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COST ACCOUNTING IN THE AUTOMATED MANUFACTURING ENVIRONMENT

by

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Thesis Advisor: K.J. Euske

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Cost Accounting in the Automated Manufacturing Environment

by

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ABSTRACT

Cost accounting and product costing techniques are used by firms to measure the amount of resources consumed in the production of goods. Writings in the current literature [Johnson, 1987; Kaplan, 1987; Howell, 1987] have argued that traditional cost accounting should be modified in an automated manufacturing environment. The purpose of this thesis is to determine whether traditional cost accounting techniques should be modified in the automated manufacturing environment. Data for this thesis were obtained from archival research of the current literature relating to cost accounting in the automated manufacturing environment. The conclusion of this thesis is based on a comprehensive analysis of that literature. The author concludes that traditional cost accounting techniques should be modified in the automated manufacturing environment.

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I. BACKGROUND

A. INTRODUCTION

This chapter consists of four parts. Part A is the background for this thesis. In Part B, the organization of the thesis is described. Part C covers the methodology by which information was compiled for this study. Part D provides a historical look at the development of traditional product costing techniques.

B. BACKGROUND

Manufacturers employ various accounting systems in order to measure the cost of manufacturing their product. Sound managerial decision making requires a timely, relevant, and accurate measure of the resources consumed in the manufacture of that product. This thesis discusses how manufacturers determine the costs attributable to the production of their product. Furthermore, the relevancy of these product costing techniques is analyzed in the automated factory where computer assisted manufacturing techniques are used.

Every manufacturing process requires a unique blend of specific, often limited resources. Materials and labor are required to produce the automobiles we drive and the clothing we wear. If a manufacturer is to produce quality products at competitive prices, sufficient technology and accurate cost data must be available. Today, the manufacturing landscape covers a wider global span than 20 years ago. Today, world class manufacturers are employing automated manufacturing systems and techniques to produce consumer goods. Some overseas firms have unique advantages, such as less expensive labor and lower capital costs, when compared to firms in the United States. But, American companies also have some advantages, for example, being closer to many major market distribution centers. However, some feel that American manufacturers suffer from a lack of relevant and accurate product costing techniques [Howell, 1986; Johnson, 1987; Kaplan 1987].

C. ORGANIZATION

This thesis is divided into six chapters. Chapter I provides an introduction to this thesis and a discussion of the origin of traditional product costing techniques. Chapter I discusses why product costing became important, and how product costing techniques were developed. Chapter II contrasts the traditional manufacturing environment, which spawned the traditional product costing techniques in use today, with the new manufacturing environment under automated manufacturing capability. Chapter III presents a discussion of traditional product costing methods and the supporting techniques necessary to allocate indirect production costs. This discussion provides the conceptual basis for Chapters IV and V. Chapter IV discusses the impact of manufacturing hardware on cost accounting. Chapter V discusses the impact of this new automated hardware on aspects of manufacturing such as product quality and inventory levels. Chapter VI offers recommendations based on the findings contained in the prior chapters. Chapter VI also summarizes the major points of this thesis and contains some recommendations for related topics worthy of additional research.

D. METHODOLOGY

This section describes the manner in which information was obtained for this study. The primary source of data for this thesis was archival research of the current literature relating to cost accounting in the Computer Integrated Manufacturing (CIM) environment. Traditional job and process costing are discussed in order to present the historical perspective and to describe the techniques in use today. The results of recent surveys in cost accounting practices were reviewed and the relevant data have been incorporated into this thesis. Contemporary writings, interviews, and summaries from conferences, such as "The Conference on Cost Accounting, Robotics, and The New Manufacturing Environment" of February 1987, have been reviewed for this thesis.

E. ORIGIN OF PRODUCT COSTING

In order to understand the reasons why some of the traditional managerial and product costing techniques appear weak in the new manufacturing environment, it is instructive to review the historical development of managerial accounting. In this section, the origins of management accounting are discussed. This section traces the evolution of product costing techniques from the early 1800's to the present. It is shown why accurate product costing became a necessary adjunct to accounting systems, and how managers tailored product costing systems to their needs. It is helpful to examine product costing under the larger heading of management accounting, since management accounting is the framework within which many of the product costing concepts were developed. For clarity, the discussion concerning the development of product costing is separated into five distinct periods as follows:

1. Pre-1800
2. 1800-1850
3. 1850-1880
4. 1880-1930
5. 1930-1987

The manufacturing processes and transactions prior to 1800 are examined first.

1. Pre-1800: In the Beginning

Because of the way in which manufacturing processes were accomplished before 1800, profit was easily measured without resorting to specific product costing techniques as we know them today. Before the Industrial Revolution, most manufacturing was accomplished by hand, often in homes and rural areas. During this time, most manufacturing business transactions took place between a business owner, that is an entrepreneur, and a second, entrepreneur [Chandler, 1977]. This meant that most manufacturing was performed as a chain among separate business owners. The raw materials would be gathered or accumulated by the first entrepreneur, who would then pass the goods to the second entrepreneur by means of an economic transaction based on existing market conditions. As a consequence of each "entity" performing primarily only one function, there were virtually no layers of managers or employees [Johnson, 1987]. The single layer, or single skilled employees, would perform a solitary function, such as gathering the raw materials, or a single transformation process. For example, the owner of a sheep farm would raise the sheep, and shear the wool. He would then sell the wool at the "going market price" to the next entrepreneur in the chain, who would perform the next operation of processing the wool. After this was accomplished, the processed wool would be passed along, again at the market rate, to the next entrepreneur, whose specialty would be to convert processed wool into thread. After this step was completed, the thread would be sold to a weaver, who would weave the wool into cloth, and again sell the cloth to a merchant, who would then sell the "finished goods" in the marketplace to the consumer. Transactions occurred directly within the marketplace; success, in terms of profitability, was quickly and easily determined. The owner simply had to collect more cash on sales than he had previously paid to the suppliers of the input factors of production, principally labor and materials [Johnson, 1981].

Before the early 1800's, manufacturing was accomplished in different stages, each stage performed by different entrepreneurs. At each step along the way, value was added, and profit was measured within the market place as the goods changed hands from one entrepreneur to another. Profit, or loss, was discernible coincident with the economic transaction within the market structure. The manufacturing and accounting environment began to change between 1800 and 1850, as the effects of the Industrial Revolution significantly increased machinery sophistication, enabling a change in economies of scale.

2. <u>1800-1850: Effects of the Industrial Revolution</u>

This section discusses the impact of the Industrial Revolution on selected firms and on managerial and cost accounting between 1800 and 1850. During this period, manufacturing technology and production processes changed significantly as power driven machinery arrived on the manufacturing scene. This event somewhat reduced the direct labor content required in some production processes when compared to the prior era. Machines became available to perform portions of the manufacturing process, which before now had been virtually 100 percent manual labor. Although the new machines could process large volumes of direct materials, the machines themselves were not very versatile. Many still required a great deal of manual effort, so the direct labor content in manufacturing processes was still very high [Chandler, 1977]. However, this change, resulting from more capable machinery in the manufacturing process, did cause the requirements for measuring production cost information to change. Some of these accounting innovations were made by the large manufacturing firms in the textile and steel industries. Service industries, particularly the railroads, were also involved in developing some of the early cost measurement techniques. This section begins with a discussion of early cost accounting systems used by manufacturers.

Perhaps the earliest accounting systems resembling product cost systems were the cost accounting systems used by Charlton Mills in England around 1800 [Stone, 1973], the Boston Manufacturing Company around 1820 [Porter, 1980], and by Lyman Mills, a large textile manufacturing firm in New England around 1840 [Johnson, 1987]. The Lyman Mills accounting records provide the best example of early cost accounting practice [Chandler, 1977]. According to Johnson, Lyman Mills is "particularly important because Lyman is the earliest known example of a completely integrated double-entry cost accounting system" (1972, p. 468). By the mid-1800's, Lyman Mills was producing a wide variety of finished cotton goods, and needed an internal system to measure the effects of various manufacturing decisions. Consequently, Lyman Mills began to keep track of the amount of cotton material entering the manufacturing process, and the amount leaving the factory as finished goods. In so doing, Lyman Mills utilized a version of the standard, double entry accounting system to provide data by which to monitor the receipt and control of raw cotton, together with data concerning the cost of goods sold, and worker productivity [Johnson, 1975]. The Lyman Mills accounting system needed to capture the costs incurred in manufacturing cotton goods in a factory where multiple production processes were performed. Since the firm accomplished multiple manufacturing functions internally, Lyman Mills needed measures for the efficiency of each production step. In comparison to the pre-1800 manufacturing era, Lyman Mills was simply creating surrogate price measures. They were now conducting all the various processing functions internally, and without the marketplace to fix prices, had to generate their own values of worth to the product within the factory.

Thus, it is seen that Lyman Mills recognized, and addressed, the needs of manufacturers to measure, and utilize the basic concepts of product costing in their factory accounting process.

The "on-going" effects of the Industrial Revolution, coupled with developments in telecommunications, such as the telegraph, meant that firms could now take advantage of some larger economies of scale. Firms could even be geographically separated and still remain in close contact with corporate sub-units by means of these new communication capabilities. These kinds of technical developments enabled growth in service organizations, like the railroads, who also contributed to the methodologies for measuring cost data. By the mid-nineteenth century, the railroads were developing into the largest industry of their day. Compared to virtually all other industries, the railroads handled a significantly greater number of dollar transactions [Kaplan, 1984]. To fully appreciate the magnitude of these enterprises, one needs to recall that besides the main office, railroads also provided services from regional offices located in different parts of the country. These regional offices often executed transactions involving cash receipts both for passenger services and freight handling, while the home office made strategic decisions regarding capital outlays for costly fixed assets. Therefore the railroad companies needed to develop procedures to facilitate accounting for large numbers of cash transactions, more transactions than any other firms had previously encountered [Chandler, 1977]. Therefore, the railroads not only needed a means of evaluating the costs and expenses of their overall operation and regional sub-units, they also had to evaluate their transportation services in light of maintenance and expansion decisions. The managers and users of railroad cost data devised specific ratio measures, such a cost per ton-mile and various other operating ratios, to help them evaluate and control the performance of their organization. [Chandler, 1977] These measures were conceptually advanced for that period of time and, perhaps because they were created by those who needed the specific kinds of information, appear to have been very effective in measuring and presenting relevant cost data [Chandler, 1977]. The railroads made important contributions to the use of ratios in evaluating costs, and making management decisions derived from cost relationships per unit item. [Chandler, 1977]

Between 1800 and 1850, manufacturing and service firms were beginning to expand in response to the technological changes of the period. This expansion began creating pressure on these organizations to develop more sophisticated means of accumulating and tracking cost information, not only for their own internal decision making processes, but also for limited external use. This trend was to continue, and increase, over the next 30 years.

3. <u>1850-1880: Growth in Product Costing</u>

This section discusses the impact specific organizations had on the development of management accounting and product costing techniques. During the years between 1850 and 1880, the manufacturing capability and production complexities of many firms expanded. This expansion occurred partially in response to the increased technological capabilities in the wake of the industrial innovations of the previous 50 years [Chandler, 1977]. Many of these organizations adopted the concepts of cost measurement which had been used by the railroads and, to some extent, by the Lyman Mills system. [Kaplan, 1984] During this period, mass production and mass distribution firms became a dominant force in the growth and development of cost accounting measures [Johnson, 1987]. Some of the more dominant firms were the large manufacturing organizations, such as the Carnegie Steel Mills, and the large retail firms, such as Sears and Woolworth's [Johnson, 1987].

