead benchmarking partnerships"

5.1 "Benchmarking" as a basis for organizational change:

Any sustainable organizational change must involve changing the way organizations think. But how can this change be catalyzed? What are the requirements for change?

Figure 5.1 below depicts the different steps involved in catalyzing change within

Figure 5.1: Beckard Change Map for Pharmaceutical Manufacturing



the pharmaceutical manufacturing organization. As shown in the figure, the first step is to determine the need to change and the degree of choice about whether to change. The next step is to define the present state and the future desired state. There needs to be a means to measure both the mental models and the performance of manufacturing presents and also be able to characterize a desired future goal state. Once these states are defined, then the present state needs to be assessed relative to the desired state and the means determined to move from the present state to the desired state (Beckard et al., 1987).

Doing this however, requires that there are means to capture the mindset of people within pharmaceutical organizations and means to measure both present and desired performance. That, in turn, requires understanding the critical components of pharmaceutical manufacturing performance. Setting desired performance goals requires understanding the ideal state and characterizing the best achievable state. Benchmarking provides a means to capture these states thereby providing a means for organization learning and change.

5.2 Learning is an iterative and collaborative process

In our opinion, the first step towards promoting learning and organizational change is to be open to change ourselves. Clearly, we do not have all the answers. Moreover, these answers could not be determined in isolation. Rather than work in isolation within a university setting our strategy was to work closely with different pharmaceutical organizations. In our opinion, that was where most of the answers were.

While the goal of this study is to eventually involve most of the pharmaceutical companies throughout the world our first step was to test our ideas and learn from a small number of representative companies. At this stage our goal was to work with companies

that we expected would provide us with a sample of the variability in performance and organizational mindset that we might expect to see from the larger world sample. Hence, we chose to work with companies representing the different major sectors of the pharmaceutical industry. Our strategy was to be able to sample the brand name pharmaceutical, generic/multisource and biotechnology segments of the pharmaceutical industry. This is shown below in figure 5.2. Within each industry segment we chose to work with two companies with representative manufacturing plants.

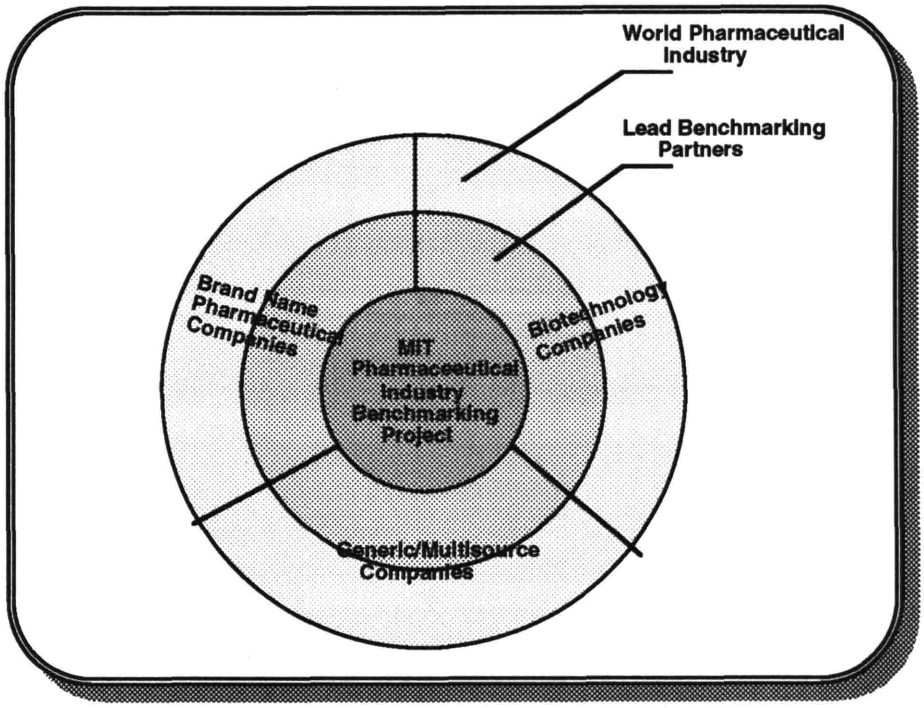


Figure 5.2: Structuring the learning through lead benchmarking partnerships

Need to define metrics and refine them. Need to understand current thinking within the pharmaceutical industry. Need to develop relationships.

5.3 Benchmarking Approach

Figure 5.3 shows the benchmarking approach that we followed during our interactions with the lead benchmarking companies. The first steps that was followed in

any benchmarking trip was to identify the critical success factors of the manufacturing organization. The qualitative one-on-one interviews provides this insight. An immediate next step was to define the business processes that needed to be benchmarked. Most pharmaceutical manufacturing organizations have functional organizations for production, materials management, quality assurance and quality control, technical services and human resource management. Each of these functions involved a set of business processes that could be benchmarked. The next step was to identify the appropriate performance indicators.

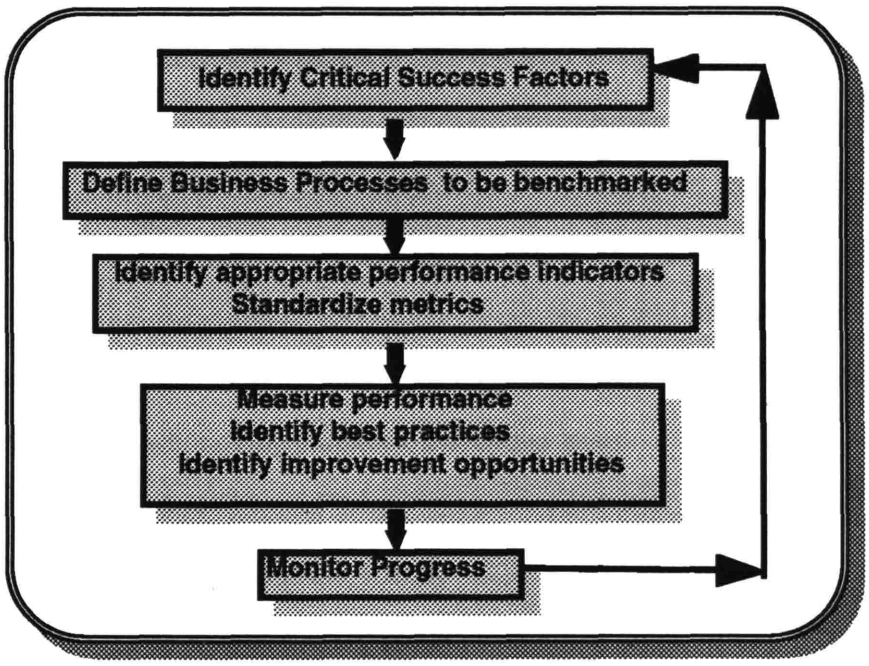


Figure 5.3: Benchmarking Approach

These performance indicators when standardized, then formed a basis to measure performance, identify best practices and improvement opportunities. The most important part of this benchmarking approach was to understand that it should be a continuous on-going process of monitoring progress and then going through another iteration of benchmarking.

An important goal of the benchmarking study was to determine the appropriate core processes to benchmark. Organizations vary significantly in their organizational structure, the products they make, the technologies they employ, the sophistication of their accounting systems and often the terminology they use to describe the similar concepts. Any benchmarking study must provide a means to control for such variability. Only then can comparisons be made across different companies and plants.

The purpose of a lead benchmarking firm is to provides us with a means to test out this benchmarking strategy on a smaller set of representative firms. It was important to understand what role a university program like the MIT Program on the Pharmaceutical Industry can play in measuring, designing and catalyzing change within the pharmaceutical manufacturing organization. The MIT project has been designed to be restricted to the measurement and analysis mode rather than being involved in the detailed implementation of the conclusions that come out of the study. However, it was important to understand that would be a long-term on-going study and that results would continuously be made available to the lead benchmarking partners on a regular basis.

5.3 MIT Benchmarking project: when, why, whom, what, where and how?

The next step was to decide on answers to the when, why, whom, what, where and how questions of benchmarking pharmaceutical manufacturing.

- **When?**

Most of the MIT benchmarking trips were when companies themselves believed that there was a need to understand the role of manufacturing. Benchmarking is a time consuming process. Hence, the first step in determining when a company got involved in the project was when it was clear that there was top management commitment to the project. It was also important to identify a primary client within the organization who

would be available to play a coordination role between the company and MIT. The MIT benchmarking team typically then made a whole day trip to the plant site.

- **Why?**

The focus of the study was to understand the strategic role of manufacturing and promote organizational learning by benchmarking pharmaceutical manufacturing efficiency and effectiveness.

- **Whom?**

Our goal was to initially focus our efforts at benchmarking within the pharmaceutical industry. The study would then be expanded to other industries. Once we determined the number of plants that we wanted to work with, the next step was to choose among the large number of plants within each sector. Since we expected that this would require continuous ongoing interaction an important criteria was easy access to the plant and its personnel. Hence only plants within the U.S. were chosen to be lead benchmarking partners in this stage of the study. The study will be extended to other regions of the world in the near future.

- **What?**

Our initial goal was to confine our study to departmental or functional performance. The next goal of the benchmarking process involved benchmarking the core manufacturing sub processes and required a cross-functional focus on the value chain and an understanding of the linking of activities across the organization to meet customer expectations in the most efficient and effective manner possible.

- **Where to get information?**

Once within the company, most of our benchmarking information was obtained from a set of qualitative interviews, a quantitative questionnaire, informal discussions, telephone conversations, a detailed plant and facilities tour and other information provided by the company. A confidentiality agreement was signed with all such companies.

- **How?**

The initial trip typically involved describing the goals and the scope of the project. At this time the company's interest in becoming a lead benchmarking partner was determined and discussed together with the costs and benefits of the relationship.

The presentation was typically followed up with a detailed plant tour where the benchmarking team developed an understanding of the primary process flow within the plant and got a subjective feel for the work environment. The plant tour was typically followed up with detailed qualitative interviews with different functional heads within the manufacturing organization. This process was usually one on one and was meant to capture the mindset of the different individuals towards manufacturing performance and its role in the company. At this stage, a quantitative performance metrics questionnaire is explained and left with the company to fill out. A period of three weeks was typically allocated for companies to fill out this questionnaire and send it back to MIT. We anticipated that the time commitment will initially involve on the order of ten person days from the partner firm. This includes discussion time and interviews as well as time to access information associated with batch records, human resources, financial, results and manufacturing facilities.

Given the sensitive nature of this project, confidentiality was a critical issue. A confidentiality agreement was always signed between the MIT project team and the lead benchmarking partner to protect the firms property rights. In addition, when the data is

used to provide feedback to the companies, they will be sufficiently normalized and aggregated such that a set of results could not be associated with any particular firm. Each firm, however, would recognize their own results and would be able to compare with other company's data. In addition, future publications of methodologies and results would be independent of the individual firm's identity.

Chapter 6

Pharmaceutical Manufacturing: understanding its strategic role

6.1 Characterizing mental models

Any organizational change must involve changing the mind of the organization. Hence any benchmarking project that aims at improving pharmaceutical manufacturing must be able to capture the both the present mindsets and be able to characterize ideal or desired mindsets. Hence, the qualitative one-on-one interviews. The goal during these interviews is to able to capture the mental models of various individuals within the manufacturing organization. These mental models were to be used to understand the present state of thinking within the pharmaceutical organization regarding manufacturing.

Our strategy during these interviews was to pursue a dialog mode of inquiry (Schein, 1988). The interviews were designed to be very open ended and unstructured. The purpose in doing so was to provide an environment to capture the structure of the mental models of the individuals within the organization rather than to reinforce our own mental model structures. Our goal was to be open to completely new thinking and opinions.

It is important to understand that a benchmarking study that aims to measure performance can be viewed as being quite threatening by individuals within the organization and can lead to a defensive attitude. By keeping the interviews open-ended and unstructured our goal was to ensure that we captured the actual thinking of the different individuals rather than their interpretation of what they thought we wanted to hear.

6.2 Pharmaceutical Manufacturing: assessing the old perceptions

The pharmaceutical industry traditionally has pointed to R&D (also marketing sometimes) as being the primary driver of success. The strategy for success has been to increase R&D expenditures and improve R&D productivity. Manufacturing, on the other hand, was relegated to a significantly less important role.

First, the conventional view has been that the manufacturing cost was such a small fraction of revenues that it was not important. Hence, it represented a low leverage point to improve performance of the pharmaceutical organization. Second, it was not clear if it was even possible to improve manufacturing performance even if a company wanted to. The perception within the industry was that most manufacturing decisions were already locked in by the regulatory requirements of agencies like the Food and Drug Administration (FDA).

Hence, the approach to pharmaceutical manufacturing to simply make sure it was "out of the way" and off the critical path. "Just don't screw up" was the attitude towards pharmaceutical manufacturing. Clearly, most organizations, had a "defensive strategy" towards manufacturing. This organizational mindset towards manufacturing determined the strategic choices that the organization made regarding manufacturing.

Table 6.1 shows the major types of manufacturing choices as defined by Wheelright and Hayes (Wheelright et al., 1985). Most pharmaceutical companies followed a conservative or defensive strategy when marking both hardware (i.e. structural) and software (i.e. infrastructural) choices.

Qualitative interviews provided a basis for understand manufacturing choices made by the pharmaceutical organization. Pharmaceutical companies typically built a number of

different facilities in different locations. These plants typically had significant excess capacity. Given the conservative defensive strategy, new technology was typically viewed with skepticism. Hence, most equipment and process technology was typically quite old and manual. Batch processing was the typical mode of operation. Most pharmaceutical manufacturing plants were also highly vertically integrated.

MAJOR TYPES OF MANUFACTURING CHOICES

STRUCTURAL	• **Capacity**	Amount Timing Type
	• **Facilities**	Size Location Specialization
	• **Equipment/process technology**	Scale Flexibility Interconnectedness
	• **Vertical Integration**	Direction Extent Balance
INFRASTRUCTURAL	• **Vendors**	Number Structure Relationship
	• **New Products**	Hands off Start-up Modification
	• **Human Resources**	Selection and training Compensation Security
	• **Quality**	Definition Role Responsibility
	• **Systems**	Organization Schedules Control

Table 6.1: Major types of structural and infrastructural manufacturing choices

The infrastructural choices made by the manufacturing function were similarly defensive (also called conservative). The manufacturing organization reflected the mindset of the rest of the organization. Manufacturing choices towards vendors, new products, human resources, quality and systems were highly conservative. Vendors were typically kept at arms length for fear of losing proprietary technology and trade secrets. Similarly, the introduction of new products was limited and designed to be separated from the routine

manufacturing. Human resources choices at the higher level were typically influenced significantly by educational backgrounds. Turnover was low. The definition of quality was in terms of conformance rather than performance. Quality was overwhelmingly defined in terms of conformance to FDA specifications. Process quality was defined as doing the same thing we did before while product quality was defined as producing the same product that was produced before (and approved by the FDA). The systems were usually driven by the quality assurance function whose primary goal was to ensure that the products that left the plant was in compliance with the regulatory requirements.

It seems that most pharmaceutical companies traditionally have had a defensive strategy towards manufacturing. Manufacturing was either isolated from most corporate strategy decisions or was often reactive to strategies developed for R&D and marketing.

6.2 Pharmaceutical Manufacturing: its new strategic role

It seems clear, that traditional pharmaceutical manufacturing has been viewed as being reactive to decisions made in other parts of the pharmaceutical organization. Table 6.2 shows the stages in manufacturing strategic role as described by Wheelwright and Hayes (Wheelwright et. al, 1985). In this framework, traditionally pharmaceutical manufacturing can be viewed as being mostly in Stage 1.

There seems to be significant potential for pharmaceutical manufacturing to move up from Stage 1 to Stages 2, 3 or 4. However, the first step in doing so is to change the established mental models towards pharmaceutical manufacturing.

A important step in doing so is to understand that manufacturing or operations strategy can and should support the business or corporate strategy (Moody, 1990). Competitiveness in the pharmaceutical industry, is based on maintenance of a product

STAGES IN MANUFACTURING'S STRATEGIC ROLE

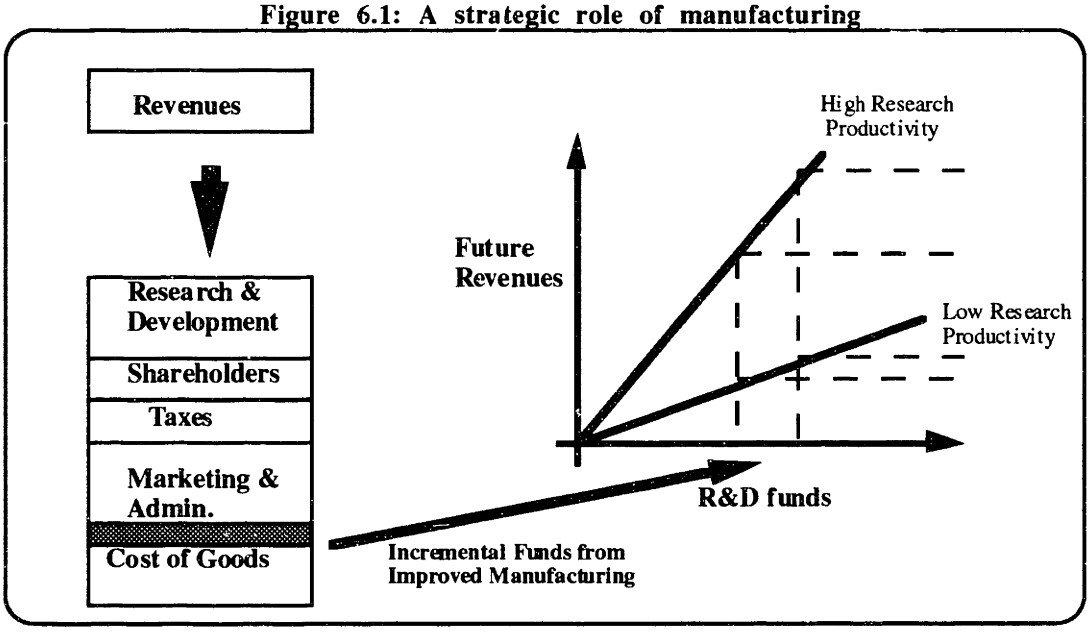
STAGE 1	**Minimize manufacturing's negative potential: "internally neutral"**	Outside experts are called in to make decisions about strategic manufacturig issues. Internal, detailed management control systems are the primary means for monitoring manufacturing performance. Manufacturing is kept flexible and reactive
STAGE 2	**Achieve parity with competitors: "externally neutral"**	"industry practice" is followed. The planning horizon for manufacturing investment decisions is extended to incorporate a single-business cycle. Capital investment is the primary means for catching up with competition or achieving a competitive edge.
STAGE 3	**Provide credible support to the business strategy: "internally supportive"**	Manufacturing investments are screened for consistency with the business strategy. A manufacturing strategy is formulated and pursued. Longer-term manufacturing developments and trends are addressed systematically.
STAGE 4	**Pursue a manufacturing-based competitive advantage: "externally supportive"**	Efforts are made to anticipate the potential of new manufacturing practices and technologies. Manufacturing is involved "up front" in major marketing and engineering decisions (and vice versa). Long-range programs are pursued in order to acquire capabilities in advance of needs.

Table 6.2: Stages in Manufacturing's Strategic Role

pipeline that will ensure future revenues to reward investors and continue to finance the process of new drug discovery. The traditional industry has financed its own growth through profits while the newer entrants, utilizing the discoveries of biotechnology, have relied on public and private equity financing. Hence, any factor with impact on financing research will directly impact the competitiveness of the firms in the industry. Manufacturing has a key role in being able to do so (Plossl, 1991). As shown in figure 6.1, research can be financed either by increasing revenues or decreasing costs. Given the

intense price pressure and consolidation of buyer power, increased revenues have become an increasingly difficult source of addition capital for R&D. Hence, increasingly, pharmaceutical companies are looking towards reducing their costs and increasing their R&D productivity as a means to maintaining reasonable shareholder returns. Marketing and manufacturing are two areas that are being targeted for cost reduction.