Andrew Carnegie's steel mills provide a particularly good example of the importance of cost accounting information for managing an enterprise [Johnson, 1975]. Carnegie was renowned for his concern for cost data. His staff developed the means of accumulating costs as the various types of raw materials used in steel making flowed through the different stages of steel production. The core of Carnegie's product cost system was the use of a voucher sub-system whereby each department listed the amount, type, and cost of materials and labor consumed as each order passed through the separate factory processes. [Chandler, 1977]. Carnegie meticulously tracked the material costs, labor costs, variable costs, and what are known today as fixed costs [Johnson, 1987]. Variable costs were those costs which would rise or fall as the production level varied. Fixed costs, on the other hand, were those costs which were incurred in a lump sum which then remained fixed for an established period of time. Carnegie used variable material and labor cost information produced by this system to manage the operating tempo of his steel mills, and to set product prices. Fixed costs, such as depreciation and maintenance, were treated differently as discussed later. By continually and carefully analyzing the cost data, and aggressively pricing products, he consistently operated his steel mills at full capacity. During recessionary periods, he could cut prices to maintain demand, often forcing competitors out of business. From the standpoint of profitably managing a large manufacturing business, Carnegie was clearly among the best of his time, and one of the underpinnings of his cost management system success was the product costing mechanisms that he and his staff developed

[Chandler, 1977]. In creating Carnegie Steel's cost system, Carnegie and his staff drew heavily on some of the same concepts previously devised by the railroads. According to Chandler,

> Carnegie's pre-eminence in the industry came from his commitment to technological change and his imaginative transferal to manufacturing of administrative controls developed on the railroads. (1977, p. 268)

Carnegie's concern for complete cost information, and his creative use of cost ratios contributed to the development of early cost accounting.

Despite the benefits of the Industrial Revolution, Carnegie's manufacturing processes still required significant direct labor input. Therefore, the accounting measures of his day were often based on a high content of direct labor. During this period, the focus was on prime (labor and material) costs, conversion costs, and operating data [Chandler, 1977]. There apparently was little analysis of factory overhead or its allocation to product costs. Chandler says,

> Carnegie and his associates appear to have paid almost no attention to overhead and depreciation. Administrative overhead and sales expenses were comparatively small and estimated in a rough fashion. Carnegie relied on replacement accounting by charging repair, maintenance, and renewals to operating costs. (1977 p. 268)

Major retailers and distributors of the late 1800's also contributed to the development of additional product costing techniques, including the use of ratios. These firms needed different types of operating measurements, so they devised particular ratios to provide the management data they needed. These firms, such as Sears, Woolworth's, and Marshall Field's created measures, such as gross margin by department, and inventory stockturn, to assist them in management decision making and evaluating the costs of their business [Johnson, 1987].

During this period, firms apparently became more cognizant of the value of accurate product cost data. They, the operators, collected detailed cost data, and fashioned these data into ratios. These ratios described the business transactions in terms that would help managers more effectively evaluate their firm's performance. These innovations provided the background for the industrial engineers of the next period to develop even more accurate cost data by application of engineering principles.

4. <u>1880-1930: The Scientific Management Movement</u>

This section first discusses some of the new product costing concepts which were introduced by managers trained in industrial engineering. Frederick Taylor, and others, established new process costing techniques based on applications of engineering principles. Secondly, this section discusses the use of these product costing concepts at the same time that structural changes began to occur in corporate organizations, and firms began to decentralize. This section starts with a discussion of the inception of product costing concepts based on engineering principles.

a. Effects of the Industrial Engineers

One of the first effects of the industrial engineer involvement was the introduction of the formal notion of work standards [Johnson, 1987]. Innovators of this period, like Taylor, developed physical standards (such as labor grade, labor hours per unit, and material quantities per unit), which were then converted into standards in order to determine projected labor and material costs [Johnson, 1987]. As work standards were established, standard costs were obtained and related to standard volume, throughput, and plant capacity.

A second effect was the refinement made to the concept of measuring and allocating prime costs [Kaplan, 1984]. These refinements gave firms a greater ability to accurately price their products in accordance with their costs. Fixed assets were accounted for under the concept of replacement accounting, so that fixed capital costs were not allocated to products or periods; however, certain other related items, like repairs, were assigned to the cost of manufacturing [Kaplan, 1984]. These "finished product" unit prices were specifically designed to improve management decision making capability, and were similar to "conversion efficiency" measures previously formulated by the railroads and steel mills. [Kaplan, 1984]

As a result of these innovations, again by the "users" themselves, labor and materials were able to be more efficiently controlled by the firm's managers. Implementation of these new concepts occurred at a time when the structure of the firm itself was changing. The relationship between these two events is discussed in the next section.

b. Effects of Corporate Restructuring

The evolutionary process of large manufacturing firms also prompted some changes to the growing areas of management accounting and product costing. In the early 1900's, some firms began to grow significantly in size as they decentralized and expanded into multiple markets. As companies moved into several product lines (for example, DuPont moving from strictly producing gunpowder into the production of paint and synthetic fibers), these companies found it expedient to decentralize management because the information systems of the day were not capable of enabling sound management of a large, multi-product, decentralized organization [Johnson, 1986]. It became apparent that, where multiple product lines were concerned, divisions organized along those product lines seemed to operate more effectively than a single, all encompassing, hierarchical organizational framework [Chandler, 1977]. This new organizational structure also freed top corporate management to concentrate on strategic policy decisions, while the individual division managers concentrated on the daily operating decisions affecting their particular divisions [Chandler, 1977]. Of course, corporate headquarters still retained overall responsibility for the divisions [Chandler, 1977].

Similar evolutionary changes also occurred in the growing General Motors organization, under the leadership of Alfred Sloan. By creating annual operations forecasts, flexible budgets, and tools for establishing management compensation programs, GM's management accounting system helped management achieve "centralized control with decentralized budgets" [Johnson, 1978]. These innovative concepts offered a relatively effective means of controlling growing organizations as they decentralized into separate divisions.

These changes in the corporate structure necessitated various changes in the accounting and product cost systems in order to enable managers at different levels to effectively evaluate the trade-offs associated with product mix decisions, and corresponding decisions relating to investment strategy, and capital acquisitions. Manufacturers now had to coordinate various activities within vertically integrated manufacturing organizations and to make decisions regarding the best use of capital among the different options and divisions. Although decentralization fragmented the firm, it worked well at such places as DuPont and General Motors [Chandler, 1977]. Relevant product costs were more effectively tracked in a decentralized environment, because divisional managers were primarily responsible for their own operation, smaller in scope than the overall organization.

Around this time, other product costing techniques, which are still in practice today, came into existence. First, the concept of standard costing was expanded and applied to flexible budgets and variance measurements. This enabled more accurate monitoring of operations by top management, and facilitated process adjustments. Second, managers recognized the relationship between direct labor, and overhead expenses and thus, began to base overhead allocations on direct labor. Third, the concept of Return on Investment (ROI), engineered by Donaldson Brown at DuPont, and employed by Sloan at GM, became an established measure by which to analyze performance. [Johnson, 1975]

Thus it appears that by the late 1920's, many of the manufacturing accounting concepts used today had been discussed, developed, and put into practice. Cost accounts for labor, material, and overhead were in use, as were standard costs, variance analysis, and flexible budgets. These concepts had been developed by managers and engineers for the explicit purposes of determining operating costs, measuring process and worker performance, and enabling better organizational control by top management. This information was intended primarily for internal management use, and there was no requirement that the data exactly match the information produced by the transaction books, which were used to prepare financial statements for external consumption [Kaplan, 1984].

5. 1930-1988: Into the Present

The process costing techniques and corporate management control systems developed at DuPont and General Motors seem to have served as the model systems for most major firms today [Johnson, 1986]. However, the diversity of products, decentralization of corporate organizations, and especially the complexity of the manufacturing process has continued to increase. This section discusses some of these issues.

There have been innovative concepts relating to costing processes during this period, many of which derive from the Operations Research field. Such techniques as learning curve analysis, economic order quantity, and regression models offer some refinement to cost estimation processes. Few of the tools however provide significant refinement to the area of measuring and allocating prime costs and overhead. [Kaplan, 1984].

Recently, some manufacturing organizations have appeared as network organizations. These network structures link together (virtually by telephone only) the various functions necessary to produce and distribute consumer goods [Miles, 1986]. Often such companies seem to seek less costly overseas labor. Some manufacturing firms are now utilizing computer assisted manufacturing technology in their processes. All these shifting conditions, some of which are truly major in scope, suggest modifications to product costing may be needed.

Because product costing techniques have apparently not adapted to today's manufacturing technology, some firms now seem to be experiencing distorted product costs. This condition can prevent firms from accurately recognizing the true effects of their economic transactions [Johnson, 1987].

6. Summary

Product costing in the manufacturing industry appears to have begun in the early 1800's. As machinery became more automated during the Industrial Revolution, innovative managers devised engineered measures enabling them to more accurately determine product costs. As firms evolved into decentralized, multi-product manufacturers in the beginning of the twentieth century, corresponding modifications were made to product costing systems to facilitate cost and performance measurement as well as strategic investment decisions. However, since 1930, there appear to have been few innovations in product costing to accompany the simultaneously occurring increases in manufacturing technology complexity and capacity. Today firms are observed utilizing computer assisted design, engineering, and manufacturing techniques. However many firms are still using traditional product costing in this new manufacturing environment [Johnson, 1987]. Is traditional product costing still giving us accurate product cost information? Should efforts be made to make product costing more relevant? What are the attributes of this new manufacturing environment? The answers to some of these questions are discussed in the next chapter as the new manufacturing environment is examined and compared to the traditional manufacturing environment.

II. NEW VERSUS OLD MANUFACTURING ENVIRONMENT

A. INTRODUCTION

In the last chapter, it was shown that many of today's product costing techniques were developed by the early 1900's. Those product costing techniques satisfied the needs of managers in a highly labor intensive manufacturing environment.

In the 1960's, both here and abroad, manufacturing technology began to change. Mechanized manufacturing systems attained higher levels of capability and sophistication. Computers, capable of communicating with, and controlling these mechanized manufacturing systems were also developed. Increasing global competition has resulted in many manufacturers incorporating these computerized manufacturing techniques into their production processes [Lee, 1987]. What significant features characterize this new manufacturing environment? What changes are occurring today because of automation in product manufacturing? Do these changes affect traditional costing systems and the product costing techniques still commonly used today? This chapter discusses features of the new factory environment.

B. THE NEW MANUFACTURING ENVIRONMENT

As discussed in this chapter, manufacturing technology has undergone some dramatic innovations over the last 20 years. To successfully compete in the global market today, firms must continually produce quality products, while simultaneously meeting demands for shorter leadtime, and greater flexibility. To meet this challenge, aggressive firms are taking advantage of newer, and often more automated, forms of manufacturing systems [Lee, 1987]. As such firms begin to employ this more innovative type of technology, other firms find it necessary to follow suit to remain competitive [Lee, 1987]. Therefore, it seems as though the growth in sophistication and capabilities of manufacturing technology is here to stay, and will continue to increase.

The arrival of these new manufacturing systems ushers in some significant changes in the manufacturing environment, particularly when compared to the traditional factory. Brimson (1986) presents some of the contrasts between the traditional environment and the new environment:

Traditional Environemnt	New Environment
Longer lead times	Shorter lead times
Manual information systems	Computerized information
Workers transport material	Machines transport material
Workers operate machines	Machines operate machines
More error tolerance	Less error tolerance
Longer product life cycle	Shorter product life cycle
Higher variable costs	Higher fixed costs

Although the above listing is not all inclusive, it indicates differences between the two manufacturing environments. These contrasts arise primarily due to the introduction of automated manufacturing systems [Brimson, 1986].

The next section contains a discussion of the various automated systems that are being used in today's competitive manufacturing environment. Several hypotheses are offered to explain why some of the contrasts noted above may occur with the use of these automated manufacturing systems.

C. AUTOMATED MANUFACTURING SYSTEMS

This section contains a discussion of the different automated systems being used by today's competitive manufacturers. Additionally, other systems are discussed which may become more prevalent over the next 10 years as competition in the global market becomes even more intense. First, the characteristics of an industrial robot are discussed. Secondly, the next higher level of sophistication, the Flexible Manufacturing System (FMS), is examined. This chapter concludes with a description of Computer Integrated Manufacturing.

1. Industrial Robots

Commercial use of the industrial robot appears to have begun during the 1950's. At that time, most manufacturing robots were single purpose machines, individually programmed to perform, at most, only a few specific functions [Kleindorfer, 1985]. As the computer industry attained higher levels of capability, application of computers to robots became more prevalent. During the mid-1970's, robots controlled by general purpose, digital computers were introduced into the commercial sector [Kleindorfer, 1985]. Such innovations vastly expanded the potential capabilities of industrial robots. The computer could automatically provide manufacturing instructions and procedural guidance directly to the machine, which was capable of performing the manufacturing function. These profound changes served as the beginning point of some of the major new thrusts seen in manufacturing technology.

Industrial robots today can perform a wide variety of manufacturing functions. Robot versatility encompasses many tasks previously performed by human labor. Because robots seldom become ill, engage in labor disputes, or terminate employment on short notice, industrial robots can add a degree of workforce stability for the firm. Simultaneously, employment of robots can enable workers to engage in more stimulating jobs and safer working conditions [Weimer, 1986]. Using current technology, manufacturing robots can weld, spray, paint, handle materials, load machines, assemble parts, machine (manufacture), and inspect parts. Further, industrial robots, upgraded with vision and other sensory technology, can compensate for variations in materials and accomplish even more diversified activities, often relieving the traditional direct labor worker of the more monotonous and dangerous jobs. Of the various robotic functions noted above, it appears that the area of product assembly is the fastest growing application of robotic technology [Weimer, 1986]. Manufacturing processes which are labor assembly intensive undergo significant changes as a result of the introduction of robotic technology [Miller, 1986]. Besides their adaptability to the assembly function, another strength of robotic technology today lies in their tremendous flexibility when upgraded with state-of-the-art hardware and linked to supervisory, computer control. Today a robot under such conditions can perform several manufacturing functions at once, while simultaneously working with multiple products [Weimer, 1986]. Besides enabling a variety of outputs, such flexibility can reduce capital outlays when modifying the end product [Miller, 1986]. Industrial robots can significantly alter traditional manufacturing processes.

Despite the many advantages robots offer, they do come with some limitations. One is cost. In 1983, the cost of welding robots was around $160,000, while less expensive material handling robots could be obtained for about $75,000 [Kleindorfer, 1985]. According to Kleindorfer, the robotic unit itself represented about 50% of the cost, while necessary accessories amounted to another 30%, leaving the remaining 20% to be absorbed by installation charges. A second limitation affecting robotic systems is the requirement that some of the items which they must handle be specially prepared. This requirement arises due to the limited number of ways in which robots can receive items, perform mechanical operations, and subsequently pass the product to the next operation. For example, robot gripping systems can only handle products prepared in ways which are compatible with that particular type of gripper.

Nevertheless, robotic manufacturing systems are one way in which today's manufacturers are competing in the marketplace. While robots may represent a relatively low level of automated manufacturing, they do offer a significant increase in manufacturing capabilities. These capabilities portend major changes, as discussed later, to the ways in which production costs are measured and evaluated.

2. Flexible Manufacturing Systems (FMS)

In the last section, the capabilities, advantages, and some of the limitations of industrial robots as single, automated manufacturing machines were discussed. In this section a discussion of the Flexible Manufacturing System (FMS) is presented.

Kleindorfer describes a flexible manufacturing system as:

> A group of CNC (computer numerical control) machine tools linked by an automated materials handling system, whose operation is integrated by supervisory computer control. Integral to an FMS is the capability to handle

> any member of similar families of parts in random order. (1985, p. 12)

In practice, it appears that the exact makeup of an FMS may vary somewhat with different types and amounts of machinery. However, the basic concept still applies, whether robots or other types of computer controlled machine tools are used.

Flexible Manufacturing Systems have been described by some as a central part of the factory of the future [Lee, 1987]. FMS promises a variety of significant advantages, such as greater productivity, higher product quality, improved quality consistency and reductions in work in process inventories and direct labor costs. The key element in a typical FMS is that control to manage the workload derives from the firm's central information system. Virtually all elements of the manufacturing system are directed by a master computer station which monitors numerous machine functions, such as fault analysis, and work in process cycles. The amount of computer control is determined by the system's complexity. There is minimum direct labor involved in operating an FMS. Manpower is still required to support certain aspects of the system, such as computer programming support and machine maintenance. Despite many strong points, FMS's are relatively expensive, and thus may not be appropriate for every firm. It appears that FMS's have been developed mostly to serve the middle ground of batch manufacturing where the part variety is not great enough to justify dedicated processes, such as transfer lines, yet the part variety is too high to be efficient with stand alone machine tools. [Young, 1986]

The current literature suggests that in 1987, most flexible manufacturing systems were employed in a limited number of industries, such as the automotive industry, and the aerospace industry [Foster, 1988]. To ensure maximum productivity, these firms designed redundancy into their flexible manufacturing systems. For instance, LTV Aerospace Defense Co., Vought Aero Products Div., Dallas utilizes a very sophisticated, computer integrated flexible manufacturing cell, consisting of eight machining centers. As a result of the system redundancies and multiple backups, the division claims that the system is operational greater than 90% of the time. Furthermore, their system runs three daily shifts, six days per week, with Sunday set aside for preventive maintenance [Wilson, 1985]. Such capabilities carry implications for costing systems and manufacturing strategies. Increased versatility may well mean that many parts, which previously required outside purchase, can now be produced more economically in-house. Also, significant increases in productivity typically result from this kind of automation. At LTV, for example, the FMS reduced 200,000 hours of conventional machining time to only 70,000 hours. It reduced direct labor content by two thirds, and resulted in lower necessary skill levels to load the machines, as compared to the previous higher skill level required to operate the previous machines [Wilson, 1985]. Following machine loading, there is typically no direct human intervention in this fully automated system until unloading. All of these characteristics suggest a significant restructuring of manufacturing costs in labor and other cost areas. The entire FMS concept stands out in contrast to the traditional manufacturing environment.

Flexible Manufacturing Systems stand on the middle ground between the single industrial robot machine, and a total Computer Integrated Manufacturing system. FMSs, like robots, appear capable of altering the manner in which production costs are incurred, and as we discuss later, the manner in which costs should be measured and treated.

3. Computer Integrated Manufacturing (CIM)

The next level of sophistication in automated manufacturing is usually referred to as a fully developed Computer Integrated Manufacturing (CIM) system [Lee, 1987]. The CIM system normally consists of several subordinate systems, usually referred to as Computer Aided Drafting (CAD), Computer Aided Engineering (CAE), and Computer Aided Manufacturing (CAM). In order to gain an appreciation for the capabilities, and product costing implications of each of these subsystems, it is helpful to take a brief look at each one separately.

a. Computer Assisted Design (CAD)

According to Goetsch,

> Computer aided design, involves using the computer as a tool in the design of a product, and the development of drawings for that product. In addition, the computer is used for compiling parts lists, bills of materials, schedules, and all of the other tasks which together with making drawings, are collectively known as drafting. (1983, p. 65)

Computer aided design is a key concept in CIM, however automated methods of constructing graphics is not purely a phenomena of this decade. In the 1950's, the U.S. military employed an interactive graphics system called "Sage." About 15 years ago, General Motors was beginning to experiment with the application of computer graphics to computer generated design drawings. In the last decade, many other firms, especially in the aerospace and electronics industries, have engaged in more sophisticated use of computer aided product design. [Ryan, 1979]

There are several unique characteristics that make computer assistance in design advantageous to the automated manufacturing process. A draftsman is creative, but relatively slow and communicates in a limited number of ways. Conversely, the computer is mechanical, fast, capable of communicating through multiple mediums simultaneously, and can produce output quickly and accurately. Consequently, matching man and machine should produce significant savings of time and money in the long term, while yielding drawings of higher quality. Dollar savings of 6:1, and time savings from 20:1 even up to 50:1, have been reported [Ryan, 1979]. These levels of savings in dollars and labor are significant, but assume greater importance because of their timing at the initial stages of a new product's life, when many major life cycle cost decisions must be made.

Additionally, most of today's automated drafting machines are easy to operate, and capable of direct translation of rough sketches into high quality drawings. These machines are easily adaptable for use in three-dimensional construction, engineering drawings, manufacturing drawings, tool design, assembly drawings, electrical schematics, piping and hydraulic layouts [Ryan, 1979].

The product design stage can now be automated such that the manual chore, faced by the traditional draftsman of laboriously plotting and drawing preliminary designs using triangles and T-squares, can be replaced by computer capability. Automation of this function is especially valuable when speed, flexibility and accuracy are desired. Additional benefits accrue when the drawings are directly put into a common company data base accessible by the product engineering staff. [Ryan, 1979]

b. Computer Assisted Engineering (CAE)

The benefits of Computer Assisted Design multiply when interfaced with the engineering function. In the traditional manufacturing environment, the engineers would produce the drawings by hand, then submit the drawings to the manufacturing department to verify feasibility and manufacturability. In the automated CAE environment, the engineer designs the product using computer graphics. The drawings are immediately accessible to the manufacturing personnel simply by accessing the company's data base. Validation, especially if done algorithmically by computer calculations, can also be performed more quickly, and any necessary modification can be accomplished immediately. This represents a key feature of the CIM concept, especially where new products are concerned. The product can be designed quickly and accurately, precisely to customer specifications, and concurrently validated by those who must actually manufacture it. All necessary changes can be incorporated before beginning the manufacturing stage. The introduction of automation reduces the manual intensity of the manufacturing process, but at the same time it adds another dimension to measuring product cost. The next section illustrates how CAE and CAD lead to Computer Aided Manufacturing and the actual fabrication of the product.

c. Computer Aided Manufacturing (CAM)

In the true CIM environment, virtually all product manufacturing is performed under the supervisory control of a central computer. The product drawings, parts descriptions, and material lists become the initial driving force for the automated manufacturing process. Materials and assembly information, loaded into the data base at the CAD/CAE stage, become the bill of materials, list of supplies, and quality assurance measure of the product [Weimer, 1986]. In accordance with the master schedule, the necessary parts and materials arrive at the proper manufacturing points on the factory floor. As the product flows through each point, the necessary functions, such as cutting, welding, painting, assembly, and inspection are each performed in proper sequence. Automatic process monitoring and product inspection are conducted under computer control. Often, as shown earlier in the case of LTV's Flexible Manufacturing System, the manufacturing process can be entirely completed with very little direct human intervention. Direct labor is not even needed for materials handling during the production process.