Figure 6.1: A strategic role of manufacturing



It is in this light that manufacturing takes on an increasingly important strategic role for the industry. With the cost of goods sold (COGS) on average at 20-25% of revenues and R&D at 12-15%, a 15% reduction in manufacturing cost can provide a 25% increase in R&D funding. This increased R&D funding, in turn, leads to a stream of future revenues. Clearly, even with revenue constraints, there is an opportunity for firms to improve their long term competitiveness through manufacturing excellence. This is true whether the pharmaceutical company has a high or a low research productivity.

However, manufacturing has a significantly larger role to play (Suzaki, 1987). Manufacturing should be viewed a source of competitive advantage. Profit is revenues minus costs. While improving manufacturing can reduce costs and thereby increase

profits, manufacturing should be used to enhance profits by increasing revenues (Goldratt, 1992). Manufacturing should be a source of advantage in cost, quality and flexibility. Both quality and flexibility serve to enhance profitability by increasing revenues. This involving manufacturing up front in major R&D and marketing choices and vice versa.

Chapter 7

Learning by benchmarking functional areas within manufacturing

7.1 Benchmarking functional areas involved in manufacturing

One of our first steps was to benchmark the different functional areas involved in manufacturing. Most manufacturing organizations had different functional groups for production, finance, human resources, quality assurance and materials management. Hence we defined a set of metrics to measure the performance within each of these functional areas. Benchmarking functional areas within the manufacturing organization was a low cost-low benefit strategy and allowed us to work within the existing organizational structure and accounting systems of the different companies while providing us with an opportunity to gauge opportunities for improving manufacturing effectiveness and efficiencies.

7.2 Functional benchmarking questionnaire

Table 7.1 depicts the metrics used to measure performance within each functional area. As can be seen this first generation questionnaire contained approximately 75 different. The detailed functional questionnaire is in Appendix A. These metrics were tested in 10 different plant representing generating approximately 15 sets of data (some plants were measured on a multi-year basis). Some of the results are described in section 6.4. Typically the questionnaire became the responsibility of one person within the firm who distributed the questionnaire so that it could be filled out by the individual functional

heads. In general, filling out this questionnaire took approximately 60 man hours of work and was done over a period of 1 to 3 months after the initial presentation to the company.

BENCHMARKING METRICS FOR FUNCTIONAL AREAS

PRODUCTION METRICS
Are prod'n operations on JIT
How many total products are produced
Number products use dedicated facilities
How many products produced year-round
Total number of lots manufactured
Lots mfr right 1sr time / Total lots mfr
Avg cycle time for products (wks)
Avg raw mat'l inventory (wks)
Avg time req'd for line turnover (hrs)
Avg number of inter-plant transfers
Discard rate for fermentation operations
Number new products introduced into mfg
Avg age of equipment used in mfg (yrs)
Average capacity utilization of facility
Average capacity utilization of manpower
Degree of automation (1-low, 5-high)
New product ramp-up time (wks)
Total number lots mfr for top 5 products
Number of years top 5 products produced

HUMAN RESOURCE MANAGEMENT METRICS
Total # of plant prod'n employees
Prod'n employees / Total # of employees
Maintenance employees / Prod'n employees
Prod'n employee turnover
Lost workday cases per 100 employees
Prod'n employee job absence rate
Percent employees involved in work teams
Avg weekly o.t. hrs for prod'n employees
Avg hrs of training / Total work hours

QUALITY ASSURANCE/OPERATIONS METRICS
Total complaints / Millions of units
Vendor lots aprv'd / Total lots rec'd
Avg QC release time for raw mat'ls (hrs)
Avg QC release time for F.G.'s (hrs)
Avg length of QC hold on F.G.'s (days)
Avg actual raw mat'l test time (hrs)
Avg actual finished good test time (hrs)

MATERIALS MANAGEMENT/HANDLING METRICS
Number dates missed / Total deliveries
Finished goods stock / Total Inventory
Work-in-process / Total inventory
Percent on-time del'vry from suppliers
Total number suppliers for top 5 mat'ls

FINANCIAL METRICS
Prod'n O-H cost / Total cost of F.G.'s
Maintenance exp's / Total cost of F.G.'s
Sales / Number of prod'n employees (mil)
Total value avg raw mat'l inv held (mil)
Total value of avg work-in-process (mil)
Total value of avg F.G.'s inv held (mil)
Typical inventory holding cost
Total cost F.G.'s / Total cost of G.B.
Plant value construction-purchase (mil)
Year plant operational or purchased
Discount rate used on plant value

OTHER MISCELLANEOUS METRICS
Number suggestions by prod'n employees
Number suggestions by maint employees
Total number of ideas implemented
Actual sales / Aggregate forecast req't
Personnel dedicated to process improve't
Significant process-plant modifications
Trigger for process-plant modifications
External (eg. FDA, EPA, Customer)
Internal (eg. Ideas, cont improvement, QC)

Table 7.1 : Benchmarking metrics used for different functional areas

7.3 Functional Benchmarking Results:

7.3.1 Human Resource Management

Table 7.2 shows 13 column of data involving 9 different plants. P1 to P4 represent active ingredient manufacturing plants. G0, G1 and G2 represent bulk formulation and packaging plants. B1 and B2 represent biotechnology plants. When measured by the number of plant production employees the biotechnology plants studied were significantly smaller. There is a significant variability in the ratio of production employees to total employees and the ratio of maintenance employees to production employees. There is significant variability in the production employee turnover. Both the ratio of maintenance to production employees and the production employee turnover are abnormally high in the case of the two biotechnology plants included in the table. The reasons for these high numbers are not clear but it is noteworthy that both the plants have a very small number of production employees. Hence the ratios could be skewed.

Table 7.2: Human Resource Management data

Measure	P1	P2	P3	P4	G0	G1-90	G1-91	G1-92	G2-90	G2-91	G2-92	B193	B293
Total # of plant prod'n employees	--	--	--	--	--	229	233	230	324	318	316	3.5	7
Prod'n employees / Total employees	42%	50%	73%	79%	61%	59%	57%	55%	82%	80%	80%		-
Maintenance/ Prod'n employees	--	--	--	--	--	12%	12%	12%	5%	5%	6%	29%	14%
Prod'n employee turnover	1%	1%	2%	3%	1%	3%	3%	4%	5%	2%	4%	29%	43%
Lost workday cases/100 employees	0.0	4.4	3.1	0.0	3.8	1.2	1.2	1.1	1.9	1.8	2.0	-	-
Prod'n employee job absence rate	3%	4%	4%	3%	6%	4.0%	3.2%	3.7%	2%	2%	2%	-	-
% employees involved in work teams	0%	0%	0%	0%	0%	48.0%	49.0%	55.0%	100%	100%	100%	100%	100%
Weekly o.t. hrs for prod'n employees	10.2	4.0	14.0	4.0	4.3	3.0	3.7	2.1	2	2	2.1	4	1
Avg hrs of training / Total work hrs	--	--	--	--	--	-	5%	6%	1%	1%	1%	5%	3%
# suggestions by prod'n employees	N/Tr	30	430	177	3	34	104	18	40	54	37	-	-
# suggestions by maint employees	--	--	--	--	--	21	68	12	3	1	5	-	-
Total number of ideas implemented	N/Tr	12	301	67	0	12	33	11	43	39	37	-	-

The number of lost workday case per 100 employees varies between 0 and 6%. Production employee absentee rate varies between 2 to 4%. Similarly, worker morale and involvement is captured by a number of metrics. The % of employees in work teams varies wildly. Due to the highly subjective nature of defining involvement in work teams we

suspect that it is more likely that the numbers in the table do not capture what was desired. Worker weekly overtime range from 1% to 10.2%. 1-5% of the total work hours are spent on training.

There is significant variability among the number of suggestions made by production and maintenance employees among the different plants. The biotechnology plants B1 and B2 do not have formal suggestion mechanisms. Plant G2 takes an active roles in the suggestion process and implements a large fraction of the ideas that are suggested by employees.

7.3.2 Financial

Table 7.3 shows 11 columns of financial data obtained from 7 different plants. Plants P1 to P5 depict active ingredient plants while plots G0,G1 and G2 depict bulk formulation and packaging plants. As can been seen plot G2 has the higher production overhead costs as a fraction of its finished goods costs. Plant G1, on the other hand, has the highest sales per employee.

Table 7.3: Financial data

Measure	P1	P2	P3	P4	P5	G1-90	G1-91	G1-92	G2-90	G2-91	G2-92
Prod'n O-H cost / Total cost of F.G.'s	29%	18%	34%	34%	13%	19%	23%	30%	46%	51%	52%
Maintenance exp's / Total cost of F.G.'s	4%	4%	8%	4%	5%	-	1%	42%	4.10%	3.90%	3.60%
Sales / Number of prod'n employees (mil $)	--	0.7	0.6	0.2	--	3.8	3.8	4.2	0.4	0.5	0.6
Total value avg raw mat'l inv held (mil S)	11.6	3.4	17.0	4.1	5.0	8.2	8.8	13.1	9.1	9.8	14.6
Total value of avg work-in-process (mil $)	28.6	30.1	43.3	16.2	3.8	7.7	8.5	9.4	1.2	1.3	1.8
Total value of avg F.G.'s inv held (mil $)	14.9	19.6	17.0	7.8	16.3	0.1	22.8	30.0	11.9	20.3	25.8
Typical inventory holding cost (%)	13%	13%	13%	13%	9%	9%	9%	9%	8.50%	6.30%	3.60%

The active ingredient manufacturing plants P1 to P4 have a significantly larger amount of money tied up in inventory. Most of this difference in inventory is in the value of the work-in-progress. Raw material, work-in-process and finished goods inventory all all going up for plants G1 and G2. Similarly the overhead costs are going up for both

plants G1 and G2. The inventory holding cost depicts the company's perception of how much it cost the company to hold inventory.

7.3.3 Production

Table 7.4 depicts 16 columns of data describing production data obtained from 10 different plants. P1 to P4 depict active ingredient manufacturing plants, G0, G1 and G2 depict bulk formulation and packaging plants and B1, B2 and B3 depict biotechnology plants.

It is clear from all the different plants visited that the plant personnel did not perceive themselves as pursuing a just-in-time manufacturing philosophy.

The data indicate generic bulk formulation and packaging plants deal with a larger number of products compared to the biotechnology and active ingredient plants (not shown). Also most bulk formulation and packaging plants do not have dedicated facilities as a result. That is they use the same facility to make different products. In fact while biotechnology plants make the same products year round, the bulk formulation plants do not make any of their many products year round. The bulk formulation plants make a significantly larger number of lots per year. There is significant variability in the number of lots that are manufactured right the first time.

The cycle time for products show significant variability. It is interesting to note that there are no clear difference in cycle times between active ingredient manufacture, bulk formulation and biotechnology plants. The raw material levels in terms of the number of weeks that they would take to be consumed (this number is useful because it scales the actual raw material level by the rate at which it is consumed) shows it to vary between 3

weeks to 17 weeks. There seems to be some correlation between the lots manufactured right the first time and the amount of raw material inventory.

There seems to be a clear difference in the time that it takes for line turnover. Bulk formulation plants have a quicker turnover time of between 4 to 80 weeks. Active ingredients plants, on the other hand have a significantly larger turnover time. Biotechnology plants on the other hand are often dedicated and hence for some there is no line turnover at all. Unlike bulk formulation plants, both active ingredient plants and biotechnology plants perform a larger number of inter-plant transfers. The reasons for this are unclear but bring issues regarding interplant transfers. Only plants P1 and P2 and the biotechnology plants involves bioprocesses/fermentations. The discard rates indicate variability in their performance. The larger discard rate of plant B3 is due to the use of animal cell culture.

Probably because of the need to do multiple setups and change between products the multi-product bulk formulation plants have lower capacity utilization levels when compared to brand name active ingredient manufacturing plants and the biotechnology plants. The biotechnology plant with their dedicated facilities had higher utilization levels. However, they seems to be less automated. This may be to the inherently larger variability in these bioprocesses which makes them difficult to automate. Bulk formulation plants manufactured significantly more lots than the biotechnology plants.

7.3.4 Quality Assurance/Operations

Table 7.5 shows 11 columns of quality assurance/operations data from 7 different plants. P1 to P4 are brand name active ingredient manufacturing plants while G0,G1 and G2 are bulk formulation and packaging plants. The number of complaints per million units

Table 7.4: Production data

Measure	P1	P2	P3	P4	G0	G1-90	G1-91	G1-92	G2-90	G2-91	G2-92	B193	B293	B391	B392	B393
Are prod'n operations on JIT?	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
# of products	--	--	--	--	--	48	46	44	222	226	221	2	4	3	4	2
Products with dedicated facilities	--	--	--	--	--	0	0	0	1	1	1	1	4	2	2	2
# products produced year-round	--	--	--	--	--	0	0	0	-	-	-	2	4	2	2	2
Total # of lots manufactured	--	--	--	--	--	1300	1329	1441	1440	1479	1411	44	134	20	34	25
Lots mfr right 1sr time / Total lots	76%	75%	81%	28%	80%	98%	75%	98%	52%	49%	43%	68.20%	99.3%	45%	50%	76%
Cycle time for products (wks)	19.8	9.3	21.0	29.0	15.8	17.0	16.3	16.3	23.0	23.0	23.0	34.0	12.0	22.0	22.0	26.0
Avg raw mat'l inventory (wks)	10.0	4.0	8.0	16.0	3.0	6.0	5.0	5.0	7.0	7.0	9.0	3.0	3.0	17.0	17.0	17.0
Time for line turnover (hrs)	292	184	234	236	80	15	15	15	4	4	4	-	4	N/AP	N/Ap	N/Ap
# of inter-plant transfers	2	3	3	2	0	0	0	0	0	0	0	2	4	3	3	3
Discard rate for fermentations	5%	2%	N/Ap	N/Ap	N/Ap	N/Ap	N/Ap	N/Ap	N/Ap	N/Ap	N/Ap	0	0	20%	10%	10%
# new products introduced	--	--	--	--	--	2	0	0	0	0	0	0	0	0	1	0
Age of equipment used (yrs)	9	8	9	7	7	7	7	8	6	7	8	4	6	5	6	7
Capacity utilization of facility	70%	85%	84%	89%	65%	70%	75%	80%	50%	62%	74%	100%	90%	85%	95%	90%
Capacity utilization of manpower	--	--	--	--	--	87%	92%	97%	10%	60%	60%	95%	95%	100%	100%	100%
Degree of automation (1-5)	3	4	4	4	4	3	4	4	4	4	4	2	2	2	2	3
New product ramp-up time (wks)	--	--	--	--	--	-	8	-	-	-	-	-	-	10	N/.Ap	N/Ap
Total # lots mfr - top 5 products	--	--	--	--	--	908	950	1030	40	55	54	250	325	20	34	25
# of yrs top 5 products produced	--	--	--	--	--	13	14	15	10	10	10	6	3	2	3	4

vary considerably. G0 is clearly the best plant along this dimension while plant G2 not only has the highest number of complaints but is actually getting worse over the 3 years sampled.

Table 7.5: Quality Assurance/Operations data

Measure	P1	P2	P3	P4	G0	G1-90	G1-91	G1-92	G2-90	G2-91	G2-92
Avg actual raw mat'l test time (hrs)	6	8	8	6	5	8	7.0	6.4	20	20	20
Avg QC release time for raw mat'ls (hrs)	350	72	336	168	108	520	477.0	434.0	672	672	672
Vendor lots aprv'd / Total lots rec'd	96%	98%	95%	98%	97%	N/Av	99.9%	99.6%	92.30%	97.50%	90%
Avg actual finished good test time (hrs)	10	14	15	8	12	13	11.4	10.4	-	-	4
Avg QC release time for F.G.'s (hrs)	410	480	504	120	355	190	170.0	156.0	120	120	120
Avg length of QC hold on F.G.'s (days)	90	20	21	24	5	18	18.0	15.0	-	-	6
Total complaints / Millions of units	52	24	28	15	5	22	22	14	56.7	79.5	89.7

A large fraction of the vendors lots that are received, are approved. Plant G1 has the best record while once again plant G2 has the worse record. Plant G2 also has the longest release time for its raw materials. Another particularly perturbing observation about G2 is that all its numbers are either constant or are becoming worse. This is in contrast with plant G1 which seems to be improving along most of the dimensions.

There is considerable difference in the time required to actually test raw materials or finished goods and the time for raw materials or finished goods release.

7.3.5 Materials Management

Table 7.6 depicts 11 columns of data obtained from 7 different pharmaceutical plants in the U.S. P1 to P4 describe brand name active ingredient manufacturing plants while G0, G1 and G2 represent bulk formulation and packaging plants over multiple years. The table shows that six metrics uses to capture the performance of the materials management function.

The percentage on-time delivery from suppliers are higher for the active ingredient manufacturing companies P1 to P4 when compared to the bulk formulation and packaging plants of G0, G1 and G2. This is possibly because most chemical manufacturing plants have fewer suppliers and have better relationships with them. Plant G2 has significantly lower on-delivery performance from its suppliers. However its performance has improvement over the three years sampled while the performance of plant G1 has deteriorated.

Table 7.6: Materials Management data

Measure	P1	P2	P3	P4	G0	G1-90	G1-91	G1-92	G2-90	G2-91	G2-92
Percent on-time del'vry from suppliers	95%	98%	96%	97%	91%	93%	92%	90%	83.70%	86.70%	92.40%
Total number suppliers for top 5 mat'ls	--	--	--	--	--	3.00	3	3	6	6	6
Raw material/Total inventory	21%	6%	22%	14%	20%	28%	26%	25%	48%	60%	68%
Work-in-process / Total inventory	52%	57%	56%	58%	15%	21%	20%	18%	7.60%	2.70%	2.20%
Finished goods stock / Total Inventory	27%	37%	22%	28%	65%	51%	54%	57%	44%	37%	30%
Number dates missed / Total deliveries	17%	3%	3%	2%	7%	2%	2%	2%	16%	13.20%	7.60%
Actual sales / Aggregate forecast req't	92%	101%	91%	99%	109%	-	-	-	91.80%	103%	96%

This lower on-delivery for bulk formulation plants correlates with them having to keep a larger fraction of their inventory as raw material inventory. However, bulk formulation plants also maintain higher fractions of inventory as finished goods inventory when compared to a active ingredient manufacturing plants. The number of due dates missed/total deliveries metric indicates that this varies between 2% to 17%. These higher fractions of inventory finished goods inventory, however, do result in higher customer service levels in the case of G1 but do not in the case of G2. Another clear characteristic is that active ingredient manufacturing plants have a significantly higher fraction of their inventory as work-in-process inventory. This could have many reasons including a larger number of processing steps, inherent complexity, larger batch sizes, larger cycle times or just poor inventory management. The actual sales/aggregate sales metric indicates that sales vary between 91% and 109% of the forecast.

7.4 Limitations of the functional approach to benchmarking

Clearly, this functional approach to benchmarking provided us with some valuable insights into pharmaceutical manufacturing. Some clear trends were highlighted and some important questions raised. However, using the different functional groups within pharmaceutical manufacturing as a basis for benchmarking is a low cost low benefit strategy. It is low cost because it works within the existing functional organization structure of the organization and looks at performance measures based on who performs a particular task. For example, the vendor lots approved is a quality assurance metric simply because QA actually approves or reject a lot. This information is easy to get because it is requested from the function that actually does the testing. However, this is of low benefit because it continues to drive the organization to think vertically in terms of its own functions. What we want the performance measures to do is to lead people to think horizontally in terms of the different functions together trying to satisfy a customer. It is more important to think in terms of what the customer wants and how value is created along the way than simply each function by itself. Hence, the performance measures and the benchmarking should focus on the activities that a manufacturing organization has to perform rather than who performs it.

Chapter 8

Learning by benchmarking core processes within manufacturing

8.1 A generic process flow diagram for pharmaceutical manufacturing

Pharmaceutical manufacturing involves many different methods to make different kinds of products. There are a wide range of technologies involved. Each manufacturing process can be very different and can have different starting and ending points. In addition, there is significant variability in the number of steps involved in manufacturing a pharmaceutical. In addition, many of these steps could be performed in different facilities within the same location, completely different locations within the same company or in completely different companies. This makes it difficult to be able to compare manufacturing processes.