Although CIM is usually visualized as primarily appropriate for job order type manufacturing, it is also valuable for process manufacturing. For example, one of General Electric's chemical plants consists of a collection of tanks, hoppers, and filtration systems. These systems are under computerized control, which must ensure accurate, continuous replacement and rejuvenation of the electrolytic-zinc solution used in galvanizing cell plates [Weimer, 1986].

Thus, computers can be successfully employed to initiate, conduct, and monitor manufacturing processes in specific job, or continuous flow factory environments. This application of computerized control represents significant implications for cost measurement [Brimson, 1986]. Yet besides the hardware, there are major computer software considerations involved in operating these automated devices. The importance of computer software is examined in the next section.

d. CIM Software

As with any automated device, computers used to automate manufacturing must be properly programmed in order to perform all the necessary routines and subroutines. CIM is no exception and, indeed, software is the common denominator that links together each piece of hardware, and causes all the necessary manufacturing functions to be performed automatically.

The software sophistication relates directly to the complexity and diversity of the firm's manufacturing process. Some firms began automating several years ago with basic robotic capability. As they increased their inventory of such systems over several years, these firms began to acquire "islands of automation," which unfortunately were not always able to communicate effectively with each other. To deal with this problem, several firms, such as General Motors, Ford, Du Pont, IBM, John Deere, and Boeing, have developed and employed a standard computer "language" known as "Manufacturing Automation Protocol," or MAP [Bartik, 1985]. While a detailed description of automated manufacturing software is outside the scope of this thesis, it is important to note that computer software is critical to the effective interface and function of each automated manufacturing unit, and that often this requirement may entail significant consideration and expense.

As described in the above section, the new manufacturing environment, whether composed of single automated systems or multiple systems, is capable of producing output under significantly different circumstances than the traditional manufacturing environment. The hardware capabilities linked by the powerful software network takes much of the operation out of human hands, often removing workers from monotonous tasks and freeing them for more challenging, stimulating duties. At the same time, automation brings changes to other accounting areas in the new manufacturing environment. The next section focuses on these related areas.

D. OTHER AREAS OF CHANGE

Besides the introduction of automated manufacturing hardware and software systems, other manufacturing areas are also affected. These areas, too, are touched by the implications for new ways of cost tracking and measurement which we discuss in the following chapters. These areas include small batch manufacturing, product inspection, capital investment, vendor support and inventory.

1. Batch Sizes

One of the effects of automated manufacturing seems to be a trend towards smaller batch manufacturing. The claim has been made that one goal of CIM is batch processing in lots of one single item [Lee, 1987]. The impetus to produce smaller batches may derive from greater competitive pressures for decreased product lead times, for increased manufacturing productivity, and for greater flexibility in the manufacturing process [Lee, 1987]. Each of these considerations carry implications for the cost accountant trying to provide relevant product costing information in the new factory environment.

2. Product Inspections

Another potential of increased automation may be a decreased need for product quality inspection. If products are by made machines, which do not fatigue, theoretically each product should be the same quality as the last, and all should be in accordance with customer specifications. As the machines wear out, their efficiency may diminish. However, during their economically useful life, this should not be a problem. While few would advocate total elimination of the inspection function, automation seems to justify reducing the time and money dedicated to inspection activities, and thus has a corresponding effect on the firm's costing information. [Howell, 1987]

3. Capital Investment Decisions

Still another, and perhaps more significant, aspect of automation involves the initial capital investment decision. Automated manufacturing systems require relatively large outlays of funds. The size of these outlays may be impossible to adequately justify under traditional project cost justification models [Kaplan, 1986]. Yet, in practice, successful companies often seem to achieve satisfactory payback in three to five years. Factors contributing to this payback can be difficult to quantify because they relate to improved quality, improved customer satisfaction, and other variables that sometimes defy strict quantitative analysis. Therefore, the capital acquisition decision may also require special treatment by the cost accountant and corporate executives whenever automated manufacturing technology is concerned.

4. Vendor Support

A final area which is significantly affected in the new manufacturing environment is vendor support and related inventory. Traditionally, firms often purchased materials inventory in excess of their immediate needs to compensate for scheduling or production delays and backlogs. In an automated environment, product manufacturing begins with the customer order and hence "pulls" the product through the manufacturing process. Firms which hold unneeded inventory incur unnecessary costs, so they will be motivated to hold zero or minimum inventory and respond to each customer order as it is received. Vendor support becomes critical because shorter lead times, shorter setups, reduced inspections, and faster throughput demand a close relationship with the vendor and very reliable quality and delivery schedules. In fact, the vendor may become a virtual extension of the factory. Minimizing material inventories, work in process inventories, and finished goods inventories dramatically affect some of the fundamental concepts of traditional cost accounting. [Howell, 1987]

These concepts of smaller batch processing, fewer inspection costs, modified capital investment criteria, and changes to vendor and inventory relationships represent new operating methodologies of the manufacturing process that must be confronted and understood. In the new manufacturing environment, they are significantly effected by the introduction of automated systems and therefore need to be evaluated by each firm based on their own unique circumstances.

E. SUMMARY

The manufacturing operation today, as practiced by world class manufacturers, is noticeably different from the environment in which product costing, cost accounting, and traditional standard measurements originated. Based on the concepts discussed in this chapter, the apparent long-term trends in manufacturing cost behavior seem to be:

1. The significance of direct labor costs will decrease as a significant factor in product costs, while allocated costs will increase.

2. Fixed costs will become a greater portion of total costs.

3. Job shop manufacturing will become more like process manufacturing.

4. Set-up costs (costs incurred to prepare equipment and related resources for producing a specified number of finished units or operations) will decrease [Horngren, 1987].

5. Manufacturing will become more capital intensive. Additionally, the dependency on blue collar workers has been replaced by a dependency on information workers as the key ingredient for implementing programs leading to higher quality and greater flexibility. Firms are now trying to emphasize those technologies, robotics, FMS, CAE, CAD, CAM, and CIM, which will make them more competitive by minimizing their costs while maximizing their customers' satisfaction. Movement to these advanced manufacturing techniques imply some major changes to the traditional ways in which manufacturing costs have been measured and evaluated. Consequently, this movement could result in the need to reevaluate some of the current bases for product costing because many traditional product costing techniques seem to be deficient in an automated manufacturing environment. The next chapter illustrates how product costing is traditionally performed, and some of the accounting weaknesses that appear in the automated environment.

III. PRODUCT COSTING

A. INTRODUCTION

The previous chapter discussed some of the production innovations used today by various manufacturing firms. It was implied that these technological innovations suggest changes should be made in the way production costs are tracked, accumulated and eventually assigned to product units. This chapter begins with a discussion regarding the purpose and importance of accurate product costing. Then, the methods by which cost accountants have traditionally endeavored to achieve these purposes are discussed. Finally, an analysis is presented of the weaknesses in these traditional product costing methods when applied in the new manufacturing environment. This analysis includes a discussion of overhead allocation bases, overhead cost pools, product quality, and CIM justification.

B. THE ROLE OF PRODUCT COSTING

1. The Purpose of Product Costing

The primary purpose of any product costing system is to fairly allocate the firm's costs of production to the units produced. These production costs may be expressed as the sum of all related material costs, labor costs, and overhead costs applicable to the units of output produced.

2. The Importance of Product Costing

Accurate product cost data are important to decision makers both inside and outside the firm. As seen in Chapter I, accountants and industrial engineers realized this importance and developed the methods of determining product cost information over 50 years ago. Although the underlying concepts are still in common use today, two accounting structures have evolved to provide financial information to two different groups of business decision makers. Both of these accounting structures require product cost information. [Kaplan, 1984]

First, there is the financial accounting structure, which is primarily intended for use by decision makers outside the firm. This group of decision makers includes creditors, investors, and governmental regulatory agencies (such as the Securities and Exchange Commission, and Internal Revenue Service (IRS)). These users need reliable financial information in order to make decisions regarding business loans, investments, and regulatory compliance. Common reports provided to these users include the firm's independently audited Balance Sheet, Income Statement, and Statement of Cash Flows. A body of knowledge, known as Generally Accepted Accounting Principles (GAAP), specifies how accounting is to be done for external reporting purposes. Compliance with GAAP is important to ensure accounting data are reported in a consistent manner [Wilcox, 1984].

Secondly, there is the management accounting system, which is intended primarily for use by the internal managers of the firm. The management accounting systems usually include the cost, or product, costing function. Management needs data provided by this system primarily for the following reasons:

1. Planning and controlling day-to-day operations.
2. Long range planning and decision making.
3. Problem identification and solution.

In support of these two needs, cost accounting provides internal management with costs of products, operations, guidance for setting selling prices, and for comparison purposes between planned costs and actual costs. Accurate product cost data in this context are therefore important in order to intelligently evaluate alternative actions. [Horngren, 1987]

Management accounting systems are not regulated by external groups as are financial accounting systems. However, there are common categories between these two reporting systems, and when this occurs, GAAP is usually followed [Kaplan, 1987]. An example of a common category, included in both financial and managerial, accounting systems involves product cost determination. Product cost information is important for internal management decisions.

Product cost information also must be determined for inventory valuation on the Balance Sheet. To fairly determine inventory value, one must be able to accurately measure the costs of producing that inventory.

Some accounting experts believe that too much emphasis is being placed on techniques for valuing inventory for external reporting [Johnson, 1987]. They argue that this is dangerous because GAAP governs external reporting, and although firms comply with GAAP, these principles do not provide adequate focus on product costs to adequately meet management's decision needs. Johnson and Kaplan (1987) believe cost accounting systems suffer as a result of the financial accounting thrust of traditional product cost systems.

How well the cost accounting system accomplishes its purpose often directly impacts the overall success of the firm itself. Accurate and timely measures of the costs of input factors of production, or resources, can be crucial in answering questions such as: Which products should be produced? What quantities should be produced? Should certain items be purchased from outside sources? Should production be expanded? The significance of product cost systems lies in providing managers with the accurate and relevant data they need to make intelligent business decisions, and also in providing appropriate data to meet external reporting requirements.

In summary, the purpose of a product costing system is to fairly measure the costs incurred in manufacturing the firm's product. The accuracy and relevance of product cost information is important to decision makers, both inside and outside the firm, who must make business and operating decisions based on the information provided by the product cost system. How is this product cost data actually determined in the traditional environment? The next section presents a discussion of the two traditional product costing techniques.

3. Traditional Product Costing Methods

Historically, accountants have used two primary methods of determining product costs. One method is the job order costing method. This method is usually used when prime production costs can be directly traced to specific orders. A second method, known as the Process Costing Method, is more appropriate when goods are produced in a continuous process, so that production costs can not be traced to specific units of completed product. This section briefly discusses these two methods, the characteristics of each, and the techniques, including cost pools and allocation methods, used to determine the proper cost to be assigned to product units. Performance measurement, using the product costs produced by these two traditional product costing methods, is also discussed.

a. Job Order Product Costing System

Job order product costing systems have traditionally been employed under manufacturing circumstances where end products, differ in terms of composition or structure. Since the output differs, production will frequently consume differing amounts of the input factors of production. To assign manufacturing costs to groups of unique products, firms place costs into three categories: the direct costs of material, the direct costs of labor, and any indirect manufacturing costs [Horngren, 1987]. Material and labor are directly accumulated as the product undergoes the manufacturing process [Horngren, 1987]. Other factory costs, known as indirect manufacturing costs, are accrued indirectly as product conversion progresses [Horngren, 1987].