Hence, one of our early goals was to formulate a generic but simplified process flow diagram for pharmaceutical manufacturing. The goal in doing so was to ensure that the process flow diagram was at a generic or high enough level that would allow each plant to identify with it, while low enough or specific enough such that we would be able to see variability in manufacturing effectiveness and efficiency across these same plants. Given, this generic process flow diagram we could further customize it for each different plant if required. This idea of a generic flow diagram was important because it allowed us to visualize the flow of materials through a manufacturing plant using a common set of building blocks. This was important because it allowed us to discuss industry structure, relationships with suppliers and customers and different dimension of inventory management and quality operations. In addition, the process flow diagram provided us

with a systematic starting point to formulate appropriate performance metrics to measure manufacturing efficiency and effectiveness.

Figure 8.1 shows the simplified generic process flow diagram for pharmaceutical manufacturing. As can be seen, this process flow diagram consists of three kinds of primary building blocks: material processing or production, inventory and quality control. Each of the them is represented graphically as a different geometric shape.

The shaded rectangles depict manufacturing or production or actual material processing steps. Each shaded rectangle is actually an aggregated description of a number of more detailed steps (on the order to one to thirty different material processing steps). These are the steps that involves actually changing the physical or chemical state of the material or its surroundings. Typical material processing steps include fermentation, centrifugation, mixing, cell disruption, filtration, formulation, tableting, filling and packaging.

The circles depict quality control steps. They are usually designed to ensure the quality of the product produced at the preceding step. There is a strong regulatory component to this operations and quality control is typically coordinated with the function of quality assurance. Once again, it is important to understand that this is a simplification. There are typically a number of QC steps after (and sometime before and during) many of the individual material processing steps. The distinction between a QC step and a material processing step in that the QC step does not change the nature of the material. It is usually designed to test certain properties of the material at different points along the process flow diagram.

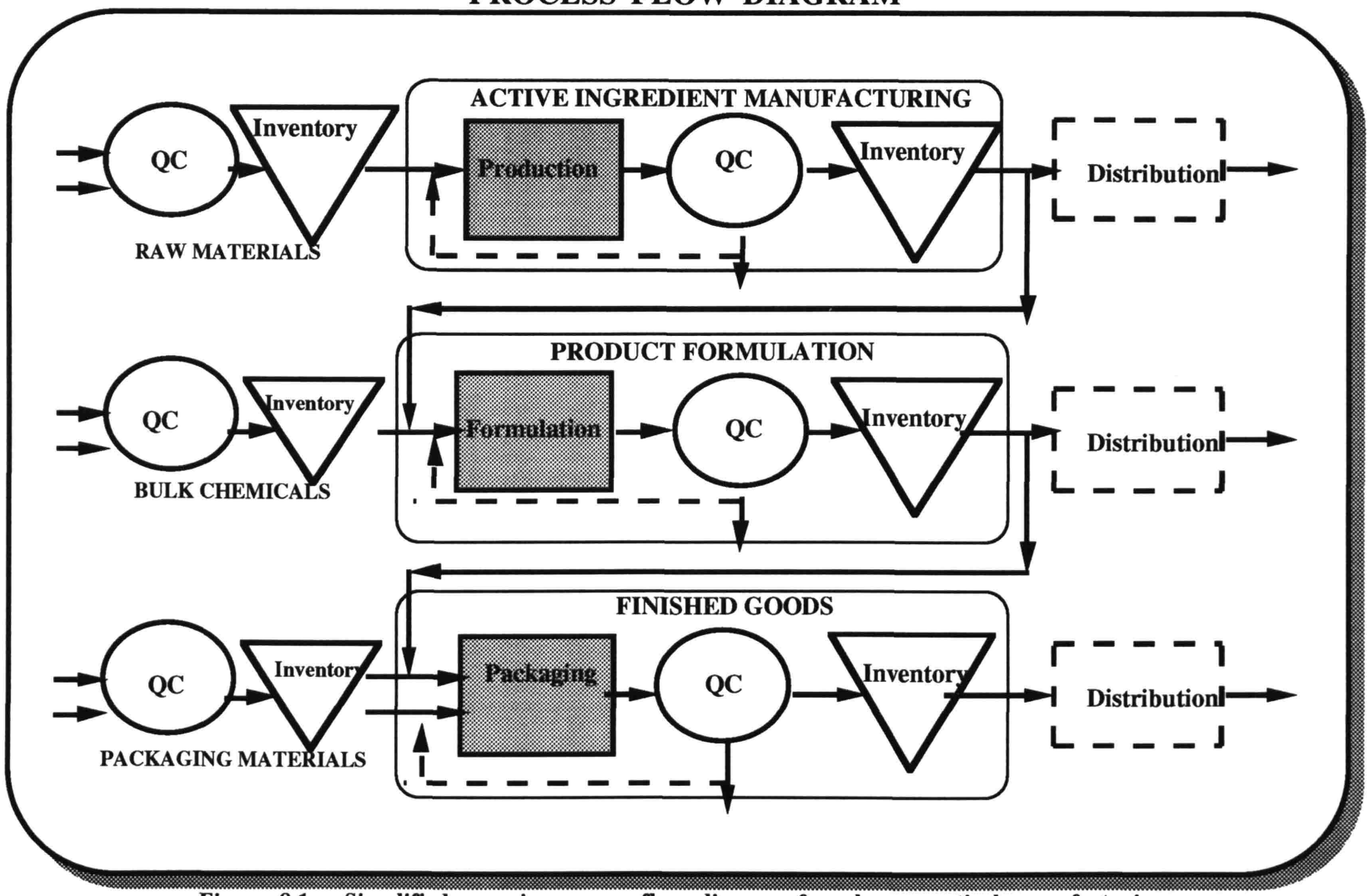


Figure 8.1: Simplified generic process flow diagram for pharmaceutical manufacturing

The triangles depict inventory. This is typically a non-value added step and usually involves material that is waiting to be processed, analyzed by QC or shipped. Once again, the process flow diagram simplifies the concept of inventory by showing it in an aggregated manner. Inventory is built up before and after each individual processing and QC step. Inventory levels are important to understand because they are often symptoms that can help characterize manufacturing effectiveness and efficiency.

The arrows within the diagram that go from left to right indicate a flow of material along the process flow diagram from raw material to final product. In addition, there are a few dotted arrows indicating waste and rejects by QC and possible reprocessing. There dotted arrows are meant to indicate waste, rework or reprocessing. These are important measures in determining quality performance.

Another important feature of the process flow diagram is that it breaks up the manufacturing process into three main types of manufacturing: active ingredient manufacturing, product formulation and packaging. While the distinction is not always clear, active ingredient production, formulation and packaging are usually very different kinds of processes. Active ingredient manufacturing usually involves modifications in the chemical nature of the material. Most processing steps involve principles of chemistry or biology. Active ingredient manufacturing is usually a series of a large number of steps. It is usually more proprietary in nature. Typical steps include fermentation, centrifugation, filtration, and extraction. Bulk formulation, on the other hand, typically involves changing the physical nature of the product. Fewer steps are involved. Most processing steps involve principles of physics. Examples of formulation steps include mixing, tableting and polishing. Packaging using involves changes to the products surroundings rather than the product itself.

In each of the three stages there is a need to bring in raw materials from the previous stage. This involves doing QC analysis and is often associated with inventory. For active ingredient manufacture the raw materials are typically from chemical manufactures. The materials coming in the bulk formulation stage could be either from the same plant, a different plant within the same company or from a totally different company. This is also the case for package although, formulation and packaging are typically in the same facility. Each of these stages can used either directly sell that stage's product or to provide material inputs into the next stage.

8.2 Determining the appropriate levels of benchmarking

As described in the previous chapter, the benchmarking of the different functional areas involved in manufacturing was a quick low cost- low benefit means to quickly gauge the opportunity that may exist for improving pharmaceutical manufacturing. This first pass approach offered us some insights into the supplier relationships, inventory levels and the cycle times for quality assurance. Clearly, there is an opportunity for improvement. However, this opportunity was still defined very vaguely and did not provide a means for a company to take action or for us to determine the underlying causes of the inefficiencies. At this aggregate level it was also very difficult to compare across companies.

One of the first decisions to make at this stages, was to determine the appropriate level to do the next phase of benchmarking. As shown in figure 8.2 below, benchmarking could be done at a number of different levels. At the level of the pharmaceutical organization benchmarking if often done in terms of metrics like the return on investment (ROI). While this might be a useful metric, it is too aggregate and does not help a manufacturing plant target its improvements. Similarly, at the level of the manufacturing

organization, the benchmarks of the functional areas are still too aggregate to help target improvement.

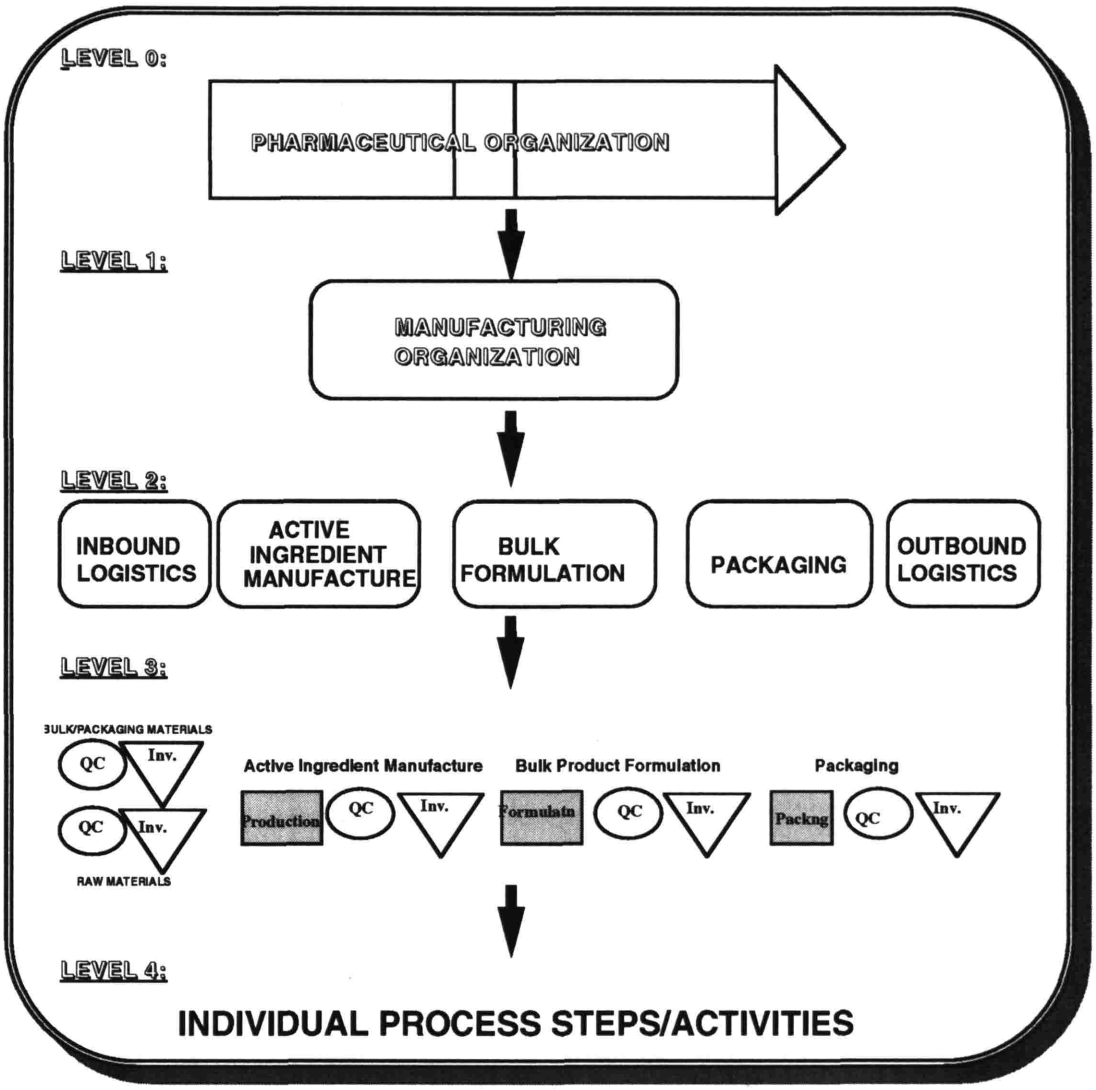


Figure 8.2 : Determining the appropriate level of analysis for benchmarking

We believe it is necessary to go down to the level of the five core manufacturing sub-processes. It is important for benchmarks to at least be at this level of disaggregation because not all companies or plants perform all the five sub processes. Hence they would be difficult to compare at the overall plant level. Rather, comparison should be made at the sub process level or below. As shown in the figure above, most of the sub processes

consist of a number of process steps that typically include production, inventory and quality control. We believe that the process flow diagram should be the basic vocabulary for benchmarking and benchmarks need to be determined around this generalized process flow diagram.

There are, however, different levels of detail at which the process flow diagram can be written. Processes when described completely typically involve upto a few hundred to a few thousand steps. For this study, we determined that the level of detail for the process flow diagram benchmarking was to be determined by a cost-benefit tradeoff. Figure 8.3 depicts our perceived cost benefit tradeoffs.

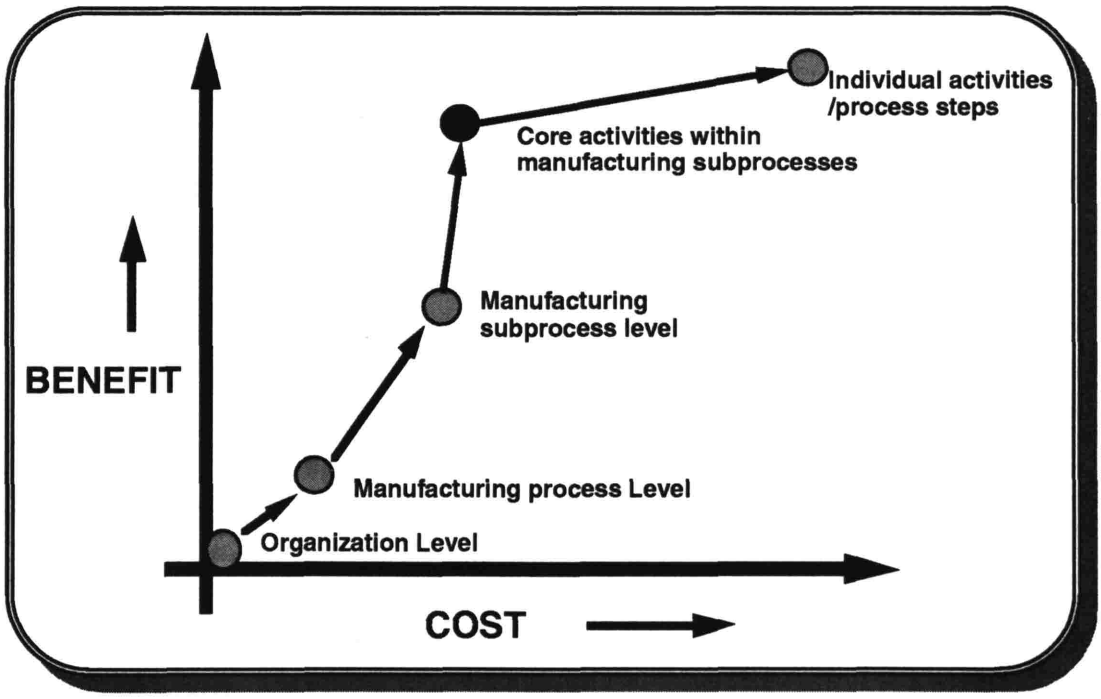


Figure 8.3: Perceived cost benefit tradeoff for different levels of analysis.

Our perception, as can be seen from this figure was that benchmarking at the core sub-process level at the level of 2-4 aggregated steps per sub process would give us the best cost-benefit tradeoff. Within each manufacturing sub process, our goal was to lump the processing, QC and inventory steps. By analyzing these three aggregate steps for each sub process for any manufacturing plant we believe we can both be generic enough to be able to compare across plants while being specific enough to be able to capture variability across plants and companies. Hence, our strategy was to go down one level, once again determine the opportunities for improvement that are highlighted at this level and then determine if another level of detail might be required. Benchmarking is a continuous process and once again, we decided to follow a "learning by doing" strategy.

8.3 Systems Thinking: inputs, outputs and a context

Each of the sub process could not be analyzed functionally. Our belief was that the functional approach hid many of the underlying issues. The functional approach led us to perform benchmarking based on the functional silos within the organizational chart. While this was easy to do because most people and information were organized in this manner, it was not as useful. This was because it did not address the underlying activities that the organization performed. Rather, the process flow diagram seems to be the more appropriate framework to use for benchmarking manufacturing; it follows the addition of value to the product as it moves from raw material to final product. However, this activity or process flow based approach would only be useful if there was a consistent and systematic means of assessing performance along the process flow.

That led us towards a "systems thinking" approach to analyzing the core sub processes within the overall process flow diagram. The appropriate view of each sub process was a system with inputs, outputs and a context. This is shown in Figure 8.4.

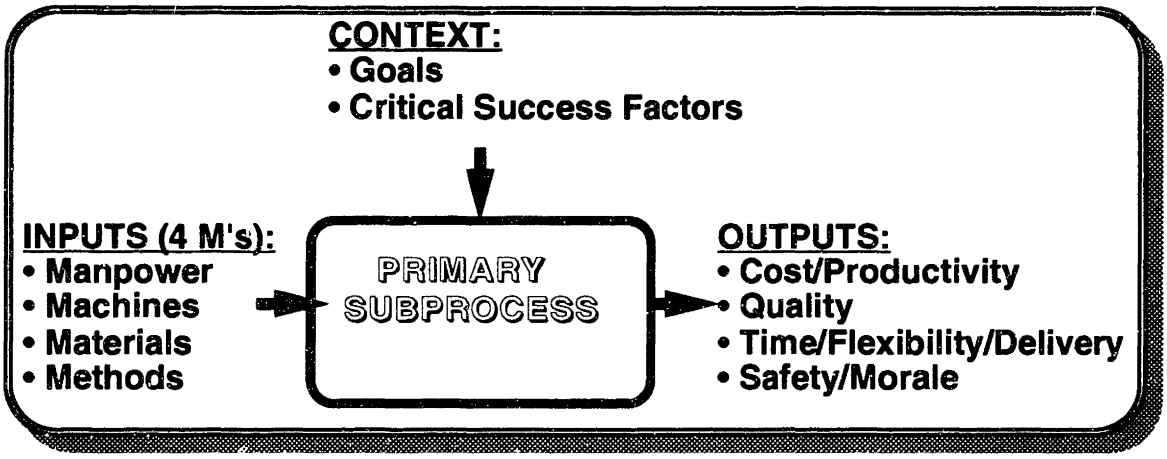


Figure 8.4: Systems Thinking: Each sub process has inputs, outputs and context

We characterize the inputs into each sub process in terms of the 4 M's: Manpower, Machines, Materials and Methods. Similarly, we characterize each sub process in terms of its outputs or its performance measures. These performance measures are cost/productivity, quality, time/flexibility/delivery and safety/morale.

In addition, each sub process has a context which dictats its goals and critical success factors. This information was mostly qualitative and was obtained though the interviews.

8.4 Framework for Learning and Benchmarking

Systems thinking in terms of the level of abstraction and inputs-outputs-context structure allows us to expand the concept of the pharmaceutical manufacturing process flow diagram to develop a framework for benchmarking. The framework shown in Figure 8.5 and depicts the one we intend to use for the benchmarking study. Using the value chain analysis defined by Michael Porter value chain (Porter, 1985) is created by a number of

different activities. These are categorized as primary activities or secondary activities. The process flow diagram represents the primary activities that are performed on the product.

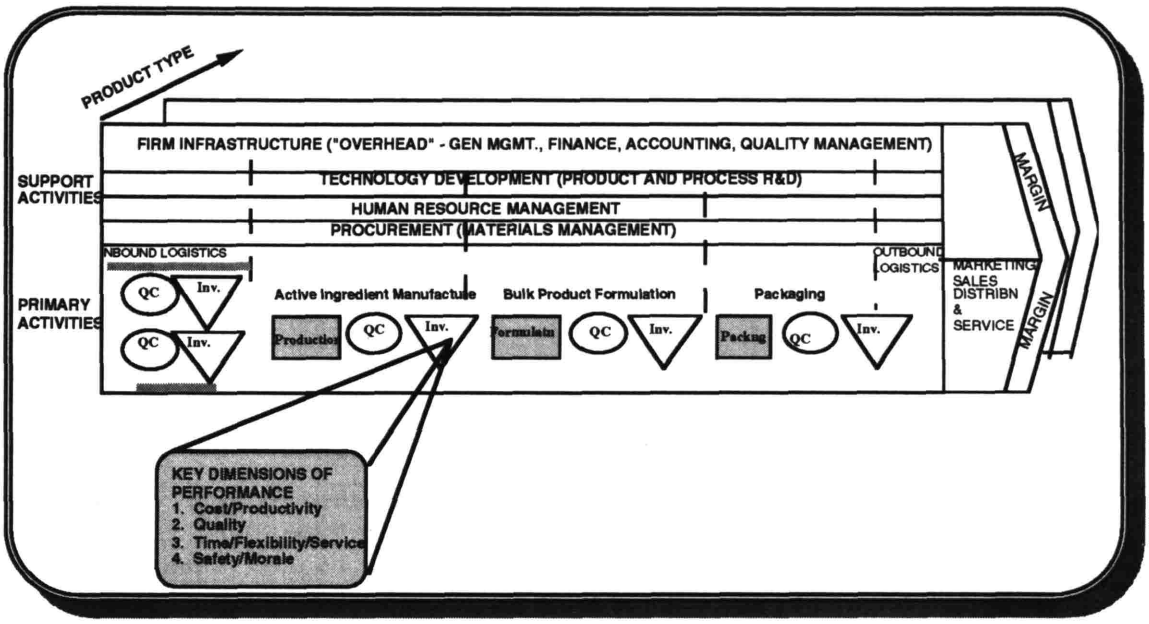


Figure 8.5: Framework for benchmarking

These primary activities are supported by the firm's infrastructure, technology development, human resource management and procurement. A process can be a single activity or a collection of activities. For pharmaceutical manufacturing, the primary activities can be grouped in to five core manufacturing sub processes: inbound logistics, active ingredient manufacture, bulk formulation, packaging and outbound logistics.

The flow of materials through several value added functions can be done in a single plant but often is done at multiple sites within a single fully integrated firm or multiple sites involving different companies. For this reason, we have chosen to develop and apply benchmarking at the sub process level in order to facilitate comparison of similar activities

on an intra- or inter-firm basis. The support activities into each sub process are the inputs. Each sub process can then be evaluated in terms of its outputs or measures of performance.

This framework also allows us to analyze different product types.

8.4 Core sub process quantitative questionnaire

The goal of the Pharmaceutical Industry Benchmarking Study was to analyze and compare manufacturing effectiveness and efficiency within the pharmaceutical industry. This questionnaire attempted to measure manufacturing performance through a series of qualitative and quantitative performance metrics. Data gathered in this questionnaire was meant to be analyzed within the context of the company's mission, goals and critical success factors.

The primary activities to pharmaceutical manufacturing are further grouped into five sequential processes. These primary processes are inbound logistics, active ingredient production, bulk product formulation , packaging and outbound logistics.

The first part of this questionnaire is subdivided into five sections. These sections correspond to the five sequential primary processes. Within each section we attempt to characterize the inputs (support activities) in term of manpower, materials, machines and methods and the outputs (dimensions of performance) in terms of Cost /Productivity, Quality , Time/Flexibility/Service and Safety/Morale.

8.4.1 INBOUND LOGISTICS:

Inbound logistics involves activities associated with receiving, storing and disseminating inputs to the product, such as material handling, warehousing, inventory control, vehicle scheduling, returns to suppliers.

Inbound logistics in a pharmaceutical plants typically involves actually receiving the material. This material is typically in inventory before the plant personnel then perform a QC analysis on the materials to check for a match to specifications. The material is then stored in the warehouse where it sits until it is required in the plant. Important determinants of the cost, quality, flexibility and morale of these operations depends on the number of people involved, their experience levels, the kind of materials involved, the relationships with the suppliers and the use of information technology. Figure 8.6 depicts some of these input measures.

In addition, there are a number of components of performance. Important indicators of performance are the levels of inventory, the fraction of lots that are approved, the times taken for actual testing and release of the materials, the timeliness of the supplier deliveries, the space layout in the warehouse and the safety and morale of the workforce.

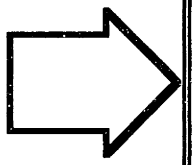
8.4.2 ACTIVE INGREDIENT MANUFACTURE:

The active ingredient manufacturing process is the one by which the pharmacologically active chemical is manufactured in a pure form. This production process can be through chemical manufacturing methods or through the use of biochemical synthesis (e.g.. fermentation or cell culture). The process includes both the production and purification of the active ingredient.

Typically active ingredient manufacture involves a number of processing steps. In addition, there are often a number of QC steps between the processing steps. In between all of these steps there are opportunities for inventory to build up.

Benchmarking the Inbound Logistics Process

INPUTS	MEASURES
• **People**	Number of people
	Avg. experience of people
	Education of people
• **Materials**	Cost of materials purchased
	Raw Materials
	Consumable Supplies
• **Methods**	Number of suppliers
	Raw Materials
	Consumable Supplies
	Number of certified suppliers
	Need to perform on-site QC
	No need to perform on-site QC
	Avg. length of supply contracts
	Dollars spent on supplier training
	Time to review a supplier
• **Machines**	Use of Information Technology



OUTPUTS	MEASURES
• **Cost/Productivity**	Average raw materials inventory level
• **Quality**	Vendor lots approved / Lots received
	# of defective released lots/# of lots released
• **Time/Flexibility/ Service**	Avg. QC release time turnaround for materials
	Average actual raw materials test time
	Lead time between order placement & release
	Average time the material sits in inventory
	% on-time deliveries from suppliers
	Time operations had to wait for materials
	# of times operations had to wait
	Average amt of waiting time
	Floor Space dedicated to inbound logistics
	Avg. distance traveled by raw materials
• **Safety/Morale**	# of safety related incidents
	# of safety related lost work days
	# suggestions submitted by employees
	# of ideas submitted that were implemented
	Employee job absence rate
	Employee turnover

Figure 8.6: Input and Output measures used to benchmark the inbound logistics process

Table 8.7 depicts the input and output measures used to benchmark the active ingredient manufacturing process. Some of the important inputs into the process that have a direct bearing on performance include the number of people, their education and training levels, the kind of materials, the number of complexity of the steps involved, the batch sizes, number of products produced, the kind of equipment and the use of information technology. Important components of performance include the cost of the active ingredient produced, the maintenance expenses, the number of lots that need to be rejected, reworked or retested, the cycle time, capacity utilization, new product introductions, schedule adherence and safety and worker morale.

8.4.3 BULK FORMULATION:

The bulk formulation process involves combining the bulk active ingredient with inert substances like diluents or extenders. The mix is then manufactured into a finished delivery form such as a pill, capsule, tablet, cream, or lotion.

Bulk formulation typically involves a fewer number of active ingredient steps than active ingredient manufacturing. Table 8.8 depicts the input and output measures associated with benchmarking the bulk formulation process. These metrics are quite similar in nature to those described for the active ingredient manufacturing process.

8.4.4 PACKAGING:

Packaging is where the finished product is packaged into bottles or vials of various sizes and/or dosage. This process also involves labeling and boxing. Packaging processes typically involve a line flow. This is in contrast to most active ingredient manufacturing and bulk formulation processing that is typically done in batches. Packaging is also the least proprietary in nature.

Benchmarking the Active Ingredient Manufacturing Process

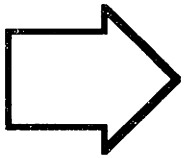
INPUTS	MEASURES
• **People**	# of direct production employees
	Maintenance employees
	Experience of people
	Education of people
• **Materials**	Cost of materials used
• **Methods**	# of proc. steps in act. ingred. mfg.
	# of these steps outsourced?
	# of steps using dedicated facilities
	Produced year round?
	Batch size
	Lot size
	# of batches/yr
	Cumulative # of batches mfg. to date
	Set-up time
	Run time
	Annual production
	# of years of production
	# of inter-plant transfers
	# of total active ingredients produced
	Avg. involvement in work teams
	# people involved in "continuous improvement"
	Fraction of time the workforce is idle
	Avg weekly overtime hrs for employees
	Average hours of training / Total work hours
	Total # of people involved in QC and QA
• **Machines**	Use of Information Technology
	Plant value at construction/purchase
	% oper. budget used for equipment enhancements
	Average age of active ingredient production equipment
	Cost of capital assumed for equipment investments

OUTPUTS	MEASURES
• **Cost/Productivity**	Total cost of active ingredient produced
	Production overhead cost
	Maintenance expenses
	Value of average work-in-process
	Value of active ingredient inventories
	Inventory holding cost
• **Quality**	Lots mfg. right first time / Total lots mfg.
	% of initiated lots that are:
	Rejected by mfg. (waste)
	Reprocessed by mfg.
	Rejected by QC/QA
	Retested by QC/QA
	# of 483 citations by FDA
	Major
	Minor
• **Time/Flexibility/ Service**	# of new prods. introduced into mfg.
	Avg. capacity utilization of facility
	Annual operating hours
	Annual hrs for prev. maintenance & turnovers
	Annual hrs the equipment is idle
	Degree of computer automation
	New product ramp-up time
	# of significant process-plant modifications
	Trigger for process-plant modification:
	External
	Internal
	Actual prodn. /forecast
• **Safety/Morale**	# suggestions submitted employees
	# of suggestions by maintenance employees
	# of suggestions by QC/QA personnel
	Total # of ideas implemented
	Total # safety related incidents
	Lost workday cases per 100 prod. employees
	Employee job absence rate
	Production employee turnover

Figure 8.7: Input and Output measures used to benchmark the active ingredient manufacturing process

Benchmarking the Bulk Formulation Process

INPUTS	MEASURES
• **People**	# of direct production employees
	Maintenance employees
	Experience of people
	Education of people
• **Materials**	Cost of materials used
• **Methods**	# of proc. steps in bulk formulation
	# of these steps outsourced?
	# of steps using dedicated facilities
	Produced year round?
	Batch size
	Lot size
	# of batches/yr
	Cumulative # of batches mfg. to date
	Set-up time
	Run time
	Annual production
	# of years of production
	# of inter-plant transfers
	# of total bulk formulations produced
	Avg. involvement in work teams
	# people involved in "continuous improvement"
	Fraction of time the workforce is idle
	Avg weekly overtime hrs for employees
	Average hours of training / Total work hours
	Total # of people involved in QC and QA
• **Machines**	Use of Information Technology
	Plant value at construction/purchase
	% oper. budget used for equipment enhancements
	Average age of bulk formulation equipment
	Cost of capital assumed for equipment investments



OUTPUTS	MEASURES
• **Cost/Productivity**	Total cost of bulk formutions produced
	Production overhead cost
	Maintenance expenses
	Value of average work-in-process
	Value of bulk formulation inventories
	Inventory holding cost
• **Quality**	Lots mfg. right first time / Total lots mfg.
	% of initiated lots that are:
	Rejected by mfg. (waste)
	Reprocessed by mfg.
	Rejected by QC/QA
	Retested by QC/QA
	# of 483 citations by FDA
	Major
	Minor
• **Time/Flexibility/ Service**	# of new prods. introduced into bulk formlation
	Avg. capacity utilization of facility
	Annual operating hours
	Annual hrs for prev. maintenance & turnovers
	Annual hrs the equipment is idle
	Degree of computer automation
	New product ramp-up time
	# of significant process-plant modifications
	Trigger for process-plant modification:
	External
	Internal
	Actual prodn. /forecast
• **Safety/Morale**	# suggestions submitted employees
	# of suggestions by maintenance employees
	# of suggestions by QC/QA personnel
	Total # of ideas implemented
	Total # safety related incidents
	Lost workday cases per 100 prod. employees
	Employee job absence rate
	Production employee turnover

Figure 8.8: Input and Output measures used to benchmark the bulk formulation process

Table 8.9 depicts the input and output measures used to benchmark the packaging operation. These measure are quite similar to those used for bulk formulation and active ingredient manufacture.

8.4.5 OUTBOUND LOGISTICS:

Outbound logistics involves activities that associated with collecting, storing and physically distributing the product such as finished goods warehousing, material handling, delivery vehicle operation, order processing, and scheduling.

Figure 8.10 shows the inputs and output measures used to benchmark the output logistics process. Important components that determine the performance include the number of people involved, their experience and education, the cost of goods sold, the number of customers and the use of information technology.

Relevant measures of performance include finished goods inventory levels, the number of customer complaints, the QC test time and release time, the number of due dates missed, the layout of the warehouse and safety and worker morale.

8.5 Results obtained from core sub process level benchmarking

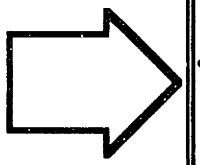
8.5.1 Inbound Logistics

Table 8.1 depicts 10 columns of inbound logistics data from 4 different plants. B1, B2 and B4 are biotechnology plants while P6 is a brand name active ingredient manufacturing plant.

Plant P6 has a larger number of people (direct and indirect) working on inbound logistics. The biotechnology plants have people with higher levels of education. Plant P6, on the other hand, purchases significantly larger value of total raw materials and

Benchmarking the Packaging Process

INPUTS	MEASURES
• **People**	# of direct packaging employees
	Maintenance employees
	Experience of people
	Education of people
• **Materials**	Cost of materials used
• **Methods**	# of proc. steps in packaging
	# of these steps outsourced?
	# of steps using dedicated facilities
	Produced year round?
	Batch size
	Lot size
	# of batches/yr
	Cumulative # of batches packaged to date
	Set-up time
	Run time
	Annual production
	# of years of production
	# of inter-plant transfers
	# of total packages produced
	Avg. involvement in work teams
	# people involved in "continuous improvement"
	Fraction of time the workforce is idle
	Avg weekly overtime hrs for employees
	Average hours of training / Total work hours
	Total # of people involved in QC and QA
• **Machines**	Use of Information Technology
	Plant value at construction/purchase
	% oper. budget used for equipment enhancements
	Average age of packaging equipment
	Cost of capital assumed for equipment investments

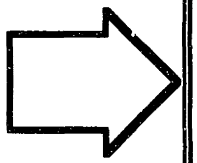


OUTPUTS	MEASURES
• **Cost/Productivity**	Total cost of packages produced
	Production overhead cost
	Maintenance expenses
	Value of average work-in-process
	Value of packaging inventories
	Inventory holding cost
• **Quality**	Lots mfg. right first time / Total lots mfg.
	% of initiated lots that are:
	Rejected by pkg. (waste)
	Reprocessed by pkg.
	Rejected by QC/QA
	Retested by QC/QA
	# of 483 citations by FDA
	Major
	Minor
• **Time/Flexibility/ Service**	# of new prods. introduced into packaging
	Avg. capacity utilization of facility
	Annual operating hours
	Annual hrs for prev. maintenance & turnovers
	Annual hrs the equipment is idle
	Degree of computer automation
	New product ramp-up time
	# of significant process-plant modifications
	Trigger for process-plant modification:
	External
	Internal
	Actual prodn. /forecast
• **Safety/Morale**	# suggestions submitted employees
	# of suggestions by maintenance employees
	# of suggestions by QC/QA personnel
	Total # of ideas implemented
	Total # safety related incidents
	Lost workday cases per 100 pkg. employees
	Employee job absence rate
	Pkg. employee turnover

Figure 8.9: Input and Output measures used to benchmark the packaging process

Benchmarking the Outbound Logistics Process

INPUTS	MEASURES
• **People**	Number of people
	Avg. experience of people
	Education of people
• **Materials**	Cost of materials sold
• **Methods**	Number of customers
	Avg. length of contracts
	$ spent on customer service training
	Time to switch customers
• **Machines**	Use of Information Technology



OUTPUTS	MEASURES
• **Cost/Productivity**	Average finished goods inventory level
• **Quality**	Total complaints / Number of units
• **Time/Flexibility/ Service**	Avg. QC release time turnaround for fin. goods
	Average length of QC hold on fin. goods
	Average actual finished goods test time
	Due dates missed / Total deliveries
	Lead time between delivery & order placement
	Avg. time the finished good sits in inventory
	Total Floor Space
	Avg. distance traveled by fin. goods
• **Safety/Morale**	# of safety related incidents
	# of safety related lost work days
	# suggestions submitted by employees
	# of ideas submitted that were implemented
	Employee job absence rate
	Employee turnover

Figure 8.10: Input and Output measures used to benchmark the outbound logistics process

Table 8.1: Inbound logistics data

INBOUND LOGISTICS		B1-92	B1-93	B2-92	B2-93	B4-92	B4-93	P6-90	P6-91	P6-92	P6-93
INPUTS:											
People	# people (direct)	**0.33**	**0.33**	0.67	0.67	**11.5**	**13.5**	6	4	4	4
	# people (indirect)	0.25	0.25	0.25	0.25	2.25	2.25	4	4	4	4
	Yrs of service in field	10	10	10	10	10	10	13	11	12	13
	Education (BS)					3	3	0	0	0	0
	Education (MS/MBA)					1.75	1.75	0	0	0	0
	Education (PhD)					0	0	0	0	0	0
	Education (High School/other)	All	All	All	All	9	11	0	0	0	0
Materials	Cost of purchased RM (million)	0.9	0.9	4.6	4.6	1.0	2.7	39.3	28.3	19.7	25.3
	Cost of purchased consumables (mill)	0.1	0.1	0.1	0.1	0.1	0.3	4.8	3.9	4.5	3.9
Methods	# of suppliers (raw materials)	**10**	**10**	12	12	**63**	**66**	**48**	**35**	**28**	**28**
	# of suppliers (consumable supplies)	6	6	6	6	-	-	**25**	**21**	**21**	**19**
	# of certified suppliers (on-site QC)	10	10	12	12	63	66	**0**	**0**	**1**	**1**
	# of certified suppliers (no on-site QC)	**0**	**0**	0	0	**0**	**0**	**0**	**0**	**0**	**0**
	Avg. length of supply contracts (yrs)	1	1	1	1	6	6	1	1	1	1
	Dollars spent on supplier training	0	0	0	0	0	0	0	0	0	0
	Time to review a supplier (wks)	**8**	**8**	8	8	0	0	**2**	**3**	**5**	**5**
Machines	Use of Info. Tech	0.5	0.5	0.5	0.5	2	2	**1**	**2**	**2**	**2**
OUTPUTS:											
Cost/Productivity	Avg. raw materials inventory level	**12**	**4**	**12**	**4**	**86**	**48**	**2.7**	**4**	**3**	**1.8**
Quality	# of vendor lots approved/lots received						**99%**	N/A	N/A	**99.20%**	**98.30%**
	# of defective released lots/lots released						3%	-	-	0%	0%
Time/Flexibility/Service	Avg. QC release time for RM (hrs)						240	N/A	N/A	18	7
	Avg. QC test time for RM						N/D	-	-	-	-
	Time bet. order placement & release (wks)							-	-	-	-
	Avg. time material sits in inventory (wks)	4	4	4	4			-	3.1	3	2.9
	% on-time deliveries from suppliers	96%	96%	96%	96%		90%	**78%**	**78%**	**85%**	**85%**
	# times operations waited for materials	0	0	0	3	2.5	2,.5	-	-	-	-
	Avg. amount of waiting time (days)	0	0	0	2 hrs	0.5	0.5	-	-	-	-
	Floor space for inbound logistics (sq. ft)	2000	2000	3000	3000	8707	8707	46,000	46,000	46,000	46,000
	Avg. distance travelled by RM after receipt	150	150	150	150	400	400	1,000	1,000	1,000	1,000
Safety/Morale	# safety related incidents in inbound logistics	0	0	-	-			2	0	0	1
	# of safety related lost work days	0	0	-	-			1	0	0	0
	# of suggestions by employees	**100**	**100**	-	-	20	25	**0**	**0**	**0**	**0**
	# of submitted ideas implemented	**50**	**50**	-	-	13	17	**0**	**0**	**0**	**0**
	Employee job absentee rate	4%	4%	-	-	12%	24%	4%	4%	4%	4%
	Employee turnover in inbound logistics	1%	1%	-	-	10%	6%	0	15%	0	0

consumables. Plants P6 and B4 have a significantly larger number of suppliers than B1 and B2. However, P6 is seems to be consistently reducing the number of its suppliers and is beginning to certify them. P6 is now taking a longer time to review a new supplier. While the on-time deliveries are relatively low for plant P6, they are improving. Similarly plant P6 is improving in terms of safety while the job absentee rate is dropping. Overall, plant P6 seems to be improving the way it does inbound logistics.