Indirect factory costs are costs which are necessary in the manufacturing process, but cannot be directly attributable in discrete, direct amounts to a specific unit of product. Costs that fall into this indirect category include such costs as depreciation on the factory and equipment, factory supervisory personnel, factory supplies (i.e., machine oil), and product inspection personnel costs. Other indirect costs include those that may be incurred by utilizing the services of other departments within the firm, for example, the data processing department or the engineering department.

To predict product costs, these indirect costs are estimated and applied to the anticipated output volume. As production proceeds, the actual indirect costs are totalled and, periodically increments are added to the direct materials and labor charges already accumulated. The trick is to apply the proper amount of cost to each job. To do this, accountants allocate these indirect costs using a basis they believe most accurately drives the incurrence of the indirect costs.

Typical allocation bases are: direct labor costs, direct labor hours, and machine hours. Traditionally, the most common base for assigning these indirect costs has been direct labor hours, because incurrence of direct labor hours has usually had a high correlation with the incurrence of these costs [Kaplan, 1984]. By periodically assigning the anticipated costs to the ongoing job requirements, the accountant endeavors to provide management with current, accurate product unit costs in order to make correct decisions as discussed earlier.

In summary, the job cost system is one method accountants have devised in order to accumulate product unit costs. The job order cost system recognizes different production processes. At times, it is also necessary to accumulate product costs when all the units of output are the same. In the next section, the traditional product cost system which is used under these conditions is discussed.

b. Process Costing Systems

When a business unit produces long-runs of similar products and employs a similar manufacturing process for each production run, a Process Costing system is often more appropriate than the Job Order cost system. Horngren defines process costing as, "A system for applying costs to like products that are mass produced in continuous fashion through a series of production steps called processes" [Horngren, 1987, p. 959]. Examples of process cost systems are found in the production of steel, chemicals, and paper.

In a process cost system, the three cost elements, namely the direct costs of material, labor, and the indirect costs, originate in a fashion similar to the job order cost system. However, in a manufacturing environment where each unit consistently consumes the same amount of input per unit of output, there is usually no need to determine the costs of different groups of products because the output is uniform. Each department that produces, or contributes partially to this type of production becomes a cost center, and therefore, process costing concentrates on the costs and production of individual departments in determining the unit costs of the product [Rayburn, 1986].

In a process costing environment, the product is completed when it has moved through all the necessary production processes since the firm, or department, is continuously producing a homogeneous product. Therefore, a time period is arbitrarily chosen, such as a two-week period or a month, to serve as the point in time at which unit costs will be determined for analysis and reporting purposes. At this pre-selected point in time, the department will determine how many units have been worked on during the period, and with this information, a unit cost can be determined and applied to each unit of good output produced. [Rayburn, 1986]

Accountants have traditionally determined unit costs using either a job cost, or alternatively, a process cost system. To be effective, these methods require accurate collection and assignment of the indirect manufacturing costs. The next section discusses, in more detail, the treatment of indirect manufacturing costs.

C. INDIRECT MANUFACTURING COSTS

As noted earlier, the basic purpose of any costing system is to track the costs of production (direct materials, direct labor, and manufacturing overhead) to the units produced. To achieve this objective, manufacturing overhead, or indirect manufacturing costs, should be considered. Kohler defines an indirect cost as,

> A functional cost not attibuted to the production of a specified good or service, but to an activity associated with production generally: e.g., a variety of factory costs, such as supervision, building depreciation, maintenance, heat, and light. (1975, p. 225)

Such indirect costs can be thought of as manufacturing costs. If these costs are significant, they should be allocated on a fair share basis to the units of output under job and process cost systems. This assignment of indirect costs is often a two step process:

(1) establishing cost pools, and

(2) making indirect cost allocations.

In order to lay the foundation for later discussions of handling indirect costs in the automated environment, the next section discusses how these costs have been traditionally handled, and what effect they have on the product costing process.

1. Establishing Indirect Cost Pools

This section discusses establishment of indirect cost pools. The second section discusses procedures for allocating costs from indirect costs pools to manufacturing output.

Horngren defines a cost pool simply as, "A cost pool is any grouping of individual costs" (1987 p. 415). By definition, indirect manufacturing costs are those costs which are difficult to directly trace to production of specific units of output. By collecting these indirect costs into cost pools, one can aggregate these costs and then attempt to allocate appropriate portions of the indirect cost pool to specific units of output on a fair share basis. Establishing cost pools enables collection of any number of costs. Individually, some of these costs may be relatively minor, such as the cost of machine oil for a single manufacturing machine. However, in toto, some indirect manufacturing costs may be quite significant, such as the cost of all lubricants required for all manufacturing machines.

When establishing a cost pool, one should attempt to pool similar costs. The concept of homogeneity is an important consideration in the formation of relevant cost pools. Ideally, costs driven by one common activity should be pooled together, because then, the costs can be allocated using that common activity for assignment. However, this ideal state is occasionally difficult in practice because of the variety of indirect costs that can occur, and the expense of indirectly tracking numerous, separate indirect cost pools.

Cost categories are sometimes consolidated into a single cost pool to minimize the cost and complexity of the firm's cost accounting system [Johnson, 1987]. This consolidation poses a potential problem in maintaining a relevant linkage between the incurrence of indirect manufacturing costs and the costs of production. This problem can be ameliorated when establishing cost pools by careful assignment of costs to categories characterized by common occurrence.

Although indirect cost pools can improve the accuracy of product cost systems, it is important that the pooled costs be grouped with as much commonality as possible. Homogeneous cost pools tend to minimize distortions caused by the presence of dissimilar costs when indirect cost allocations are made as discussed in the next section. [Cooper, 1987]

2. Allocating Indirect Costs

As noted above, in order to support any product cost system, it is necessary to assign both direct and indirect manufacturing costs to the product. The direct costs, usually direct materials and direct labor, are often relatively easy to ascertain and to identify with the product at discrete stages of production [Horngren, 1987]. However, the issue arises of how to best assign the indirect production costs to the product. Traditionally, allocation of indirect costs has been accomplished by pooling the indirect costs, as discussed earlier, and then assigning these pooled costs on a pro-rata basis to each unit produced. The proportion of the pooled costs assigned to an individual product unit has often been determined by dividing the total indirect cost pool amount by the amount of direct labor (hours or dollars) consumed in production of the product. Direct labor hours is often chosen on the presumption that it best reflects the incurrence of costs in general, and therefore indirect costs as well. Although other bases, like machine hours, direct materials dollars, or direct labor dollars, are sometimes used, the predominant method has been use of a single base and usually it has been direct labor. [Johnson, 1987]

Conceptually, any activity measure that most accurately reflects the true source of the costs incurred should be used to allocate indirect manufacturing costs. The important point is that the allocations should accurately capture the true amount of resources consumed.

So far in this section, job costing and process costing, and the related concepts of indirect cost allocation and cost pools, which are commonly used to develop product costs, have been discussed. This information provides background for discussing weaknesses of the present product costing systems, particularly in light of the employment of automated manufacturing equipment as described in the last chapter. The next section discusses some of these weaknesses.

D. PRODUCT COST SYSTEM WEAKNESSES

This section presents an examination of the weaknesses of cost accounting systems, primarily focusing on those weaknesses that are exacerbated when automation is introduced. Deficiencies in traditional product cost systems in an automated environment apparently can be associated with: indirect cost allocation bases, factory overhead pooling, lack of emphasis on quality, and capital investment justification. When determining, or measuring, product unit costs, the introduction of automated manufacturing impacts each of these important areas in a different way. The motivation for examining, and perhaps modifying, the way that these aspects interrelate derives from the following primary reasons [Horngren and Foster, 1987]:

1. To develop more accurate product cost information.
2. To develop better control of cost incurrence.

First, some of the deficiencies surrounding the treatment of indirect allocation bases are discussed.

1. <u>Indirect Cost Allocation Bases</u>

As mentioned earlier, indirect manufacturing costs are usually allocated to product units on a pro rata basis, determined by dividing a selected activity measure into the total amount of accumulated indirect costs. Traditionally, direct labor has been the common denominator for applying overhead to individual products [Schwartzbach, 1985]. Based upon a survey of 112 manufacturing firms, including Fortune 500 companies with sales in the billions, Schwartzbach (1985) found that allocation bases used for indirect factory overhead were:

Allocation Base	Per Cent of Firms using the base
Direct labor hours	35.7%
Direct labor dollars	58.0%
Machine hours	27.7%
Direct material cost	18.8%
Weight	11.6%
Other bases	8.9%

Since some firms reported using more than one base, the total percentage exceeds 100 percent. Note the number of firms using direct labor as an allocation base. Schwartzbach singled out the highly automated firms in his survey and found that only half reported using machine hours as an allocation base. He further reports that 79% of all firms reported choosing allocation bases on a "logical" relationship, and that most do not statistically validate their selection. Lack of statistical validation may contribute to the fact that few modifications to allocation bases seem to occur, even when changes in manufacturing processes occur. Thus, it seems that many firms, even a large number of highly automated firms, are allocating factory costs in a way that does not truly reflect how costs are incurred. The following example illustrates what can happen when allocations are made using a direct labor base in an automated manufacturing environment.

An example of how traditional allocation methods provide distorted product cost information is provided by

Brimson (1988, p. 53). As an illustration, Brimson cites a company which produces two products and employs a traditional cost accounting system to apply overhead using direct labor dollars. Product A uses intensive automated processes in contrast to Product B which consumes primarily direct labor. The actual cost of Product A equals the actual cost of Product B: $925. Reviewing each of the cost elements, we see:

Actual Costs:	Product A (%)	Product B (%)
Labor	$50	$200
Material	$300	$300
Technology	$200	$ 50
Other Overhead	$375	$375
Total Product Cost	$925	$925

$$\text{Overhead Applied} = \frac{\text{total cost less direct labor and material}}{\text{total direct labor cost}}$$

$$= \frac{\$1000}{\$250} = 400\%$$

Then the costs for these two products are calculated as:

Costs Assigned (By Traditional Cost Accounting Techniques):

	Product A ($)	Product B ($)
Direct Labor	$ 50	$200
Direct Material	$300	$300
Overhead	$200 (1)	$800 (2)
Total Product Cost	$550	$1300

(1) $50 x 400% = $200 (2) $200 x 400% = $800

Therefore, the traditional accounting system can significantly distort the product cost when using a direct labor base in an automated factory environment. As stated earlier, to be effective, the allocation bases must capture the true cause and effect relationship between manufacturing activities and manufacturing cost incurrence. Overhead cost pools are discussed in the next section.

2. Overhead Cost Pools

The notion of accumulating indirect costs into overhead pools arose to facilitate the assignment of such costs. These cost allocation procedures began in an environment based on longer life cycles and fewer products than those typical of the new manufacturing environment. [Johnson, 1987] In order to most effectively make such cost assignments, costs with similar characteristics (e.g., short term, long term, variable) should be pooled together according to homogeneous cost drivers. A cost driver is defined as the reason for the incurrence of the cost [Cooper 1987].