Plant B4, on the other hand, with its high raw material inventory levels and large number of suppliers have a high employee absentee and turnover rate. The suggestion mechanism is improving.

8.5.2 Active Ingredient Manufacture

Table 8.2 shows 6 columns of active ingredient manufacturing data from two different plants. B4 represents a biotechnology plant while P6 represents a brand name active ingredient manufacturing plant. P6 started off with a significantly larger number of production employees but the number is seen to be dropping while the numbers for B4 are increasing. The biotechnology plant is seen to have a higher educated workforce.

There is are more processing steps involved in the biotechnology process. In addition all the steps involve dedicated facilities. The batch sizes for the biotechnology process are significantly higher, the set-up times significantly longer and the number of products significantly lower. The biotechnology plants involves a significant number of interplant transfers.

The active ingredient plant P6 uses a lot more overtime hours while the biotechnology plant does more total training. The number people involved in active ingredient QC is comparable. This number is going up in the case of plant P6.

The brand-name active ingredient plant produces higher total value active ingredient that the biotechnology plant and has higher overhead expenses. Maintenance expenses are comparable. The waste levels in the active ingredient production plant of P6 depict no clear trend. It is surprising to note that biotechnology plant B4 retests as much as 100% of its QC lots. Plant B4 also operates its plants for a fewer number of hours during the year. Plant B4 indicates a higher number of lots produced and a higher number rejected.

The dedicated biotechnology plant is run considerably fewer hours than the plant P6. Plant B4 also involves a larger number of process-plant modifications. Plant P6 actually equals or exceeds its initially scheduled production requirements. The absentee rate is higher for plant P6. Plant P6 also seems to had a large layoff in 1991.

8.5.3 Bulk Formulation

Table 8.3 depicts 4 columns of bulk formulation data all collected from the same plant P6 over multiple years. The table indicates that there have not been significant changes in the number of direct production or maintenance employees. Bulk formulation, here involves only one process step. There is no change in the batch size, or the set up time or run time of the bulk formulation step.

The % of waste in dropped significantly in the plant P6. This is because of the focus in plant P6 on waste levels.

8.5.4 Packaging

Table 8.4 depicts the packaging data for plant P6. The columns indicate that packaging is represented as being one processing step. Most of the products are produced

Table 8.2: Active Ingredient manufacturing data

ACTIVE INGRED MANUFACTURE		B4-92	B4-93	P6-90	P6-91	P6-92	P6-93
INPUTS							
Manpower	# of direct prodn. employees	33	78	**103**	**57**	**57**	**53**
	# Maintenance employees	3	3	NA	13	8	7
	Education (BS)		35	6	7	7	7
	Education (MS/MBA)		3	0	0	0	0
	Education (PhD)		0	0	0	0	0
	Education (High School/Other)		40	0	0	0	0
Method	# of process steps	7	7	4,2,1	NA,2,1	NA,2,1	NA,2,1
	# of these steps outsourced?	0	0	0,0,0	NA,0,0	NA,0,0	NA,0,0
	# of steps using dedicated facilities	7	7	4,2,0	NA,2,0	NA,2,0	NA,2,0
	Produced year round?	N	Y	Y,Y,Y	NA,Y,Y	NA,Y,Y	NA,Y,Y
	Batch size (liters)	7500	7500	180,45,30	NA,45,30	NA,45,30	NA,182,30
	# of batches/yr			1800,950,59	NA,1000,50	NA,980,59	NA,200,60
	Cumulative # of batches mfg. to date	23	86				
	Set-up time (hrs)	**88**	**174**	**24,48,48**	**NA,24,48**	**NA,24,48**	**NA,48,48**
	Annual prodn.	72	72	350,44,1.8	NA,45,1.5	NA,45,1.8	NA,43,1.8
	# of inter-plant transfers	4	5	0,0,0	NA,0,0	NA,0,0	NA,0,0
	# total active ingredients produced	1	1	8	8	8	8
	Involvement in work teams (1-5)	**1**	**2.5**	**1**	**1**	**2**	**2**
	# people in cont. improvement (direct)		17	0	3	7	12
	# people in cont. improvement (indirect)		5	0	24	61	100
	%f time the workforce is idle	0	0	0	0	0	0
	Wkly overtime hr for employees		5	592	601	617	586
	Avg. hrs of training/total wk hrs.		**15%**				
	Hrs of training/wk hrs (FDA stipulated)			0.24%	0.49%	0.46%	0.43%
	Hrs of training/wk hrs (On job training)			0.16%	0.26%	0.26%	0.27%
	Hrs of training/wk hrs (off job training)			NA	NA	NA	NA
	Avg. hrs training/work hrs (other)			0.29%	0.33%	0.33%	0.57%
	# people in active ingred. QC		30	**35**	**37**	**42**	**42**
Machines	Plant value at construction/purchase (M)		8.1	28.5	22.7	25.0	27.8
	% oper. budget for equipt. improvmnts		N/D	**20.20%**	**57.30%**	**28.50%**	**73%**
	Age of prodn. equipment (yrs)	4	5	5.7	6.2	5.8	5.9
OUTPUTS							
Cost/Productivity	Cost of active ingredient produced (M)	11.0	14.8	46.4	72.6	48.9	46.4
	Production overhead cost	9.4	10.9	16.0	14.4	15.6	19.3
	Maintenance expenses	1.2	1.2	1.3	1.1	1.1	0.9
	Value active ingred. inventory held (m)	11.9	12.7	14.3	4.9	4.7	4.6
	Perception of inventory holding cost	18%	18%	NA	NA	NA	NA
Quality	Lots right first time/Total lots mfg.			96.65%	94.80%	98.05%	97.85%
	Discard Rate (waste)			3.35%	5.20%	1.95%	2.15%
	Total lots scheduled for production	23	86				
	Total lots unsuccessfully mfg.	0	4				
	Total lots released by QC.	22	63				
	Total lots rejected by QA	1	19				
	Total lots retested by QC	**100%**	**100%**				
	# of 483 citations (major)			6	1	2	0
	# of 483 citations (minor)	N/A	3	1	0	0	0
Time/Flex./Service	# new active ingred. introduced	**0**	**0**	**0**	**0**	**0**	**0**
	Annual operating hrs of facility	3600	3600	6900	5900	5900	5600
	Hrs reqd. for prev. maint. & turnovers	800	800	NA	320	961.25	759.5
	Annual hrs the equipment is idle	**4400**	0	**96**	**216**	**216**	**48**
	Degree of computer automation	4	4	1	1	1	3
	New product ramp-up time		N/A	NA	NA	NA	NA
	# significant process-plant modifications	3	3	0	0	3	1
	Actual prodn./forecasted requirements		112%	100%	121%	106%	126%
Safety/Morale	# suggestions by prodn employees		N/A	0	0	0	2
	# suggestions by maintenance employees		N/A	0	0	0	2
	# suggestions by QC/QA personnel		N/A	0	0	0	0
	Total # of ideas submitted implemented			0	0	0	0
	# of safety related incidents			19	16	9	10
	Lost workday cases/100 prod employees			0	1.25	4.2	3.3
	Prod. employee job absence rate		2%?	4%	4%	4%	4%
	Prod. employee turnover		10%?	0%	44%	0%	0%

Table 8.3: Bulk formulation data

BULK FORMULATION		P6-90	P6-91	P6-92	P6-93
INPUTS					
Manpower	# of direct prodn. employees	4	5	5	5
	# of Maintenance employees	NA	1	2	2
	Education (BS)	0	0	0	0
	Education (MS/MBA)	0	0	0	0
	Education (PhD)	0	0	0	0
	Education (High School/other)	0	0	0	0
Method	# of process steps in bulk formulation	1,1,1	1,1,1	1,1,1	1,1,1
	# of these steps outsourced?	0,0,0	0,0,0	0,0,0	0,0,0
	# of steps using dedicated facilities	0,0,0	0,0,0	0,0,0	0,0,0
	Produced year round?	Y	Y	Y	Y
	Batch size	315,275,74	315,275,74	315,275,74	315,275,74
	# of batches/yr	104,9,39	109,10,18	110,7,6	105,18,1
	Cumulative # of batches mfg. to date				
	Set-up time (hrs)	8,8,8	8,8,8	8,8,8	8,8,8
	Run-time (hrs)	10,10,10	10,10,10	10,10,10	10,10,10
	Annual prodn.	33,2.5,2.9	34,2.7,1.4	35,1.9,0.5	33,3.1,0.08
	# of yrs. of prodn.				
	# of inter-plant transfers	0,0,0	0,0,0	0,0,0	0,0,0
	# total bulk formulations produced?	5	5	4	5
	Involvement in work teams	**1**	**1**	**1**	**2**
	# of people in continuous improvement (direct)	0	0	0	1
	# of people in continuous improvement (indirect)	0	0	0	1
	Fraction of time the workforce is idle	0	0	0	0
	Wkly overtime hr for bulk formulation employees	19	34	22	19
	Hrs of training/total work hrs (FDA stipulated)	0.19%	0.46%	0.45%	0.43%
	Hrs of training/total work hrs (On the job training)	0.63%	0.52%	0.63%	0.54%
	Hrs of training/total work hrs (other training)	0.31%	0.23%	0.36%	0.42%
	# of people involved in QC and QA	**47**	**50**	**56**	**54**
OUTPUTS					
Cost/Productivity	Cost of bulk formulations produced (annual) (m)	27.49	51.42	31.16	30.6
	Production overhead cost	11.26	2.23	14.14	15.82
	Maintenance expenses	0.19	0.21	0.18	0.17
	Total value of avg. bulk formulation inventory held	2.57	3.09	1.07	1.04
Quality	Lots right the first time/Total lots mfg.	89%	98.50%	98.50%	98.80%
	Discard Rate	11%	1.50%	1.50%	1.50%
	# of 483 citations (major)	2	3	0	0
	# of 483 citations (minor)	0	0	0	0
Time/Flexibility/Service	# of new bulk formulations introduced into mfg.	0	0	0	0
	Annual operating hrs of facility	760	685	615	620
	Hrs required for prev. maint. and turnovers	NA	126.1	51	62
	Annual hrs the equipment is idle	7056	7527	7653	7520
	Degree of computer automation	1	1	1	1
	New product ramp-up time	NA	NA	NA	NA
	# of significant process-plant modifications	0	0	0	0
	Trigger for process-plant modifications (external)	0	0	0	0
	Trigger for process-plant modifications (internal)	0	0	0	0
	Actual prodn./Aggregate forecast requirements	100%	95%	87%	101%
Safety/Morale	# of suggestions by bulk formulation employees	0	0	0	1
	# of suggestions by maintenance employees	0	0	0	0
	# of suggestions submitted by QC/QA personnel	0	0	0	0
	Total # of ideas submitted that were implemented	0	0	0	0
	Total # of safety related incidents	0	2	0	1
	Lost workday cases/100 bulk formulation employees	0	0	0	40
	Bulk formulation employee job absence rate	4%	4%	4%	4%
	Bulk formulation employee turnover	0	0	0	0

year round with batch sizes that did not change. However, the number of batches made each year does change.

The number of packagings made has reduced and the work involved in teams and continuous improvement projects has gone up. The number of people in QC and QA has increased. A smaller percentage of the operating budget was being spent on equipment improvement.

The cost of the packaging material went up slightly and so did the packaging overhead cost. Maintenance expenses seem to have dropped. The waste levels are showing an overall downward trend in packaging as well. However, the facility is being operated for fewer hours and kept idle for longer times.

8.5.5 Outbound Logistics

Table 8.5 depicts 10 columns of outbound logistics data from 4 different plants. B1, B2 and B4 represent biotechnology plants while P6 represents a brand name active ingredient manufacturing plant. As shown, the brand name active ingredient plant has a significantly larger number of people involved in inbound logistics both directly and indirectly. Most of the individuals working in inbound logistics have a number of years of experience. They are slightly more educated in the case of the biotechnology plants. Similarly, the cost of materials sold are significantly larger in the case of the active ingredient manufacturing plant. Plants B1 and B4 have a long contract length. B1 and B2 perceive themselves as being more automated than the others.

The biotechnology plants hold a significantly larger amount of finished goods inventory. However, plants B1 and B4 are decreasing their inventory levels. Plant B4 still has a particularly high finished goods inventory level. Plant B4 has an abnormally high number of customer complaints in 1993. In addition, plant B4 has a smaller fraction of employee suggestions implemented and the highest job absentee rate. Plants B1 and B2

Table 8.4: Packaging data

PACKAGING		P6-90	P6-91	P6-92	P6-93
INPUTS					
Manpower	# of direct prodn. employees in packaging	80	78	78	76
	Maintenance employees in packaging	NA	9	7	6
	Education (BS)	18	20	20	20
	Education (MS/MBA)	0	0	0	0
	Education (PhD)	0	0	0	0
	Education (High School/Other)	0	0	0	0
Method	# of process steps in packaging	1,1,1	1,1,1	1,1,1	1,1,1
	# of these steps outsourced?	0,0,0	0,0,0	0,0,0	0,0,0
	# of steps using dedicated facilities	0,0,0	0,0,0	0,0,0	0,0,0
	Produced year round?	Y	Y	Y	Y
	Batch size	35.14.5,38	35,14.5,38	35,14.5,38	35,14.5,38
	# of batches/yr	245,234,96	225,125,101	229,48,115	217,51,115
	Set-up time (hrs)	4,4,24	4,4,24	4,4,24	4,4,24
	Run time (hrs)	12,12,12	12,12,12	12,12,12	12,12,12
	Annual prodn.	8560;3386;3650	7877;1819;3852	8021;698;4390	7591;734;4382
	# of inter-plant transfers	0	0	0	0
	# total packagings are produced?	41	41	30	33
	Involvement in work teams	1	1	1	2
	# people in cont. improvement (direct)	0	3	3	3
	# people in cont. improvement (indirect)	0	8	8	8
	% time the workforce is idle	0	0	0	0
	Weekly overtime hr	293	195	236	231
	Hrs training/work hrs (FDA stipulated)	0.18%	0.41%	0.45%	0.50%
	Hrs training/work hrs (On the job training)	0.43%	0.43%	0.39%	0.37%
	Hrs training/work hrs (off the job training)	NA	NA	NA	NA
	Hrs training/work hrs (other training)	0.37%	0.23%	0.36%	0.50%
	Total # of people involved in QC and QA	47	50	56	54
Machines	Plant value at construction/purchase (m)	13.47	13.49	13.68	14.44
	% oper. budget for eqpmt. improvemnts.	14.60%	10.70%	7.20%	6.10%
	Avg. age of packaging equipment	5.7	6.6	7.1	6.8
OUTPUTS					
Cost/Productivity	Cost of packagings produced (annual)	36.4	39.34	39.87	41.94
	Packaging overhead cost	16.02	23.18	25.07	26.74
	Maintenance expenses	0.87	0.91	0.81	0.66
	Total value of avg. WIP	NA	NA	NA	NA
	Value of avg. packaging. inventory held	3.25	6.79	5.51	4.66
Quality	Lots right first time/Total lots mfg.	**87%**	**93.60%**	**97.90%**	**96.30%**
	Discard rate for packaging (waste)	**13%**	**6.40%**	**2.10%**	**3.70%**
	# of 483 citations (major)	0	0	3	0
	# of 483 citations (minor)	0	0	0	0
Time/Flex/Service	# of new prods introduced into packaging	0	0	0	0
	Annual operating hrs of facility	**2300**	**1784**	**1568**	**1532**
	Hrs reqd for prevent. maint. & turnovers	**NA**	**3320**	**2003**	**2020**
	Hrs the equipment is idle	**4666**	**5432**	**5503**	**5664**
	Degree of computer automation	**2**	**2**	**3**	**3**
	New product ramp-up time	NA	NA	NA	NA
	# significant process-plant modifications	0	0	0	0
	Actual prodn./forecasted requirements	**100%**	**99%**	**87%**	**95%**
Safety/Morale	# suggestions by packaging employees	0	0	0	5
	# suggestions by maintenance employees	**0**	**0**	**2**	**2**
	# of suggestions by QC/QA personnel	**0**	**0**	**0**	**0**
	# ideas submitted implemented	**0**	**0**	**2**	**5**
	# of safety related incidents in packaging	**51**	**16**	**14**	**29**
	Lost workday cases/100 pack. employees	**16**	**10.7**	**6.2**	**7.3**
	Packaging employee job absence rate	**4%**	**4%**	**4%**	**4%**
	Packaging employee turnover	**0**	**2%**	**2%**	**2%**

on the other hand, have an abnormally high employee turnover in outbound logistics of 100%. This is probably because the results are skewed by the very small number of people involved.

Table 8.5: Outbound logistics data

OUTBOUND LOGISTICS		B1-92	B1-93	B2-92	B2-93	B4-92	B4-93	P6-90	P6-91	P6-92	P6-93
INPUTS:											
People	# people (direct)	0	0.33	0.33	0.33	1.5	1.5	6	4	4	4
	# people (indirect)					0.25	0.25	3	2	2	2
	Yrs of service in field	10	10	10	10			13	11	12	13
	Education (BS)	-	-	-	-	0	0	0	0	0	0
	Education (MS/MBA)	-	-	-	-	0.75	0.75	0	0	0	0
	Education (PhD)	-	-	-	-	0	0	0	0	0	0
	Education (High School/other)	All	All	All	All	1	1	0	0	0	0
Materials	Cost of materials sold (M)	0.755	0.692	7.8	12.1	9.687	19.622	86.34	66.41	52.71	57.53
Methods	# of customers	4	4	400	600	1	1	5	5	5	5
	Length of contracts (yrs)	10	10	NA	NA	15	14	NA	NA	NA	NA
	$ spent on customer service training (M)	0.5	0.5	2	2	0	0	0	0	0	0
	Time to switch customers (wks)	NA	NA	NA	NA	N/A	N/A	0	0	0	0
Machines	Use of Info. Tech (1 to 5)	3	3	3	3	1	1	1	2	2	2
OUTPUTS:											
Cost/Productivity	Finished goods inventory (wks)	**8**	**6**	**30**	**30**	60	41	7	7	7	7
Quality	Total complaints/# of units					0%	24%				
Time/Flexibility/Service	QC finished goods release time (hrs)	30 days		60 days	-		115	**NA**	**456**	**408**	**528**
	Avg. test time for finished goods (hrs)			600	-		115	NA	NA	NA	NA
	Length of QC hold on finished goods (hrs)	0		30 days	-	150	510	**182**	**182**	**350**	**350**
	Time bet. delivery & order placement (wks)	< 1day	< 1day	< 1day	< 1day			12	12	12	12
	Time finished goods sits in inventory (wks)	8	8	4	4	60	41	**12**	**10**	**8**	**7**
	Floor space for outbound logistics (sq. ft)	1000	1000	2000	2000		1655	46,000	46,000	46,000	46,000
	Distance travelled by Finished goods (ft)	150	150	150	150		400	3,000	3,000	3,000	3,000
Safety/Morale	# of safety related incidents	0	0	0	0			1	1	0	0
	# of safety related lost work days	0	0	0	0			1	0	0	0
	# of suggestions submitted	25	25	25	25		10	0	0	1	2
	# of ideas submitted implemented	25	25	25	25		5	0	0	1	2
	Employee job absentee rate	0%	0%	0%	0%		5%	**4%**	**4%**	**3%**	**3%**
	Employee turnover	0%	100%	0%	100%		N/A	0	33%	0%	0%

It is useful to note that the brand name active ingredient manufacturing plant P6 has been reducing its finished goods inventory over the last four years. The number of safety related incidents and lost work days are down and the number of ideas submitted and implemented are up. Similarly, its job absentee rate is slowly going down. Hence, along some dimensions P6 is showing significant continuous improvement.