As firms acquire increased automated manufacturing technology, the traditional cost pools should be reevaluated in light of new conversion techniques introduced by automation. Recall that direct manufacturing costs are directly traceable to the production activity related to specific units of output, whereas, indirect manufacturing costs cannot be so traced. These indirect costs can be categorized as short-term, or long-term. Short-term refers to the length of a single manufacturing cycle, or 12 months, whichever is longer [Wilcox, 1984]. Short term variable costs, such as the costs for machine lubricants, should be traced to products by use of volume-related cost drivers [Cooper, 1987]. Under automation, such assignment may increase, or decrease, the amount of cost depending on the amount of resources consumed. Three potential means of assigning pooled, short-term, variable costs to products are machine hours, material dollars, and direct labor hours. On the other hand, for long-term variable costs, such as service department costs, Cooper (1987) suggests that effective cost drivers may be the number of production runs, the number of shipments, or hours of data processing time. Therefore, as production processes change, it is likely that some of the cost structures will change, which in turn dictates the need for a review of the composition of existing cost pools.

However, others challenge the relevance of overhead cost allocation, believing that some indirect costs are uncontrollable, and also believing that the responsibility for some of these costs is clouded [Bonsack, 1986]. For example, Schwartzbach (1985) reported that 57.5% of the 40 highly automated companies in his survey did not separate machine operating costs from other overhead costs. These companies apparently included all overhead costs in a single cost pool. This amalgamation illustrates the potential for a variety of indirect costs, such as machine operating costs, factory supervision costs, and materials handling costs to be placed in the same overhead cost pool. This potential, coupled with the number of possible ways these aggregated costs can then be assigned, demonstrates why care should be taken to maintain relevance between indirect costs incurred and allocated, especially when production processes change and factories transition to automation.

In summary, overhead cost pools should be formulated with care. The changing cost structures, as firms begin to employ automation, suggest that the contents of factory overhead cost pools should be reviewed. In the next section, the cost of quality, another aspect of product costing that assumes new dimensions in the automated environment, is discussed.

3. Product Quality

Traditional product costing concepts appear to exhibit some weakness in accounting for product quality in the new manufacturing environment [Morse, 1987]. Traditional manufacturing processes generate predictable amounts of scrap and defective product units. To account for this predictability, many manufacturers frequently include scrap and rework costs in standard product costs [Bonsack, 1986]. This procedure can enable price setting that will recover part of the cost of wasted effort by enabling manufacturers to know the predicted cost of scrap, and to include this cost into the price of the product. However, this procedure can also obscure some manufacturing costs and cause related problems. This practice can lead management into accepting waste as normal, and result in these costs being accepted and passed along instead of being critically considered and possibly eliminated [Bonsack, 1983]. This distortion of operating performance can misguide management decision making, and may be even more deleterious for the firm in an extremely competitive manufacturing environment. Tolerance by management for lower quality output can be a problem under traditional manufacturing by weakening the firm's long-term competitive position [Lee, 1986]. However, as discussed in the next chapter, the capability to produce higher quality output is often much greater in the new manufacturing environment.

Therefore, traditional treatment of the costs of quality represents a potential problem in an automated manufacturing facility. Similarly, traditional techniques for justifying acquisition of computerized manufacturing equipment can lead to unreliable results. Justifying the acquisition of computer integrated manufacturing equipment is discussed in the next section.

4. Justifying CIM Acquisition

Like accounting for product quality, traditional acquisition justification techniques need to be reevaluated when applied to the acquisition of automated manufacturing equipment. When firms attempt to rationalize the very technology they need to remain competitive, they often experience difficulty in trying to justify the acquisition of CIM technology by using traditional justification techniques [Seed, 1984]. These difficulties can be related to factors associated with the time horizon as well as to factors relating to traditional accounting techniques [Kaplan, 1986]. This section discusses three of these issues: management conservatism, short-term investment payback, and the traditional quantitative criteria for capital acquisitions.

Conservatism on the part of managers seems to suggest a general reluctance to engage in a risky venture, such as CIM acquisition [Lee, 1987]. CIM technology usually represents a sizeable investment and unless its advantages can be conclusively proven, there is a tendency for management to avoid the uncertainty of payback on the investment, especially in light of the concern for short term profits.

A second difficulty in justifying CIM acquisition lies in the short payback requirement many firms have adopted. According to Kaplan (1986), many U.S. companies utilize hurdle rates of 15% or more and payback periods of five years or less. As a consequence, these firms find it exceedingly difficult to justify a CIM investment in spite of significant savings in the number of employees, floor space, and production capability.

Thirdly, the emphasis on quantitative justification is detrimental to the case for CIM acquisition. Many of the advantages of CIM technology accrue in qualitative categories such as improved product quality, customer service, greater product variety and overall productivity [Kaplan, 1986]. Without accurately quantifying all relevant factors, both tangible and intangible, the case for CIM acquisition can be difficult to justify.

Therefore, weaknesses in traditional accounting methodologies, namely a lack of depth in asset justification techniques, becomes exacerbated in the new manufacturing environment. The affect on product unit costs is an inability to adapt to new production processes.

E. SUMMARY

This chapter discussed the significance of product costing, and noted that accurate product costing is an important input into the corporate management process. Accountants have primarily used job costing and process costing methods coupled with allocation of indirect, or overhead, costs in order to determine accurate product costs. These methods, developed over 50 years ago for costing purposes at that time, show some signs of weakness as manufacturing processes change and particularly when automation replaces direct manual labor. Some of these deficiencies relate directly to the allocation of indirect costs, while other weaknesses indirectly relate to product costing by affecting how managers view short term and long term actions and how firms make decisions whether or not to automate their manufacturing process. In the next chapter, characteristics of the new manufacturing environment are discussed which suggest that modifications should be made to product costing techniques in order to improve some of the deficiencies discussed in this chapter.

IV. APPRAISAL OF HARDWARE IMPLICATIONS

A. INTRODUCTION

After the discussions of various levels of automation in the new manufacturing environment (Chapter III), and some of the weaknesses in traditional product costing methods (Chapter IV), this chapter presents a discussion of some apparent cost accounting problems in the automated manufacturing environment. First, this chapter begins with a discussion of the different views, held by current users and accountants, regarding the nature of current cost accounting systems in the automated factory. Second, product costing problems as related to the automated factory are discussed. As a basis for this discussion, each level of factory automation is examined separately. The value of attacking and solving some of these problems can be seen in the results of a 1987 research project co-sponsored by the National Association of Accountants, and CAM-I Inc. That research project included a survey of business units who utilize a number of different manufacturing methods. The survey indicated that 54% of the respondents were either dissatisfied with product costing or feel it needs improvement [Howell, 1987].

Some manufacturing processes are notably different under automation, and hence may deserve different accounting treatment than under traditional methods. Each machine, and each level of automation, possesses strengths, weaknesses, and limitations. Each strength, weakness and limitation should be addressed by the organization's costing system if management is to have accurate product cost data. Therefore, it is important to understand how the characteristics of these machines affect the product cost measurement system. The industrial robot is presented first, followed by presentations on a Materials Handling System (MHS), Flexible Manufacturing System (FMS), and finally, a CAD/CAM system. In discussing each level, the focus is on four potentially troublesome areas for cost accounting under automation. These four areas are: system acquisition, cost control, product costing, and performance measurement. The primary source for the information presented in this chapter is Bennett et al. (1987), which summarizes the results of a recent survey, sponsored by NAA and CAM-I. This survey illustrates the differing views held by various users of cost accounting systems. These differing viewpoints are discussed in the next section.

B. CLIMATE FOR COST ACCOUNTING CHANGES

The current literature indicates that there are differing views on at least three aspects of current costing systems [Keys, 1986; Seed, 1986; Howell, 1986; Bennett et al., 1987]. First, users of cost accounting information express different levels of satisfaction with the effectiveness of current cost accounting systems [Bennett et al., 1987]. For example, it was found that, "62 percent of the users are unhappy with current cost accounting practices, while 54 percent of the preparers were not satisfied" (1987, p. 41). Bennett's research suggests that users are not content with at least some of today's cost accounting procedures.

The second aspect of cost accounting, on which differing views seem to exist, concerns the origins of the problems that users perceive with current cost accounting systems. Most respondents to Bennett's survey indicated the belief that many of today's cost accounting problems did not originate under automation [Bennett et al., 1987]. These respondents felt problems have existed for years, but become more visible and potentially more serious under automation [Bennett et al., 1987].

Third, there appear to be differing views on the amount of change needed to align the capabilities of cost accounting systems with the requirements for those systems. Most respondents, as well as some observers [Keys, 1986; Seed, 1986; Fox, 1986; Howell, 1987], seem to feel that necessary accounting changes can be incorporated within the existing accounting framework by formulating some new measures and definitions. According to Seed, "Solutions to the problems that we have to face can be accomplished within the framework of the (management accounting) system" (1986,

p. 45). On the other hand, Howell predicts more significant changes, "Virtually everything that a cost accountant relies on and is paid for goes out the window" (1986, p. 106).

Discussions of these issues are found in the current literature, and indicate differing perspectives from which users view current cost accounting systems.

C. THE INDUSTRIAL ROBOT

This section presents a discussion of the lowest automation level: the stand alone, automated, manufacturing machine. This device could be an industrial robot, numerical control machine, or single machine tool. These devices, while different, are similar enough to be categorized as the entry level for today's automated manufacturing processes. For consistency in this thesis, this automation level is referred to as the industrial robot. These are the machines, usually not under computerized network control, which individually perform various manufacturing functions such as welding, spraying, or grinding. Most of these systems are operated on a "one operator to one machine" basis, although in some cases, one person may operate several machines [Keys, 1986]. Occasionally, these devices may be computerized, and they may also be equipped with features such as sensory control and vision systems. The consequence of greater computerization and additional features is usually to lower direct labor input and to increase the importance associated with depreciation and other machine costs. In this environment, depreciation and other machine related costs surpass direct labor as major cost factors [Keys, 1986].

When applying traditional cost accounting to industrial robot systems, six categories of accounting issues can be identified [Keys, 1986]. These categories are:

1. Greater difficulty in categorizing labor of machine operators as direct or indirect.

2. Greater fixed amounts of direct labor, less variable direct labor.

3. Greater difficulty in quantifying benefits derived from automation.

4. Greater emphasis on the short run, potentially jeopardizing the long term.

5. Greater inaccuracy of overhead allocations.

6. Greater difficulty in measuring the performance of automation.

Each of these areas is discussed in greater detail below.

1. <u>Labor Identification</u>

The first cost accounting issue arises in the attempt to identify manufacturing labor as direct or indirect. There are three aspects to this issue. First is the problem of "satellite work" (unmanned machining). Satellite work is defined as work performed by a machine operator on a secondary job, while the primary job is still in progress. In an automated environment, the situation can arise where a machine operator may be primarily tending one machine job, and have time to simultaneously perform or monitor a second machine job. This situation raises the issue of categorizing wage time as direct or indirect. [Bennett, et al., 1987].

A second related labor measurement problem occurs when the operator could be performing a second job, but no second job is available. Unless the operator is being paid purely for attendance, some means to account for this idle time needs to be found, rather than charge one job with the wages sufficient for two jobs. [Keys, 1986]

Thirdly, a problem arises in situations where there are more operators than machines. Again, this creates idle time which must be counted.

2. <u>Fixed Direct Labor versus Variable Direct Labor</u>

The second cost accounting issue, according to Keys, occurs as increments of direct labor change from mostly variable to mostly fixed. This shift occurs in the automated environment as machines assume more of the direct manufacturing functions, and the number of direct labor workers decreases. The decrease in direct labor is offset by increased machine capability, and fewer, but more highly skilled workers. The result can be an increase in production without an increase in direct labor. The cost of labor appears to be more fixed because it is less affected by variations in production volume.

3. <u>Difficulty in Quantifying Benefits</u>

A third cost accounting issue arises in quantifying the benefits of automation. This is a problem both in the project acquisition justification phase, as well as in performance reporting. Many benefits of automation, such as faster response to market shifts, decreased lead times, and increased manufacturing flexibility, are qualitative and difficult to accurately quantify [Kaplan, 1986]. Even direct labor savings can be difficult to quantify because companies often retain and relocate workers displaced by automation. Since there is no easy way of quantifying many benefits of automation, companies are likely judging these qualities on subjective grounds [Keys, 1986].

Several approaches can be used in dealing with this difficulty. First, discounted cash flows should be analyzed using only the quantifiable benefits. Sometimes the investment in automation may be justifiable purely on the basis of quantitative factors. Secondly, if quantitative factors alone do not suffice, relevant qualitative factors should be introduced. When qualitative factors are included, they should be analyzed in ways which assess, as accurately as possible, their true contributions. In this process, it is important to avoid overestimating the power of automation, or the belief that automation can somehow cure all problems. Also, it is important to realize that a careful analysis of projected direct labor reductions is necessary, because many workers displaced by automation are not released from the corporate payroll, but rather are simply reassigned within the company. [Keys, 1986]

4. Overemphasis on the Short Run

As noted by contemporary authors, [e.g., Kaplan, 1987; Hayes & Abernathy, 1980; Howell, 1987; Lee, 1987], a weakness of many firms is a preoccupation with short-term profits, often potentially to the detriment of long-run corporate health and competitive posture. According to Keys (1986), there are two aspects of this preoccupation.

First, there appears to be a greater emphasis on efficiency, at the expense of productivity. This can occur when the cost accounting system pressures the managers to maximize machine time on the most efficient machines, which maximizes efficiency. Conversely, maximum productivity may sometimes dictate occasional use of less efficient machines. For instance, meeting a special order deadline may require the use of full factory machine capacity. Some of these machines may be older and create more waste than the newer machines. Yet, to meet the deadline and avoid losing the sale, the manager may be motivated to utilize all these machines, old and new, in order to meet the deadline. Since the accounting system does not record lost sales, there is little incentive within the accounting system to achieve greater productivity. [Keys, 1986]

Secondly, the acquisition of automated manufacturing machinery usually involves considerable cost. Thus, its depreciation expense, for several years is likely to be higher than the depreciation on the older machinery that it replaced. This may decrease return on investment (ROI), and discourage investment in automation. This can be a problem, because in the long run, competitive advantage (which is harder to measure) and corporate wealth may actually be maximized by incorporating advanced technology. Related to the ROI issue is the observation according to Keys, that sometimes the economic life of automation is overestimated. Proper determination of useful life requires careful analysis of strategic goals as well as planned machine use.

A third concern of managers is the difficulty in training personnel to optimize machine use [Bennett et al., 1987]. Managers expressed concern that when demand fell, they were pressured to cut costs, and then funds to pay for training were not available. When production increased, the emphasis was on production and there was no time to learn how to improve manufacturing skills [Keys, 1986].

Keys suggests several possible recommendations to help overcome this overemphasis on the short term. First, from a management perspective, it may be helpful to keep two sets of accounting records, as some European firms do. One set of records framed for external reporting, and the other set designed for use by internal management. A potential disadvantage of this option is cost. However, as more sophisticated accounting software becomes available at lower cost, two sets of books, or at least portions of two sets, may become a more practical solution. Other possible solutions involve placing less emphasis on short-term profitability, tieing management incentives to longer term goals, and use of different valuation bases for measuring costs.

5. Overhead Allocations

The fifth cost accounting issue concerns allocation of factory overhead. As noted in the previous chapter, proper use of overhead pools and subsequent overhead allocations require careful analysis in order to accurately assign costs to cost objectives. Two symptoms of possible overhead problems are extremely high overhead rates, and extremely volatile overhead rates [Keys, 1986]. There can be several possible reasons for these overhead problems in the automated environment. The first potential reason for overhead problems in an automated manufacturing environment can be related to the use of improper allocation bases. It appears that many automated firms continue to use direct labor as an overhead allocation base [Bennett et al., 1987]. In an automated factory or department, the use of machine hours may be more appropriate, because direct labor hours and machinery hours may be different for a variety of reasons. For example, the existence of more machines than operators, or the requirements for set-up time and machine idle time may cause machine hours to be a better measure of value-added to the product than direct labor. Direct labor is usually not a good measure of machinery costs, when the direct labor content is below 10 percent. [Bennett et al., 1987]

A second possible reason for overhead problems in an automated environment can be related to variations in the level of manufacturing activity. Production volume is sometimes hard to accurately estimate. Yet, estimates are occasionally necessary in order to gauge the share of fixed overhead expenses to assign to the product for bidding on a project, or for planning purposes. When forecasts of production differ from actual production, a variance in the amount of fixed overhead expenses assigned to the individual products can occur. This variance occurs because fixed overhead was originally based on the estimated production volume which was different from actual production. [Johnson, 1987].

There are several possible solutions to the difficulties discussed above. First, the use of machine hours is warranted if machine hours provides a better measurement base than direct labor. According to Cooper,

> As firms introduce more automated machinery, direct labor is increasingly engaged in set-up and supervisory functions (rather than actually performing work on the product) and no longer represents a reasonable surrogate for resources demanded by products. (1987, p. 215)

Second, management could consider implementation of a transaction base to allocate overhead. Transactions are defined as those activities necessary to support production. Studies by Cooper and Kaplan (1987), and Miller and Vollman

(1985), suggest that many overhead costs vary with transactions.

> Such transactions may occur to order, schedule, receive, inspect and pay for shipments; to move, track, and count inventory; to schedule production work; to set up machines; to perform quality assurance, to implement engineering change orders; and to expedite and ship orders. [Cooper and Kaplan, 1987:p. 225].

A transaction base accounts for the resources consumed in executing the activities required to manufacture the product.

A third possible solution may be the use of departmental overhead rates, instead of a single plant wide rate. Use of departmental overhead rates may be especially appropriate if one department is more highly automated than another [Keys, 1986].

6. Performance Measurement

The sixth cost accounting issue in the automated factory environment concerns performance measurement. The issue can be addressed in terms of individuals, machines, departments, or combinations of these three categories. The focus here is on the machine-labor interaction. Performance measurement, using traditional measures, becomes difficult in the robotic environment, because the benefits and cash flows unique to each machine can be difficult to separate and quantify. This difficulty may be partially caused by the machine-labor interaction in the automated factory. This difficulty has been observed in attempts to use direct labor to measure machine utilization [Bennett et al., 1987].

As noted earlier, such efforts to use direct labor to measure machine utilization can produce inaccurate information because of machine set-up time, machine idle time, and a difference between the number of operators and machines [Keys, 1986]. As discussed earlier, possible solutions may be to treat all labor as an indirect charge, or alternatively as a fixed charge,in an automated work center [Keys, 1986].

7. Summary

The introduction of automated technology, even at the simplest automation level seems to magnify existing cost accounting and product costing weaknesses. These issues include difficulty in categorizing labor, quantifying benefits, allocating overhead, and measuring performance. In the following sections, the occurrrnce of many of these same accounting issues at the other levels of automated manufacturing is discussed. The cost accounting issues associated with the automated material handling level is discussed in the next section.

D. MATERIAL HANDLING SYSTEMS

Material Handling Systems (MHS) are those automated systems which store and retrieve inventory supplies, such as, direct materials and finished goods. MHS systems also shuttle partially completed products from process to process, often with little or no human intervention. Although these systems increase the speed and accuracy of handling inventory, they also accentuate many of the same cost accounting issues addressed in the last section.

1. System Acquisition

Cost justifying the acquisition of MHS can be very difficult. This occurs for the same reasons as for the stand alone machine, but can be more exaggerated because of the higher initial cost of an MHS. As a capital budgeting decision, MHS should be justified by discounted cash flow techniques; yet this method fails to capture the true effects of many of the qualitative benefits (e.g., increased flexibility) of MHS [Kaplan, 1986].

At present, firm's acquiring MHS appear to understand the benefits these systems offer, such as faster order picking, increased inventory data accuracy, and decreased inventory space requirements. How these competitive advantages are woven into the firm's strategic competitive plan then appears to become a matter of subjective judgement [Bennett et al., 1987]. However, guidelines have been used by various firms in attempting to quantify these benefits [Agee, 1980]. These guidelines include:

1. Ratios which measure the utilization of people. Such a ratio measures the proportion of the labor force currently assigned to material handling activities. A projected change in this ratio under automation can be used as in input into the justification analysis. [Agee, 1980].

2. Measures of production equipment utilization. If production equipment is projected to be operating more frequently when MHS is in use, the costs of this

increased operation should be included in the justification process. [Agee, 1980]

Other possible measures include energy consumption, material control, and manufacturing efficiency. Like investment justification for other levels of automation, there is no single justification method for MHS that works best for all firms [Bennett et al., 1987]. Unanticipated events and qualitative factors can sometimes influence the results in unpredictable ways. For example, the experience of Tandy/Bell Howell offers insight into the results of one firm's acquisition process. Management originally expected the MHS to pay for itself in two years. But, because of higher than expected use, and lower than expected film cost, actual payback occurred in less than one year [Weimer, 1986].

2. Controlling Costs

Employment of machine labor instead of human labor tends to increase fixed costs associated with machinery, and tends to decrease variable costs of hourly wages. Often higher fixed costs, and depreciation expense related to mechanized systems, reduce the ability of the work center supervisor to control costs at his level. [Bennett et al., 1987]

This restructuring of cost content and cost flow suggests that the cost structure of automated work centers should be carefully re-analyzed when factory automation is introduced. This analysis should be designed to verify that the costs for which the work centers are assigned responsibility, are actually costs over which the work centers have control.

3. Product Costing

Usually, the cost of MHS is treated as overhead and indirectly allocated to products using indirect cost pools [Bennett et al., 1987]. As discussed previously, sometimes the methods of forming a cost pool may be questionable, especially when dissimilar costs are aggregated. The automated environment can cause a deleterious change in the effectiveness of traditional allocation techniques as illustrated earlier by the Brimson example in Chapter II.

Some companies have sought ways to improve their costing system by improving their overhead allocation process [Lee, 1987]. One example is that of a company which set up their material handling function as a separate cost center [Bennett et al., 1987]. This arrangement makes the cost of material handling somewhat easier to trace, and thus should improve product costing. As a second example, and also an illustration of improving cost accounting within the existing framework, another firm developed two separate overhead rates. One rate was used for materials purchased for manufacturing, while the other rate was used for materials purchased for assembly [Bennett et al., 1987]. This dual rate framework may enable more accurate product costing, especially when the raw material requires extensive preparation expense to prepare for assembly [Bennett et al., 1987].

4. Performance Measurement

A primary measure of performance is the system's "operational ready time." As automation takes the place of manual labor, performance measurement systems will need to be reconfigured to reflect system availability. Additional measures must be created or modified to assess the frequency of errors made by the system, and also the amount of time required to restore the system to operational readiness if it becomes inoperative [Bennett et al., 1987].

5. Summary

Many of the same cost accounting issues that apply to stand alone automated systems, also apply to MHS. Often an MHS has more moving parts than a single stand alone system, and, interfaces with a wide variety of other systems. Both of these features imply greater complexity and consequently more expense for MHS than for a stand alone machine. In the next section, the cost accounting issues related to a higher level of manufacturing complexity, the Flexible Manufacturing System, are discussed.