8.6 Evaluation of core sub process benchmarking approach

The verdict is not yet out. More benchmarking data is still coming in from plants. However, in the meantime benchmarking the core manufacturing sub processes has given us some valuable insights into the performance of each of the plants. It is possible to look at each of the metrics and highlight the highs and lows. We think that this can be valuable information for each of the plants involved in the study. For many of them, it is not clear, as to where they stand relative to other plants within the industry. Clearly every plant is different. Each plant differs in its history, its strategy, product and process technology, its organizational structure and culture. Hence, there will always be reasons why the numbers need to be different for the different plants. The goal of the benchmarking study is to provide a rigorous means to understanding the sources of the variability. We think that the core manufacturing sub process approach provides a framework to identify the sources of variability in a manner that is based on the activities of the manufacturing process by analyzing the process horizontally across the value chain rather that vertically along functional lines. Within this framework all the functions are focused on the value chain and the process flow diagram as a means to be able to manage the supply chain in order to be able to ultimately provide customer satisfaction. This is the more appropriate structure for learning.

Chapter 9

Overall Results and Discussion

9.1 Learning disabilities of the pharmaceutical manufacturing organization

While each of the companies we worked with believed that manufacturing was going to become increasingly important, many did not envision the possible role that manufacturing could play as a competitive weapon. While assigned stages is always somewhat arbitrary, most pharmaceutical plants seemed to belong to Stages 1 and 2 according to Wheelwright's classification (Wheelwright, 1985) . Many are in the process of moving from Stage 1 to 2 and trying to establish parity with other plants in the industry. However, most did not envision pharmaceutical manufacturing moving into Stages 3 or 4. In their minds manufacturing still continued to be second to R&D and marketing. Manufacturing was typically reacting to choices made in R&D and marketing. Manufacturing was not seen as being a competitive weapon.

Even though most pharmaceutical companies believe that manufacturing is becoming increasingly important, most pharmaceutical organization continue to have a defensive mindset about change in manufacturing. This is because the mindset about manufacturing is slow to change (Martin, 1993). There are many good reasons for the conservative frame of mind of pharmaceutical organizations towards manufacturing. Some of them include the large cost of making a mistake in terms of FDA and regulatory requirements and the fact that most of their products make it into the human body. There is also a large return from innovative R&D that results in novel therapeutic benefit. Hence, the mind set has been to focus on research and have a defensive strategy towards manufacturing.

We argue that this defensive mindset leads to a set of defensive routines within the organization that hinder learning. As a result many pharmaceutical manufacturing organizations suffer from many of the well known learning disabilities (Senge, 1990). This is evidenced by their defensive mindset towards manufacturing. This mindset is reinforced by the view towards manufacturing of the rest of the organization. The defensive routines are also evidenced by the structural and infrastructural choices that the organization makes. The defensive mindset shows up in structural choices about capacity, facilities, technologies and vertical integration and in the infrastrural choices about vendors, new products, human resources, quality and systems.

One of the biggest barriers to change is the pharmaceutical companies prior success. Given the drastic change in the industry structure, there is a need for a appropriate innovative response (Hammer, 1993). A number of companies within our sample are beginning to respond.

9.2 Benchmarking provides a rigorous basis for organizational learning

We think that benchmarking can provide a means to catalyze organizaitional change within pharmaceutical manufacturing. The first step is to change the organizational mindset from being functional to be based on the process flow diagram or value chain. This is the framework for organizational learning through benchmarking.

Benchmarking data obtained in both the functional form and the core manufacturing process form show considerable variability along many dimensions among the plants that have been investigated. The variability should be used as a means to drive the creative team problem solving ability of the pharmaceutical manufacturing organization. This process of understanding the sources of the variability can be used to drive the organizational learning

process. Organizational learning may be the only real source of sustainable competitive advantage (Strata, 89)

9.3 Role of accounting systems

Most pharmaceutical manufacturing plants still rely heavily on traditional cost accounting techniques where only a few cost drivers are identified and overhead is typically allocated on the basis is direct labor, machine hours and floor space. This made it quite difficult for many of the plants to fill out our questionnaire because it did not always fit into their organizational structure and available accounting information (Kaplan, 1988). There has been tremendous resistance to moving towards a more activity based costing system (Donlon, et al., 1992). Most personnel within the plant believe that an activity based cost system is not worth the effort. Once again, we believe that this is because they are underestimating the benefit that can be obtained from an accurate costing system (Keegan et al., 1989). Poor accounting information and the lack of performance measures hinder organizational learning (Mcilhattan, 1987). A few of the pharmaceutical companies are now beginning to move in that direction.

9.4 Supply chain analysis of value chain.

A number of pharmaceutical companies are beginning to focus on their relationships with suppliers. For example, plant P6 has focused on its relationships with its suppliers and has begun to make progress towards reducing the number of suppliers and developing a closer relationship with a few certified suppliers. Similarly a number of companies are focusing in their customer service levels.

9.5 Cost of Quality

To measure components of the cost of quality, we measured the amount of product that incurs additional costs during processing. Such cost can result from retesting,

excessive inventory hold, reworking, scrap, etc. This parameter was not measured in the plants examined. Further, it was difficult to arrive at a consensus on what the number was and how it could be determined from available records.

Preliminary analysis suggests that a significant amount of material produced incurs some additional cost because of something not done correctly the first time. We believe this estimate is conservative. Table 9.1 shows Juran's framework for assessing the cost of quality.

In most pharmaceutical plants quality is typically defined in terms of compliance. Hence, most pharmaceutical plants had a large number of QC and QA personnel. We believe that quality has typically been inspected in. Given Juran's framework, we speculate that the internal failure costs are too high in order to keep the external failure costs down. We argue that most pharmaceutical plants must focus on decreasing internal failure costs. In addition, given the tendency to inspect in quality we suspect that the appraisal costs are very high. We argue that the pharmaceutical plants must focus instead on prevention and building quality into the process rather than having to inspect it in.

9.6 Inventory Management: Just-in-time?

None of the plants we investigated practiced the concepts of just-in-time manufacturing. None of them believe that the concepts of just-in-time manufacturing were applicable to the pharmaceutical industry. Once, again we argue that this is because they are not thinking about JIT in terms of the philosophy. Rather JIT is still simply viewed as being a reduction in inventory.

We argue that this is because they under-estimate the cost of holding inventory.

Table 9.1: Juran's Categories of Quality Costs

INTERNAL FAILURE COSTS: *costs from product defects before shipment to the customer.*

Scrap - net losses in labor and material resulting from defective goods that cannot economically be repaired or used.
Rework - costs of correcting defective products to make them usable.
Retest - costs of reinspection and retesting of products that have been reworked.
Downtime - costs of idle facilities, equipment, and labor due to defective products.
Yield losses - costs of process yields lower that could be attained through improved process control.
Disposition - the time of those involved in determining whether non conforming products are usable and what should be done with them.

EXTERNAL FAILURE COSTS: *costs associated with defects found after shipment to customer.*
Complaint adjustment - costs of investigating and responding to complaints due to defective products, faulty installation, or improper instructions to users.
Returned material - costs associated with receiving and replacing defective products returned from the field.
Warranty charges - costs of services and repairs performed under warranty contracts.
Allowances - income losses due to downgrading products for sale as seconds and to concessions made to customers who accept substandard products as is.

APPRAISAL COSTS: *costs associated with discovering the condition of products and raw materials.*
Incoming material inspection - costs associated with determining the quality of vendors' products.
Inspection and test - costs of checking product conformance through design and manufacture, including tests done on customers' premises.
Maintaining accuracy of test equipment - costs of operating and maintaining measuring instruments.
Materials and services consumed - costs of products consumed in destructive tests; also materials and services (e.g. electric power) consumed in testing.
Evaluation of stocks - costs of testing products in storage

PREVENTION COSTS: *costs associated with preventing defects and limiting failure and appraisal costs.*
Quality planning - costs of creating and communicating plans and data systems for quality, inspection, reliability, and related activities - includes the costs of preparing all necessary manuals and procedures.
New products review - costs of preparing bid proposals, evaluating new designs, preparing test and experimental programs, and related quality activities associated with launching new products.
Training - costs of developing and conducting training programs aimed at improving quality performance.
Process Control - costs of process control aimed at achieving fitness for use, as distinguished from productivity (a difficult distinction to make in practice)
Quality data acquisition and analysis - cost of operating the quality data system to get continuing data on quality performance.
Quality reporting - costs of bringing together and presenting quality data to upper management.
Improvement projects - cost of building and implementing breakthrough projects.

Most plants viewed the cost of holding inventory as being the prevailing interest rate. However, this is not the case. Inventory is just a symptom of bigger problems. The cost of holding excess inventory is significantly higher because it is a symptom of an organization that is not fixing the underlying sources of the variability but rather buffering itself against it. Inventory hides more expensive problems.

Within the framework on the economic order quantity (EOQ) model (McClain et al., 1992) we argue that the pharmaceutical manufacturing organization is overestimating the benefits of economies of scale and underestimating the ability to reduce set up costs.

Rather than really building in the flexibility into the manufacturing system but reducing manufacturing cycle times and reducing set up times (Blackburn, 1991), many pharmaceutical companies simply build in flexibility by holding excess finished goods inventory. Once again, this is an example when the organization is dominated by the marketing arm of the organization which rather than building in flexibility into the manufacturing organization simply avoids doing that by holding excess inventory.

Chapter 10

Future work

The story is far from over. Benchmarking and learning are continuous on-going processes. There are many directions to go from here.

1. Consistency Analysis:

While the data obtained so far has been quite insightful there is no way to check the accuracy of the data that has been obtained. The data may not represent reality because of many reasons including the difficulty in understanding its definition, inaccurate data with the plant itself or the need to make inaccurate approximation. Hence an important next step would be to ensure the accuracy of the data itself.

2. Additional metrics:

It is unlikely that we have already discovered the most representative set of performance metrics. Metrics defining and refining is a constant process. There will need to be significant additions and subtractions to the existing set of performance measures.

3. Level of Analysis:

It is still unclear as to what the appropriate level of analysis is. This depends on the kinds of questions that are trying to be answered and the amount of resources available. A next step may be to go down to lower level of analysis. This decision needs to be made in collaboration with the lead benchmarking partner companies.

4. Flow of Information:

Our focus so far has been on the flow of materials as represented by the process flow diagram and the value chain. A similar analysis can be made on the flow of information through the organization.

5. Structural issues:

This study has focused more on infrastructural issues within a plant rather than interaction between plants themselves. Analysis of plant networks could be done at a higher level of analysis. This is particularly important in the context of the recent trend toward rationalizing pharmaceutical plants throughout the world (Keene et al., 1990).

6. Multi-company workshop:

There has been considerable interest in getting our lead benchmarking partners together with representatives from other plants in multi-company workshop where they can discuss metrics and the results in a more collaborative manner.

7. Interactions between R&D and marketing:

Another importance manufacturing performance issue is the nature of interaction and coordination between R&D and manufacturing and manufacturing and marketing.

8. Impact of regulation:

The existing study can be considerably enhanced by being able to measure the impact of regulation on pharmaceutical manufacturing.

9. "Best-in-class" benchmarking:

All the existing plants are from within the pharmaceutical industry. A significant additional benefit can be derived by extending this analysis to plants outside the industry.

That would significantly increase the chances of obtained innovative "best-practice" solutions.

Chapter 11

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Chapter 12

Memorable quotes

Change management:

All truth goes through three steps:
First it is ridiculed, second it is violently opposed and finally it is accepted as self-evident. -- German philosopher, Arthur Schopenhauer.

We are what we think. All that we are arises with our thoughts. With our thoughts, we make our world. -- The Buddha.

Man is not the creature of circumstance; circumstances are the creations of men. -- Benjamin Disraeli.

Things do not change; we change. -- Henry David Thoreau.

When written in Chinese, the word 'crisis' is composed of two characters - one represents danger, and the other represents opportunity. -- John F. Kennedy.

We all know how Adam said to Eve: "My dear, we live in a period of transition." -- Vida D. Schudder, The Privilege of Age.

Benchmarking:

Ask and you will receive. Seek and you will find; knock, and it will be opened to you. -- Matthew 7:7.

The important thing is not to stop questioning. Curiosity has its own reason for existing. One cannot help but be in awe when he contemplates the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries merely to comprehend a little of this mystery every day. Never lose a holy curiosity. -- Albert Einstein.

If we all did things we are capable of doing, we would astound ourselves. -- Thomas A. Edison.

The knowledge of the world is only to be acquired in the world, and not in a closet. -- Lord Chesterfield.

Learning:

Experience is not what happens to a man; it is what a man does with what happens to him. -- Aldous Huxley.

He who asks questions cannot avoid the answers. -- Cameroon Proverb.

Men are wise in proportion, not to their experience, but to their capacity for experience. -- George Bernard Shaw.

Wealth is the product of man's capacity to think. -- Ayn Rand.

As the world becomes more interconnected and business becomes more complex and dynamic, work must become more "learningful". It is no longer sufficient to have one person learning for the organization, a Ford or a Sloan or a Watson. Its just not possible any longer to "figure it out" from the top, and have everyone else following the order of the "grand strategist". The organizations that will truly excel in the future will be the organizations that discover how to tap people's commitment and capacity to learn at all levels in an organization. Peter M. Senge.

We can do it:

I know of no more encouraging fact than the unquestionable ability of man to elevate his life by a conscious endeavor. Henry David Thoreau.

Ask questions:

Take away the cause, and the effect ceases. -- Miguel De Cervantes.

Life is painting a picture, not doing a sum. -- Oliver Wendell Holmes, Jr.

All perception of truth is the detection of an analogy. - Henry David Thoreau.

There can be no transforming of darkness into light and of apathy into movement without emotion. -- Carl Jung.

Nothing happens unless first a dream. -- Carl Sandburg.

We are what and where we are because we have first imagined it. -- Donald Curtis.

We first make our habits, and then our habits make us. -- John Dryden.

Hold yourself responsible for a higher standard than anybody else expects of you. -- Henry Ward Beecher.

Man's mind stretched to a new idea never goes back to its original dimensions. -- Oliver Wendell Holmes.

We lift ourselves by our thought, we climb upon our vision of ourselves. -- Orison Swett Marden.

The best effect of fine persons is felt after we have left their presence. -- Ralph Waldo Emerson.

We have time enough if we will but use it aright. -- Johann Wolfgang Von Goethe.

A mighty flame followeth a tiny spark. -- Dante.

Every man is an impossibility until he is born. -- Raplh Waldo Emerson.

We should have no regrets. We should never look back. The past in finished. There is nothing to be gained by going over it. Whatever it gave us in the experiences it brought us was something we had to know. -- Rebecca Beard, Everyman's search.

I had six honest serving men; they taught me all I knew. Their names were where and what and when and why and how and who. -- Rudyard Kipling.

The most effective way to ensure the value of the future is confront the present courageously and constructively. -- Rollo May, Man's Search for Himself.

Three helping one another will do as much as six men singly. -- Spanish Proverb.

A conclusion is the place where you got tired of thinking. Martin H. Fischer.

The fatal tendency of mankind to leave off thinking about a thing when it is no longer doubtful, is the cause of half of their errors. John Stuart Mill.

For of course, the true meaning of a term is to be found by observing what a man does with it, not by what he says about it. P. W. Bridgman.

Reality is pretty brutal, pretty filthy, when you come to grips with it. Yet it's glorious all the same. It's so real and satisfactory. -- George Bernard Shaw, Fanny's First Play.

Never cease to be convinced that life might be better - your own and other's. -- Andre Gide, The Fruits of the Earth.

The only things that evolve by themselves in an organization are disorder, friction, and malperformance. Peter Drucker.

The toughest thing about success is that you've got to keep on being a success. -- Irving Berlin.

The great thing in this world is not so much where we are, but in what direction we are moving. -- Oliver Wendell Holmes.

Man blames fate for other accidents, but feels personally responsible when he makes a hole in one. -- Horizons magazine.

To profess to have an aim and then to neglect the means of its execution is self-delusion of the most dangerous sort. -- John Dewey.

Very often a change of self is needed more than a change of scene. -- A. C. Benson.

Words:

All the fun's in how you say a thing. -- Robert Frost.

Questionnaires:

It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to fit facts. Sir Arthur Conan Doyle - The adventures of Sherlock Holmes "Scandal in Bohemia".

"What gets measured gets done" has never been so powerful a truth. -- Tom Peters, Thriving on Chaos.

To treat your facts with imagination is one thing, but to imagine your facts is another. -- John Burroughs.

Statistics is the art of lying by means of figures. Dr. Wilhelm Stekhel.

Learning:

While information may be infinite, the ways of structuring are not... You choice will be determined by the story you want to tell. -- Richard Saul Wurman.

Learning is not a task or a problem - it is a way to be in the world. Man learns as he pursues goals and projects that have meaning for him. -- Sidney Jourard.

We are not troubled by things, but by the opinions which we have of things. -- Epictetus.

Learning can be defined as the process of remembering what you are interested in. -- Richard Saul Wurman.

Questions are the creative acts of intelligence. -- Frank Kingdom.

Tell me, I'll forget. Show me, I may remember. But involve me and I'll understand. -- Chinese Proverb.

Appendix A

Functional Benchmarking Questionnaire

MIT Program on the Pharmaceutical Industry
Industry Benchmarking Project

Performance Measures Survey
Revision: 2/07/93

Instructions:

The purpose of this survey is to analyze and compare the manufacturing operations of firms within the pharmaceutical industry. The questions attempt to establish a set of measures that characterize the performance of a manufacturing business. To best capture this, each production facility or plant site must complete its own survey.

Each plant should be treated as an individual business. For example, a plant's raw materials consist of raw materials and intermediates purchased from external sources and intermediates "purchased" (or transferred) from internal sources, i.e. other plants. A plant's finished products are both final goods that will be sold to external sources or intermediates that will be "sold" (or transferred) to other internal plants.

This survey has been divided into the following six (6) categories:

Human Resource Management (HRM)
Financial (FIN)
Production (PROD)
Quality Assurance/Operations (QA)
Materials Management/Handling (MM)
Miscellaneous (MISC)

All questions should be answered in strict compliance with the definitions given. Any qualifications should be noted, referencing the survey category and question number.

All information should come from 1990, 1991, and 1992 operating data unless otherwise specified. Data should be recorded by year and by type of production facility (i.e. bulk chemical manufacturing or pharmaceutical manufacturing). If a plant site has both chemical and pharmaceutical capabilities and these operations are physically linked by continuous production then this plant can complete one (1) survey. However if the operations are separated by inventory (over 2 weeks) then treat them as separate facilities.

Where data on top 5 products is requested, the top 5 products are determined by the highest dollar sales per year (units produced per year x final or transfer price per unit).

Company: _____

Name of Facility: _____

Location of Facility: _____

Type of Facility: _____

Age of Facility: _____

Human Resource Management (HRM)

Measure	**1991**
1) Total number of direct plant production employees	_____

Employees includes only salaried and hourly personnel in the following categories:
1) Direct production employees and supervisors (Exclude administration and maintenance).
2) QC personal and supervisors involved in raw material, production, and finished goods testing
3) Employees directly involved in material management and handling

==========

2) Production employees / Total number of employees	_____

Production employees are all employees directly associated with manufacturing as defined above in question #1.
Total employees is total plant population.

==========

3) Maintenance employees / Production employees	_____

Maintenance employees include all equipment maintenance personnel but exclude buildings and ground personnel.

==========

4) Production employee turnover	_____

Number of separations / Average number employees on payroll
Turnover figures cover all permanent separations, whether voluntary or involuntary.
This does not include employees placed on temporary layoff or retirements.

==========

5) Lost workday cases per 100 employees	_____

Total number of lost workdays / [number of employees / 100]
Production employees only as defined above in question #1.

==========

6) Production employee job absence rate	_____

Number of worker-days lost through absence / Total number of worker days

==========

7) What percent of employees are involved in work teams _____

Production employees only as defined in #1.

==========

Human Resource Management (HRM) *(continued)*

Measure	**1991**
8) Average weekly overtime hours for production employees	_____

Average number of weekly overtime hours worked by production employees only.

==========

9) Average hours of training / Total work hours _____

Production employees only

==========

Financial (FIN)

Measure	**1991**
1) Production overhead cost / Total cost of finished goods	_____ _____ _____

Total cost of finished goods includes direct materials, direct labor, and overhead.

==========

2) Maintenance expenses / Total cost of finished goods	_____ _____ _____

Maintenance expenses defined as total expenses in repairs and improvements for production buildings and equipment.
Total cost of finished goods includes direct materials, direct labor, and overhead.

==========

3) Sales / Number of production employees	_____ _____ _____

Sales are total gross revenues derived from external sales or internal transfers.
Production employees are defined in HRM Section, Question #1

==========

4) Total value of average raw material inventories held	_____ _____ _____

Include all raw materials and intermediate goods received from internal or external sources.
Exclude all bulk packaging material and utilities (ie. nitrogen, hydrogen, sterile water, etc).

==========

5) Total value of average work-in-process	_____ _____ _____

This includes all material in process and excludes raw material inventory or finished goods inventory.

==========

6) Total value of average finished goods inventories held	_____ _____ _____

Include all finished goods and intermediate goods ready for shipment to internal or external customers.

==========

7) Typical inventory holding cost _____
_____
_____

Expressed as a percent.

==========

Financial (FIN) (continued)

Measure	1991
8) Total cost of finished goods / Total cost of goods bought	_____ _____ _____

See FIN question #1 for definition of cost of finished goods.
Finished goods can be intermediates transferred to another internal plant.
Cost of goods bought are all raw materials and intermediates purchased from external sources or internal plants.

==========

9) Plant value at time of construction or purchase _____

10) Year plant was operational or year purchased _____

11) Discount rate used on plant value _____

==========

Production (PROD)

Measure	1991
1) Are your production operations operating on Just-In-Time	_____ _____ _____
2) How many total products are produced	_____ _____ _____

Products are either finished goods or intermediates that will be transferred or sold to internal or external custon ~

3) How many products use dedicated facilities	_____ _____ _____
4) How many products in #3 above are produced year-round	_____ _____ _____

Continuous operations, excluding required maintenance and scheduled clean-outs.

5) Total number of iots manufactured on site	_____ _____ _____

This includes all lots manufactured for all products at the site, both for internal plant transfer or external sales.

6) Lots manufactured right first time / Total lots manufactured	_____ _____ _____

Lots right first time are lots not rejected, retested, reinspected or reprocessed.
Product reprocessed before total process completion is counted not manufactured right 1st time.
Additional testing required that is outside of normal practice is counted not manufactured right 1st time.
Lots held pending further testing or approval are counted as not manufactured right 1st time.

7) Average total resident cycle time for top 5 products	_____ _____ _____

Resident cycle time starts with receipt of all raw materials and ends with final QC approval and delivery to internal or external customers.
Top 5 products are determined by total yearly dollar sales to internal or external customers.

Production (PROD) (continued)

Measure	1991
8) Average raw materials inventory level for top 5 products	_____
	_____
	_____

Measured in production weeks
For the top 5 finished products by sales as defined above in PROD question #7.

9) Average time required for facility turnover between products	_____
	_____
	_____

Average setup time measured in total hours (includes clean-outs, re-piping, and test runs).

10) Average number of inter-plant transfers for top 5 products	_____
	_____
	_____

How many internal transfers does the product experience before its sold to an external customer.

11) Discard rate for fermentation operations	_____
	_____
	_____

Number of batches discarded for any reason over total number of batches produced

12) Number of new products introduced into manufacturing	_____
	_____
	_____

13) Average age of equipment used in process for top 5 products	_____
	_____
	_____

14) Average capacity utilization of facility _____

Exclude turnover periods or required preventive maintenance.

==========

Production (PROD) (continued)

Measure	**1991**
15) Average capacity utilization of manpower	_____
Is there a degree of underemployment of production employees.	
16) Degree of automation	_____
On a scale of (1) to (5) rate the degree of automation for the site with (1) being mostly manual and (5) being mostly automated.	
17) New product ramp-up time	_____
If a new product was introduced, how long (in weeks) was it before the first two consecutive batches were manufactured right the first time. Refer to question #6 for definition of manufactured right 1st time.	
18) Total number of lots manufactured to date for top 5 products	_____
Measured at year end	
19) Avg number of years top 5 products have been produced at plant	_____

==========

Quality Assurance/Operations (QA)

Measure	**1991**
1) Total complaints / Number of units	_____ _____ _____

Total complaints include "customer" and FDA complaints.
"Customer" includes any user (internal or external) of finished or intermediate goods
Units measured as 1 Kilo for Bulk Chem, 100 tablets for tablets and one container for all other
If a customer complaint is made against an entire 10 Kilo delivery, this counts as 10 complaints

2) Number of vendor lots approved / Number of lots received	_____ _____ _____

This includes all raw materials and intermediates supplied by external sources.
Lots being held pending further QC tests are counted as not approved.

3) Average QC release time turnaround for raw materials	_____ _____ _____

Measured in hours, from the time materials arrive at plant to the time QC officially releases material for production use
Includes intermediates received from other plants

4) Average QC release time turnaround for finished goods	_____ _____ _____

Measured in hours, from the time goods are completed to the time QC officially releases goods for shipment or sale

5) Average length of QC hold on finished goods	_____ _____ _____

The average time (in days) finished goods are held in storage by QC because of potential abnormalities

6) Average actual raw materials test time	_____ _____ _____

Average actual test run-time, measured in hours.

7) Average actual finished goods test time _____

Average actual test run-time, measured in hours.

==========

Materials Management/Handling (MM)

Measure	**1991**
1) Number of due dates missed / Total number of deliveries	_____
	_____
	_____

Deliveries are to the "customer" (ie. pharmaceutical manufacturer, next chemical plant, stock, or marketing)
This includes internal or external customers.
Partial shipments are considered missed due dates.
Renegotiated shipping dates are considered missed due date.

2) Finished goods stock / Total inventory	_____
	_____
	_____

Finished goods stock as a percent of total inventory

3) Work-In-Process / Total inventory	_____
	_____
	_____

WIP as a percent of total inventory

4) Percentage of on-time deliveries from suppliers	_____
	_____
	_____

On-time deliveries are complete usable orders (partial deliveries are not on-time)
Materials received out of specification or held for further testing are considered not on-time
Suppliers are outside vendors and inter-plant transfers

5) Total number of suppliers for top 5 material inputs purchased	_____
	_____
	_____

Includes only raw materials and intermediates purchased from external sources.
Top 5 inputs determined by total dollar value purchased for the year.

Miscellaneous (MISC)

Measure	**1991**
1) Number of suggestions submitted by production employees	_____
	_____
	_____

Any work place or process related suggestions.
Definition of production employees in HRM Section, Question #1.

==========

2) Number of suggestions submitted by maintenance employees	_____
	_____
	_____

Any work place or process related suggestions.
Include salaried and hourly employees, but exclude management and administration.

==========

3) Total number of ideas submitted that were implemented	_____
	_____
	_____

From questions #1 and #2 above.

==========

4) Actual sales / Aggregate forecast requirements for top 5 products	_____
	_____
	_____

Actual sales are the actual Kilos taken by customer at year end (external or internal customers)
Forecast are the initial production requirements at the beginning of production year (measured in Kilos)

==========

5) Number of personnel dedicated to continuous process improvement	_____
	_____
	_____
Breakdown by degree: # B.S.	_____
	_____
	_____
# M.S.	_____
	_____
	_____
# Ph.D.	_____
	_____
	_____
# Other	_____
	_____
	_____

==========

6) Number of significant process-plant modifications _____
_____
_____

Significant defined as requiring revalidation, FDA approval, or factory shutdown in excess of 1 production week. Excludes product turnover.

==========

7) Trigger for process-plant modification:

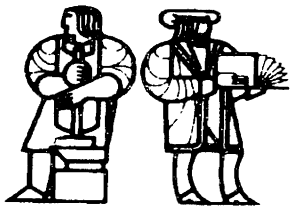
External (FDA, EPA, Customer, etc.) _____
_____
_____

Internal (ideas submitted, continuous improvement, QC, etc.) _____
_____
_____

==========

Appendix B

Core manufacturing process benchmarking questionnaire



MIT Program on the Pharmaceutical Industry

Pharmaceutical Industry Benchmarking Project

PERFORMANCE MEASURES QUESTIONNAIRE

CONFIDENTIAL

Company: _____

Name of Facility: _____

Location of Facility: _____

Primary Contact Person: _____

Title: _____

Date: _____

Please return the completed questionnaire to:
G. K. Raju,
Project Coordinator,
Pharmaceutical Industry Benchmarking Project,
MIT Room 16-011,
Massachusetts Institute of Technology,
Cambridge, MA 02139.

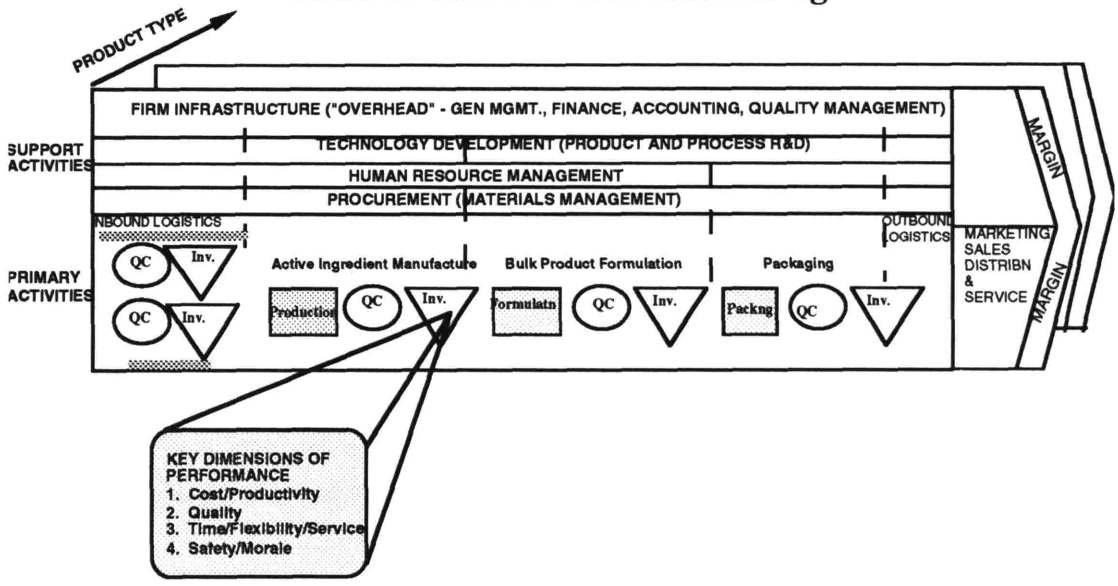
Goal:

The goal of the Pharmaceutical Industry Benchmarking Study is to analyze and compare manufacturing effectiveness and efficiency within the pharmaceutical industry. This questionnaire attempts to measure manufacturing performance through a series of qualitative and quantitative performance metrics. Data gathered in this questionnaire will be analyzed within the context of the company's mission, goals and critical success factors .

Framework for benchmarking questionnaire:

As, shown in the "framework for benchmarking" figure below, manufacturing operations are viewed as involving a set of primary and support activities. Primary activities are the activities involved in the physical creation of the product and its sale. Support activities support the primary activities by providing the material, manpower, machines and methods .

Framework for Benchmarking



The primary activities to pharmaceutical manufacturing are further grouped into five sequential processes. These primary processes are inbound logistics, active ingredient production, bulk product formulation , packaging and outbound logistics.

The first part of this questionnaire is subdivided into five sections. These sections correspond to the five sequential primary processes. Within each section we attempt to characterize the inputs (support

activities) in term of manpower, materials, machines and methods and the outputs (dimensions of performance) in terms of Cost /Productivity, Quality , Time/Flexibility/Service and Safety/Morale.

Other comments about the questionnaire:

- **Each production facility or plant site must complete its own questionnaire.** Each plant should be treated as an individual business. For example, a plant's raw materials consist of raw materials and intermediates purchased from external sources and intermediates "purchased" (or transferred) from internal sources, i.e. other plants. A plant's finished products are both final goods that will be sold to external sources or intermediates that will be "sold" (or transferred) to other internal plants. Data should be recorded by year and by type of production facility (i.e. bulk chemical manufacturing or pharmaceutical manufacturing). If a plant site has multiple manufacturing capabilities and these operations are physically linked little or no inventory held in between then this plant can complete one (1) survey. However if the operations are separated by inventory then treat them as separate facilities.

- **All questions should be answered in strict compliance with the definitions given.** Any qualifications should be noted, referencing the survey category and question number.

- **All information should come from 1990, 1991, 1992 and 1993 operating data** unless otherwise specified.

Confidentiality:

- **Both the questionnaire and the data are confidential.** The company specific details will remain confidential. Only normalized and aggregate information will be reported in an overall manner. In addition, you will be given an opportunity to review results prior to any publication. Please treat this questionnaire as being a confidential document.

PRIMARY PROCESS I
INBOUND LOGISTICS

INBOUND LOGISTICS:
Inbound logistics involves activities associated with receiving, storing and disseminating inputs to the product, such as material handling, warehousing, inventory control, vehicle scheduling, returns to suppliers.

MEASURE:	1990	1991	1992	1993
Inputs Into Inbound Logistics Process:				
People				
Number of people involved in inbound logistics				
Direct	_____	_____	_____	_____
Indirect	_____	_____	_____	_____
Avg. experience of people involved in inbound logistics Years of service (i.e. experience in field).	_____	_____	_____	_____
Education of people				
Breakdown by degree: # BS.	_____	_____	_____	_____
# M.S./MBA	_____	_____	_____	_____
# Ph.D.	_____	_____	_____	_____
# High School/Other	_____	_____	_____	_____
Materials				
Cost of materials purchased				
Raw Materials (Includes intermediates purchased from external sources)	_____	_____	_____	_____
Consumable Supplies	_____	_____	_____	_____
Methods				
Number of suppliers				
Raw Materials (Includes intermediates purchased from external sources)	_____	_____	_____	_____
Consumable Supplies	_____	_____	_____	_____
Number of certified suppliers				
Need to perform on-site QC of incoming material	_____	_____	_____	_____
Do not need to perform on-site QC	_____	_____	_____	_____
Average length of supply contracts	_____	_____	_____	_____
Dollars spent on supplier training Supplier training in JIT, quality control etc.	_____	_____	_____	_____
Time to review a supplier (vendor qualification time in weeks)	_____	_____	_____	_____

Machines

Use of Information Technology (Scale of 1 to 5) _____ _____ _____ _____
e.g.. 1 indicates Manual system, 2 a first generation MRP system,
5 indicates electronic data interchange with suppliers.

==========

Performance Of Inbound Logistics Process:

Cost/Productivity:

Average raw materials inventory level _____ _____ _____ _____

Measured in production weeks

==========

Quality:

Number of vendor lots approved / Number of lots received _____ _____ _____ _____

This includes all raw materials and intermediates supplied by external sources

Lots being held pending further QC tests are counted as not approved

==========

# of defective released lots/# of lots released _____ _____ _____ _____

==========

Time/Flexibility/Service:

Average QC release time turnaround for raw materials _____ _____ _____ _____

Measured in hours, from the time materials arrive at plant to the time QC officially releases material for product

n use Includes intermediates received from other plants

==========

Average actual raw materials test time _____ _____ _____ _____

Average actual test run-time, measured in hours

==========

Lead time between order placement and release (in weeks) _____ _____ _____ _____

==========

Average time the material sits in inventory (in weeks) _____ _____ _____ _____

==========

Percentage of on-time deliveries from suppliers _____ _____ _____ _____

On-time deliveries are complete usable orders (partial deliveries are not on-time)

Materials received out of specification or held for further testing are considered not on-time

Suppliers are outside vendors and inter-plant transfers

==========

Total time that operations has had to wait to get materials

# of times operations had to wait _____ _____ _____ _____

Average amt of waiting time _____ _____ _____ _____

==========

Total Floor Space dedicated to inbound logistics (sq. ft) _____ _____ _____ _____

==========

Average distance traveled by raw materials after receipt (ft) _____ _____ _____ _____

==========

Safety/Morale:

of safety related incidents in inbound logistics _____ _____ _____ _____

==========

# of safety related lost work days _____ _____ _____ _____

==========

suggestions submitted by employees in inbound logistics _____ _____ _____ _____

Any work place or process related suggestions

==========

# of ideas submitted that were implemented _____ _____ _____ _____

From questions #1 and #2 above

==========

Employee job absence rate in inbound logistics _____ _____ _____ _____

Number of worker-days lost through absence / Total number of worker days

==========

Employee turnover in inbound logistics _____ _____ _____ _____

Number of separations / Average number employees on payroll

Turnover figures cover all permanent separations, whether voluntary or involuntary

This does not include employees placed on temporary layoff or retirements

==========

PRIMARY PROCESS II
ACTIVE INGREDIENT MANUFACTURE

ACTIVE INGREDIENT MANUFACTURE:
This is the process in which the pharmacologically active chemical is manufactured in a pure form. This production process can be through chemical manufacturing methods or through the use of biochemical synthesis (e.g.. fermentation or cell culture). The process includes both the production and purification of the active ingredient.

MEASURE:	1990	1991	1992	1993

Inputs Into Active Ingredient Manufacture:

Manpower:

# of direct production employees in active ingredient prodn. _____ _____ _____ _____

Employees includes only salaried and hourly personnel in the following categories.

1) Direct production employees and supervisors (Exclude administration and maintenance).

2) QC personal and supervisors involved in active ingred. production

3) Employees directly involved in material management and handling in prodn.

==========

Maintenance employees related to active ingredient prodn. _____ _____ _____ _____

Maintenance employees include all equipment maintenance personnel but exclude buildings and ground personnel

==========

Material:

Method:
The following table attempts to capture some the methods employed by your firm in manufacturing the active ingredient. Please attach relevant process flow diagrams when possible. If you manufacture more than three active ingredients please add in the necessary extra columns to the table below.

Inputs to Active	Ingredient I				Ingredient II				Ingredient III			
Ingredient Manufacture	1990	1991	1992	1993	1990	1991	1992	1993	1990	1991	1992	1993
# of proc. steps in act. ingred. mfg.												
# of these steps outsourced?												
# of steps using dedicated facilities												
Produced year round?												
Batch size												
Lot size												
# of batches/yr												
Cumulative # of batches mfg. to date												
Set-up time (hrs)												
Run time (hrs)												
Annual production												
# of years of production												
# of inter-plant transfers												

How many total active ingredients are produced _____ _____ _____ _____

Products are either finished goods or intermediates that will be transferred or sold to internal or external customers

Average involvement of employees in work teams (Scale of 1-5) _____ _____ _____ _____

1 indicates that all work is done individually 5 indicates that all work is done in teams.

Education of people

Breakdown by degree:

# B.S.	_____	_____	_____	_____
# M.S./MBA	_____	_____	_____	_____
# Ph.D.	_____	_____	_____	_____
# High School/Other	_____	_____	_____	_____

people involved in "continuous improvement" _____ _____ _____ _____

Direct	_____	_____	_____	_____
Indirect	_____	_____	_____	_____

Fraction of time the workforce is idle _____ _____ _____ _____

Expressed as a percentage

Avg weekly overtime hrs for active ingred prod employees _____ _____ _____ _____

Average number of weekly overtime hours worked by production employees only

Average hours of training / Total work hours (act. ingred. prodn employees)

FDA stipulated training	_____	_____	_____	_____
On the job training	_____	_____	_____	_____
Off the job training	_____	_____	_____	_____
Other training	_____	_____	_____	_____

Total # of people involved in active ingredient QC and QA _____ _____ _____ _____

Machines:

Plant value at time of construction or purchase _____ _____ _____ _____

% yrly operating budget used for equipment enhancements _____ _____ _____ _____

Average age of active ingredient production equipment _____ _____ _____ _____

Cost of capital assumed in making equipment investments _____ _____ _____ _____

Performance Of Active Ingredient Manufacture:

Cost/Productivity

Total cost of active ingredient produced (annual) _____ _____ _____ _____

Total cost of active ingredient includes direct materials, direct labor, and overhead.

Production overhead cost _____ _____ _____ _____

Maintenance expenses _____ _____ _____ _____

Maintenance expenses defined as total expenses in repairs and improvements for production buildings and equipment

Total value of average work-in-process _____ _____ _____ _____

This includes all material in process and excludes raw material inventory or finished goods inventory

==========

Total value of average active ingredient inventories held _____ _____ _____ _____

Include all finished goods and intermediate goods ready for shipment to internal or external customers

==========

What do you perceive as your inventory holding cost? _____ _____ _____ _____

Expressed as a percent cost of capital

==========

Quality

Lots manufactured right first time / Total lots manufactured _____ _____ _____ _____

Lots right first time are lots not rejected, retested, reinspected or reprocessed

Product reprocessed before total process completion is counted not manufactured right 1st time

Additional testing required that is outside of normal practice is counted not manufactured right 1st time

Lots held pending further testing or approval are counted as not manufactured right 1st time

==========

Percentage of initiated lots that are:

Rejected by active ingred. manufacturing (waste)	_____	_____	_____	_____
Reprocessed by active ingred. manufacturing	_____	_____	_____	_____
Rejected by QC/QA	_____	_____	_____	_____
Retested by QC/QA	_____	_____	_____	_____

==========

# of 483 citations by FDA related to active ingred. mfg

Major	_____	_____	_____	_____
Minor	_____	_____	_____	_____

==========

Time/Flexibility/Service

Number of new active ingredients introduced into mfg. _____ _____ _____ _____

==========

Average capacity utilization of facility

Annual operating hours	_____	_____	_____	_____
Annual hrs reqd for preventative maintenance & turnovers	_____	_____	_____	_____
Annual hrs the equipment is idle	_____	_____	_____	_____

==========

Degree of computer automation _____ _____ _____ _____

On a scale of (1) to (5) rate the degree of automation for the site with (1) being mostly manual and (5) being mostly automated i.e. CIM.

==========

New product ramp-up time _____ _____ _____ _____

If a new product was introduced, how long (in weeks) was it before the first two consecutive batches were manufactured right the first time

==========

Number of significant process-plant modifications _____ _____ _____ _____

Significant defined as requiring revalidation, FDA approval, or factory shutdown in excess of 1 production week. Excludes product turnover

==========

Trigger for process-plant modification:

External (FDA, EPA, Customer, etc.)	_____	_____	_____	_____
Internal (ideas submitted, continuous improvement, QC, etc.)	_____	_____	_____	_____

==========

Actual prodn. / Aggregate forecast requirements _____ _____ _____ _____

Actual prodn of active ingredient (Kgs) at year end (external or internal customers)

Forecast are the initial production requirements at the beginning of production year (Kgs)

==========

Safety/Morale:

# suggestions submitted by active ingred. prodn employees	_____	_____	_____	_____

Any work place or process related suggestions

==========

# of suggestions submitted by maintenance employees	_____	_____	_____	_____

Any work place or process related suggestion

Include salaried and hourly employees, but exclude management and administration

==========

# of suggestions submitted by QC/QA personnel	_____	_____	_____	_____

Any work place or process related suggestion

==========

Total number of ideas submitted that were implemented	_____	_____	_____	_____

==========

Total # safety related incidents during active ingred. prod.	_____	_____	_____	_____

==========

Lost workday cases per 100 active ingred prod. employees	_____	_____	_____	_____

Total number of lost workdays / [number of employees / 100]

==========

Active ingredient production employee job absence rate	_____	_____	_____	_____

Number of worker-days lost through absence / Total number of worker days

==========

Active ingredient production employee turnover	_____	_____	_____	_____

Number of separations / Average number employees on payroll

Turnover figures cover all permanent separations, whether voluntary or involuntary

This does not include employees placed on temporary layoff or retirements

==========

PRIMARY PROCESS III
BULK FORMULATION

BULK FORMULATION:
This process involves combining the bulk active ingredient with inert substances like diluents or extenders. The mix is then manufactured into a finished delivery form such as a pill, capsule, tablet, cream, or lotion.

MEASURE:	1990	1991	1992	1993

Inputs into bulk formulation:

Manpower:

direct production employees in bulk formulation prodn. _____ _____ _____ _____

Employees includes only salaried and hourly personnel in the following categories.

1) Direct production employees and supervisors (Exclude administration and maintenance)

2) QC personal and supervisors involved in bulk production testing

3) Employees directly involved in material management and handling in bulk prodn

==========

Maintenance employees related to bulk formulation prodn. _____ _____ _____ _____

Maintenance employees include all equipment maintenance personnel but exclude buildings and ground personnel

==========

Material:

Method:
The following table attempts to capture some the methods employed by your firm in manufacturing the bulk product Please attach relevant process flow diagrams when possible. If you manufacture more than three bulk formulations please add in the necessary extra columns to the table below.

Inputs to Bulk	Bulk Formulation I				Bulk Formulation II				Bulk Formulation III			
Formulation	1990	1991	1992	1993	1990	1991	1992	1993	1990	1991	1992	1993
# of proc. steps in bulk formul mfg.												
# of these steps outsourced?												
# of steps using dedicated facilities												
Produced year round?												
Batch size												
Lot size												
# of batches/yr												
Cumulative # of batches mfg. to date												
Set-up time (hrs)												
Run time (hrs)												
Annual production												
# of years of production												
# of inter-plant transfers												

How many total bulk formulations are produced _____ _____ _____ _____

Products are either finished goods or intermediates that will be transferred or sold to internal or external customers

==========

Average involvement of employees in work teams (Scale of 1-5) _____ _____ _____ _____

1 indicates that all work is done individually. 5 indicates that all work is done in teams.

Education of people
Breakdown by degree: # B.S. _____ _____ _____ _____
M.S./MBA _____ _____ _____ _____
Ph.D. _____ _____ _____ _____
High School/Other _____ _____ _____ _____

people involved in continuous process improvement _____ _____ _____ _____
Direct _____ _____ _____ _____
Indirect _____ _____ _____ _____

Fraction of time the workforce is idle _____ _____ _____ _____
Expressed as a percentage

Avg weekly overtime hrs for bulk formul. prodn employees _____ _____ _____ _____
Average number of weekly overtime hours worked by production employees only

Average hours of training / Total work hours (bulk formul. prodn employees)
FDA stipulated training _____ _____ _____ _____
On the job training _____ _____ _____ _____
Off the job training _____ _____ _____ _____
Other training _____ _____ _____ _____

Total # of people involved in bulk formul. QC and QA _____ _____ _____ _____

Machines:
Plant value at time of construction or purchase _____ _____ _____ _____

% yrly operating budget used for equipment enhancements _____ _____ _____ _____

Average age of bulk form production equipment _____ _____ _____ _____

Cost of capital assumed in making equipment investments _____ _____ _____ _____

Performance of bulk formulation:
Cost/Productivity
Total cost of bulk formul. produced _____ _____ _____ _____
Total cost of bulk formuln. includes direct materials, direct labor, and overhead.

Production overhead cost _____ _____ _____ _____

Maintenance expenses _____ _____ _____ _____
Maintenance expenses defined as total expenses in repairs and improvements for production buildings and equipment

Total value of average bulk formulation work-in-process _____ _____ _____ _____
This includes all material in process and excludes raw material inventory or finished goods inventory

Total value of average bulk formulation inventories held _____ _____ _____ _____

Include all finished goods and intermediate goods ready for shipment to internal or external customers

==========

What do you perceive as being your inventory holding cost? _____ _____ _____ _____

Expressed as a percent cost of capital

==========

Quality

Lots manufactured right first time / Total lots manufactured _____ _____ _____ _____

Lots right first time are lots not rejected, retested, reinspected or reprocessed

Product reprocessed before total process completion is counted not manufactured right 1st time

Additional testing required that is outside of normal practice is counted not manufactured right 1st time

Lots held pending further testing or approval are counted as not manufactured right 1st time

==========

Percentage of initiated lots that are:

Rejected by bulk formulation (waste)	_____	_____	_____	_____
Reprocessed by bulk manufacturing	_____	_____	_____	_____
Rejected by QC/QA	_____	_____	_____	_____
Retested by QC/QA	_____	_____	_____	_____

==========

# of 483 citations by FDA related to bulk formulation

Major	_____	_____	_____	_____
Minor	_____	_____	_____	_____

==========

Time/Flexibility/Service

Number of new formulations introduced into mfg _____ _____ _____ _____

==========

Average capacity utilization of bulk formulation facility

Annual operating hours	_____	_____	_____	_____
Annual hrs reqd for preventative maintenance & turnovers	_____	_____	_____	_____
Annual hrs the equipment is idle	_____	_____	_____	_____

==========

Degree of computer automation in bulk formulation _____ _____ _____ _____

On a scale of (1) to (5) rate the degree of automation for the site with (1) being mostly manual and (5) being mostly automated i.e. CIM.

==========

New product ramp-up time for bulk formulation _____ _____ _____ _____

If a new product was introduced, how long (in weeks) was it before the first two consecutive batches were manufactured right the first time.

==========

Number of significant process-plant modifications _____ _____ _____ _____

Significant defined as requiring revalidation, FDA approval, or factory shutdown in excess of 1 production week

Excludes product turnover.

==========

Trigger for process-plant modification:

External (FDA, EPA, Customer, etc.)	_____	_____	_____	_____
Internal (ideas submitted, continuous improvement, QC, etc.)	_____	_____	_____	_____

==========

Actual prodn. / Aggregate forecast requirements _____ _____ _____ _____

Actual prodn of active ingredient (Kgs) at year end (external or internal customers)

Forecast are the initial production requirements at the beginning of production year (Kgs)

==========

Safety/Morale:

suggestions submitted by bulk formuln prodn employees _____ _____ _____ _____

Any work place or process related suggestions

==========

suggestions made by bulk formul. maintenance employees _____ _____ _____ _____

Any work place or process related suggestion

Include salaried and hourly employees, but exclude management and administration

==========

suggestions made by bulk formulation QC/QA personnel _____ _____ _____ _____

Any work place or process related suggestion

==========

Total number of ideas submitted that were implemented _____ _____ _____ _____

==========

Total # safety related incidents related to bulk formul. prod. _____ _____ _____ _____

==========

Lost workday cases per 100 bulk formul. prod. employees _____ _____ _____ _____

Total number of lost workdays / [number of employees / 100]

==========

Bulk formulation production employee job absence rate _____ _____ _____ _____

Number of worker-days lost through absence / Total number of worker days

==========

Bulk formulation production employee turnover _____ _____ _____ _____

Number of separations / Average number employees on payroll

Turnover figures cover all permanent separations, whether voluntary or involuntary

This does not include employees placed on temporary layoff or returements

==========

PRIMARY PROCESS IV
PACKAGING

PACKAGING:
The finished product is packaged into bottles or vials of various sizes and/or dosage. This process also involves labeling and boxing.

MEASURE:	1990	1991	1992	1993
Inputs into packaging:				
Manpower:				
# of direct production employees in packaging	_____	_____	_____	_____
Employees includes only salaried and hourly personnel in the following categories				
1) Direct production employees and supervisors (Exclude administration and maintenance)				
2) QC personal and supervisors involved in production testing				
3) Employees directly involved in material management and handling in prodn				
Maintenance employees related to packaging	_____	_____	_____	_____
Maintenance employees include all equipment maintenance personnel out exclude buildings and ground personnel				

Material:

Method:
The following table attempts to capture some the methods employed by your firm in packaging. Please attach relevant process flow diagrams when possible. If you manufacture more than three final package types then please add in the necessary extra columns to the table below.

Inputs to Packaging		Final Package I				Final Package II				Final Package III		
Process	1990	1991	1992	1993	1990	1991	1992	1993	1990	1991	1992	1993
# of proc. steps in packaging												
# of these steps outsourced?												
# of steps using dedicated facilities												
Produced year round?												
Batch size												
Lot size												
# of batches/yr												
Cumulative # of batches mfg. to date												
Set-up time (hrs)												
Run time (hrs)												
Annual production												
# of years of production												
# of inter-plant transfers												

How many total final package types are produced _____ _____ _____ _____

Products are either finished goods or intermediates that will be transferred or sold to internal or external customers

Avg involvement of employees in work teams (Scale of 1 to 5) _____ _____ _____ _____

1 indicates that all work is done individually. 5 indicates that all work is done in teams.

Education of people
Breakdown by degree: # B.S. _____ _____ _____ _____
M.S./MBA _____ _____ _____ _____
Ph.D. _____ _____ _____ _____
High School/Other _____ _____ _____ _____

people involved in continuous process improvement _____ _____ _____ _____
Direct _____ _____ _____ _____
Indirect _____ _____ _____ _____

Fraction of time the workforce is idle _____ _____ _____ _____
Expressed as a percentage

Average weekly overtime hrs for packaging employees _____ _____ _____ _____
Average number of weekly overtime hours worked by production employees only

Average hours of training / Total work hours (packaging employees)
FDA stipulated training _____ _____ _____ _____
On the job training _____ _____ _____ _____
Off the job training _____ _____ _____ _____
Other training _____ _____ _____ _____

Total # of people involved in packaging QC and QA _____ _____ _____ _____

Machines:
Plant value at time of construction or purchase _____ _____ _____ _____

% yrly operating budget used for equipment enhancements _____ _____ _____ _____

Average age of packaging equipment _____ _____ _____ _____

Cost of capital assumed in making investments in equipment _____ _____ _____ _____

Performance of packaging:
Cost/Productivity
Total cost of final packages _____ _____ _____ _____
Total cost of final packages includes direct materials, direct labor, & overhead.

Production overhead cost _____ _____ _____ _____

Maintenance expenses _____ _____ _____ _____
Maintenance expenses defined as total expenses in repairs and improvements for production buildings and equipment.

Total value of average packaging work-in-process _____ _____ _____ _____
This includes all material in process and excludes raw material inventory or finished goods inventory

Total value of average packaging inventories held _____ _____ _____ _____

Include all finished goods and intermediate goods ready for shipment to internal or external customers

==========

What do you perceive as being your inventory holding cost? _____ _____ _____ _____

Expressed as a percent. cost of capital

==========

Quality

Lots manufactured right first time / Total lots manufactured _____ _____ _____ _____

Lots right first time are lots not rejected, retested, reinspected or reprocessed

Product reprocessed before total process completion is counted not manufactured right 1st time

Additional testing required that is outside of normal practice is counted not manufactured right 1st time

Lots held pending further testing or approval are counted as not manufactured right 1st time

==========

Percentage of initiated lots that are:

Rejected by packaging (waste)	_____	_____	_____	_____
Reprocessed by packaging	_____	_____	_____	_____
Rejected by QC/QA	_____	_____	_____	_____
Retested by QC/QA	_____	_____	_____	_____

==========

# of 483 citations by FDA related to packaging

Major	_____	_____	_____	_____
Minor	_____	_____	_____	_____

==========

Time/Flexibility/Service

Number of new packagings introduced into packaging _____ _____ _____ _____

==========

Average capacity utilization of facility

Annual operating hours	_____	_____	_____	_____
Annual hrs reqd for preventative maintenance & turnovers	_____	_____	_____	_____
Annual hrs the equipment is idle	_____	_____	_____	_____

==========

Degree of computer automation _____ _____ _____ _____

On a scale of (1) to (5) rate the degree of automation for the site with (1) being mostly manual and (5) being mostly automated (CIM) .

==========

New product ramp-up time _____ _____ _____ _____

If a new product was introduced, how long (in weeks) was it before the first two consecutive batches were manufactured right the first time

==========

Number of significant process-plant modifications _____ _____ _____ _____

Significant defined as requiring revalidation, FDA approval, or factory shutdown in excess of 1 production week. Excludes product turnover.

==========

Trigger for process-plant modification:

External (FDA, EPA, Customer, etc.)	_____	_____	_____	_____
Internal (ideas submitted, continuous improvement, QC, etc.)	_____	_____	_____	_____

==========

Actual prodn. / Aggregate forecast requirements _____ _____ _____ _____

Actual prodn of active ingredient (Kgs) at year end (external or internal customers)

Forecast are the initial production requirements at the beginning of production year (Kgs)

==========

Safety/Morale:

suggestions submitted by packaging employees _____ _____ _____ _____

Any work place or process related suggestions

==========

suggestions made by packaging maintenance employees _____ _____ _____ _____

Any work place or process related suggestion

Include salaried and hourly employees, but exclude management and administration

==========

# of suggestions submitted by packaging QC/QA personnel _____ _____ _____ _____

Any work place or process related suggestion

==========

Total number of ideas submitted that were implemented _____ _____ _____ _____

==========

Total # of safety related incidents related to packaging _____ _____ _____ _____

==========

Lost workday cases per 100 packaging employees _____ _____ _____ _____

Total number of lost workdays / [number of employees / 100]

==========

Packaging employee job absence rate _____ _____ _____ _____

Number of worker-days lost through absence / Total number of worker days

==========

Packaging employee turnover _____ _____ _____ _____

Number of separations / Average number employees on payroll

Turnover figures cover all permanent separations, whether voluntary or involuntary

This does not include employees placed on temporary layoff or retirements

==========

PRIMARY PROCESS V
OUTBOUND LOGISTICS

OUTBOUND LOGISTICS:
Outbound logistics involves activities that associated with collecting, storing and physically distributing the product such as finished goods warehousing, material handling, delivery vehicle operation, order processing, and scheduling.

MEASURE:	1990	1991	1992	1993
Inputs into outbound logistics process:				
People				
Number of people involved in outbound logistics				
Direct	_____	_____	_____	_____
Indirect	_____	_____	_____	_____
Experience of people involved in outbound logistics Years of service.	_____	_____	_____	_____
Education of people				
Breakdown by degree: # B.S.	_____	_____	_____	_____
# M.S./MBA	_____	_____	_____	_____
# Ph.D.	_____	_____	_____	_____
# High School/Other	_____	_____	_____	_____
Materials				
Cost of materials sold	_____	_____	_____	_____
Methods				
Number of customers	_____	_____	_____	_____
Average length of contracts	_____	_____	_____	_____
Dollars spent of customer service training	_____	_____	_____	_____
Time to switch customers (in weeks)	_____	_____	_____	_____
Machines				
Use of Information Technology (Scale of 1 to 5) 1 indicates Manual, 2 a first generation MRP system, 5 indicates electronic data interchange with customer.	_____	_____	_____	_____
Performance of outbound logistics process:				
Cost/Productivity:				
Average finished goods inventory level Measured in production weeks	_____	_____	_____	_____

Quality:

Total complaints / Number of units _____ _____ _____ _____

Total complaints include "customer" and FDA complaints.

"Customer" includes any user (internal or external) of finished or intermediate goods

Units measured as 1 Kilo for Bulk Chem, 100 tablets for tablets and one container for all other

If a customer complaint is made against an entire 10 Kilo delivery, this counts as 10 complaints

==========

Time/Flexibility/Service:

Average QC release time turnaround for finished goods _____ _____ _____ _____

Measured in hours, from the time goods are completed to the time QC officially releases goods for shipment or sale

==========

Average length of QC hold on finished goods _____ _____ _____ _____

The average time (in days) finished goods are held in storage by QC because of potential abnormalities

==========

Average actual finished goods test time _____ _____ _____ _____

Average actual test run-time, measured in hours.

==========

Number of due dates missed / Total number of deliveries _____ _____ _____ _____

Deliveries are to the "customer" (i.e.. pharmaceutical manufacturer, next chemical plant, stock, or marketing) This includes internal or external customers. Partial shipments are considered missed due dates. Re negotiated shipping dates are considered missed due date.

==========

Lead time between delivery and order placement (in weeks) _____ _____ _____ _____

==========

Average time the finished good sits in inventory (in weeks) _____ _____ _____ _____

==========

Total Floor Space dedicated to inbound logistics (sq. ft) _____ _____ _____ _____

==========

Average distance traveled by finished goods (ft) _____ _____ _____ _____

==========

Safety/Morale:

of safety related incident in outbound logistics _____ _____ _____ _____

==========

#of safety related lost work days in outbound logistics _____ _____ _____ _____

==========

suggestions made by employees in outbound logistics _____ _____ _____ _____

Any work place or process related suggestions

==========

# of ideas submitted that were implemented _____ _____ _____ _____

From questions #1 and #2 above

==========

Employee job absence rate in outbound logistics _____ _____ _____ _____

Number of worker-days lost through absence / Total number of worker days

==========

Employee turnover in outbound logistics _____ _____ _____ _____

Number of separations / Average number employees on payroll

Turnover figures cover all permanent separations, whether voluntary or involuntary

This does not include employees placed on temporary layoff or retirements

==========

OVERALL ORGANIZATION

Total number of employees Total employees is total plant population	_____	_____	_____	_____
Total Plant size	_____	_____	_____	_____
Annual plant revenues	_____	_____	_____	_____