E. FLEXIBLE MANUFACTURING SYSTEMS

In this section, the cost accounting issues related to Flexible Manufacturing System (FMS) are discussed. An FMS usually links a variety of stand alone automated machines. Often this linkage includes an MHS, and is usually under computer control. This aggregated system is then capable of executing multiple manufacturing processes, such as inventory retrieval, material cutting, burring, and painting, without any direct human labor. Manufacturing technology such as this carries major implications for the traditional treatment of direct labor, wages, factory overhead and other related accounts. For instance, one can often anticipate a decrease in direct labor and a corresponding increase in factory overhead as an FMS is brought into the factory. FMS also creates many of the same cost accounting difficulties experienced under single automated machines and MHS environments.

1. <u>FMS Acquisitions</u>

Justification of FMS acquisition is affected by the same difficulties as the other previously discussed automated systems, with the added expense associated with a larger, more complex system. The qualitative benefits are among the strongest favorable considerations, yet are also the most difficult to objectively quantify. Therefore, today FMS justification is performed partially using quantitative methods, and partly using subjective valuations. [Bennett et al., 1987]

2. <u>Cost Control</u>

Cost control in the FMS environment is similar to other automated environments previously discussed [Bennett et al., 1987]. When compared to traditional factories, an

FMS equipped plant will likely have less variable direct labor, and more fixed overhead costs. [Bennett et al., 1987]

FMS generates higher fixed overhead costs than lower levels of automation, because additional complexity usually creates more capitalized expenses, computer support costs, and machine depreciation. Additional requirements include the need for a larger support staff, more computer programmers, engineers, and maintenance technicians. These items all represent fixed costs in the long run, which are controllable in the aggregate by corporate staff, but not controllable at the FMS cost center level. The FMS supervisor usually has cost control only over items such as: direct materials, tooling, set-ups, machine operator labor, and off-line inspection costs [Bennett et al., 1987].

One way to improve cost control in the FMS may be to isolate the controllable costs, and separate these from those costs over which the FMS supervisors have little control. For example, costs over which the FMS supervisor may exercise control includes costs for direct materials, tooling costs, and machine operator labor. On the other hand, the FMS supervisor may have very little capability to influence such costs as computer and machine depreciation. After total manufacturing costs are separated and the individual components become more visible, performance results can be monitored by using performance reports which compare actual versus budgeted controllable costs [Bennett et al., 1987]. According to Bennett (1987), two respondents in the NAA survey employed FMS. Both companies establish FMS budgets for costs over which the FMS supervisor has control, such as: indirect material and indirect labor costs. "Actual costs are then compared to the budgeted costs to facilitate cost control" (1987, p. 51). Such cost separation provides one method to improve cost control.

3. Product Costing

An FMS increases the amount of fixed overhead charges applicable to production since materials, tooling, and power requirements are often the only relevant variable charges. Most other costs move into the fixed category. Therefore, some companies have set up their FMS as a separate cost center with its own overhead rate [Bennett et al., 1987]. Establishing the FMS as a cost center helps to consolidate the relevant fixed and variable charges most directly applicable to the FMS operation. A final consideration, as with the other manufacturing processes, is utilization of an appropriate overhead rate. Primary candidates for appropriate overhead bases in an FMS environment include units of production, time in the FMS, and machine hours. Regardless of which overhead base is selected, care must be taken in predicting activity level on which to allocate fixed overhead. This is true because of the high level of fixed overhead in an FMS environment, and also because of the linkage under absorption costing between the budgeted fixed overhead and the predicted volume [Bennett et al., 1987]. Any divergence between predicted production volume and actual production volume, as discussed earlier, creates a variance in production volume. If this variance is considered significant by management, its cause should be investigated in order to determine what management actions are appropriate. At the same time, it is important to remember that this production volume variance is merely a measure of the cost of departing from the predicted volume which was originally used to calculate the fixed overhead rate. A production volume variance does not necessarily signify problems with the production process.

4. Performance Measurement

Because of the complexity of an FMS, performance measurement requires consideration of several features including:

1. Machine and system utilization percentages.
2. FMS productivity.
3. Actual versus planned output.
4. System flexibility.
5. Quality, amount of defects and rework.
6. Inventory levels. [Bennett et al., 1987]

Although measures for all of these features have not been fully developed, companies using an FMS have devised methods to assess system performance. One company tracks actual versus planned direct labor hours, machine and system utilization, and scrap [Bennett et al., 1987]. Another company monitors data showing work hours scheduled versus work hours used, along with machine hours downtime, and machine output [Bennett et al., 1987].

5. Summary

In summary, FMS have all the cost accounting difficulties of the lesser complicated systems, plus a few more, due primarily to added cost and complexity. FMS acquisition, using traditional justification techniques, often fails to capture a realistic cost and return relationship. Cost control is usually monitored by comparison of actual versus budgeted costs. Companies have devised different methods for product costing and performance measurement. In the next section, the cost accounting issues that arise in the integrated CAD/CAM environment are discussed.

F. CAD/CAM

Computer Assisted Design/Computer Assisted Manufacturing (CAD/CAM) links many of the concepts of the lower levels of automated manufacturing into an overall computer assisted manufacturing process which begins with product design and ends when the product rolls off the production line [Lee, 1987]. This blending of computer and machine has been achieved primarily because of advances in computer software capability during the 1970's and 1980's [Wiemer, 1986]. The

CAD process permits exploratory drawings of extraordinary precision to be created in the early product review stages. Once a product design has been approved, Computer Assisted Manufacturing takes over to schedule production, requisition materials, assemble and package the product, and in some cases, ship the product to the customer all with little direct human contact by factory personnel [Koelsch, 1985]. A fully automated manufacturing process is different from the traditional manner of production. Therefore, one may anticipate that modifications to the traditional methods of measuring manufacturing costs may be necessary.

1. CAD/CAM Acquisition

The primary cost accounting issue in CAD/CAM acquisition lies in the investment justification process [Kaplan, 1986]. It can be extremely difficult to quantify many CAD/CAM qualitative strengths, and then capture these values as a bottom line number. Nevertheless, firms have acquired CAD/CAM. Like the MHS example cited earlier, sometimes CAD/CAM payback exceeds the quantified expectations. One example occurred at Simmonds Instrument Systems, where raw savings for the first 20 months totalled $498,000 [Van Nostrand, 1984]. Van Nostrand does not state the amount of the total investment, but does state that system reliability, flexibility, utility, and payback far exceeded all expectations [Van Nostrand, 1984]. These qualities could more effectively bias the acquisition analysis if they could be quantified in the beginning. One method of quantifying qualitative, non-monetary factors is by use of risk analysis techniques [Meredith, 1988]. Using this approach, Meredith suggests converting qualitative factors, such as flexibility and utility, into frequency distributions, and then applying simulation models to determine which factors are more favorable.

2. Cost Control

The primary tool used for cost control by CAD/CAM firms is the traditional flexible budget [Bennett et al., 1987]. Often the traditional cost centers still exist, with each given its own budget. Then actual performance is compared to the planned budget. Standard costs exist in production activities but are rare in engineering, drafting, and programming. However, some firms are considering use of standards in these areas, since the repetitive nature of these tasks would seem compatible with standard costing concepts. Yet more sophisticated measures need to be developed to more accurately measure the day to day, and in some cases hour to hour, operations. [Bennett et al., 1987]

> The repetitive nature of many of the activities performed in the engineering design, drafting, and NC programming areas would seem to lend themselves to the use of standard costs to control spending and efficiency. Some companies are considering these possibilities. [Bennett et al., 1987:p. 36].

3. Product Costing

As with the other levels of automation, CAD/CAM system costs are often collected into overhead pools and allocated using a plant-wide rate [Bennett et al., 1987]. Some firms are separating portions of these costs and attempting to tie them more directly to the relevant final cost objective. For example, when a design engineer uses the computer for drafting, the job or contract associated with his efforts gets billed for the time and computer services incurred. This billing is treated as direct labor and the engineering department burden rate is then applied [Bennett et al., 1987].

Methods need to be further developed that permit additional direct tracing of CAD/CAM utilization to products. By replacing some of the indirect allocations with direct cost traceability, and by using variable costing for internal management, firms can probably improve their product cost calculations [Bennett et al., 1987].

4. <u>Performance Measurement</u>

Most firms which employ CAD/CAM technology today measure performance by comparing actual costs to budgeted costs. Often this technique fails to capture all of the benefits provided by CAD/CAM operations because of the qualitative nature of many of these benefits, such as increased flexibility. Additional factors which should be useful in evaluating CAD/CAM systems performance include:

1. Number of drawings produced.
2. Time required to develop designs.

3. Number of design programs developed.

4. Time required to perform design analysis.

The four items above can often be quantified, and used to establish standards by which future performance can be compared. Furthermore, these items illustrate concepts that should prove useful in designing CAD/CAM performance measures [Bennett et al., 1987].

5. Summary

Because CAD/CAM links many manufacturing processes to centralized computer control, CAD/CAM represents a sophisticated level of overall manufacturing capability. Under traditional cost accounting methods, CAD/CAM investment can be difficult to justify, and can result in changes to the firm's cost structure and performance measurements. Accurate product cost determination in a CAD/CAM environment requires changes to traditional accounting methods to communicate this restructuring of the manufacturing cost framework.

G. CONCLUSION

This chapter discussed levels of automated manufacturing technology, focusing on the cost accounting issues associated with each. Since each level embodies similar concepts, many of the same accounting issues are common among the different levels of automated manufacturing technology. However, the magnitude of the problem may increase as one moves to the higher levels of technology.

Besides the cost accounting issues related to different levels of automation, there are challenges for cost accountants because of the capabilities, and characteristics of the output of this new technology. The next chapter discusses product costing and cost accounting for the output of automated manufacturing.

V. APPRAISAL OF PROCESS IMPLICATIONS

As discussed in Chapter IV, implementation of manufacturing automation presents many challenges to the cost accountant. Prior to this chapter, emphasis has been placed on the accounting changes suggested by the characteristics of the various automated manufacturing hardware levels. However, there are potentially other aspects of the new manufacturing environment which imply other modifications to traditional cost accounting should be made. This chapter focuses on these other aspects that occur in the actual manufacturing process. The emphasis here is on accounting changes which appear necessary because of the ways in which these machines produce products. Automated manufacturing typically enables higher product quality, lower inventories, increased manufacturing flexibility, and changes to the firm's cost structure [Howell, 1987]. What effect do changes in these areas have on product costing? This chapter presents a discussion of these concepts as related to cost accounting in the new manufacturing environment. We start with a discussion of cost accounting for increased quality.

A. INCREASED MANUFACTURING QUALITY

According to Howell, "Quality is a significant cost driver for the manufacturer" (1987, p. 22). One major reason why firms acquire automated manufacturing technology is to improve the quality of their output [Morse, 1987]. Therefore, accurate information concerning quality costs should be available to management in order to accurately assess the impact of automation on the quality of their firm's output. This section discusses the kinds of quality costs, and different approaches to measuring quality costs.

1. Types of Quality Costs

Quality costs are the costs of preventing faulty products from reaching the customer, or alternatively, the cost incurred for correcting product problems once the product is in the field [Morse, 1987]. According to Morse (1987), quality costs can be grouped into three categories: prevention costs, appraisal costs, and failure costs. Each has a different financial impact on the firm. This section presents a discussion of each of these types of quality costs.

First, prevention costs are the costs a company incurs to reduce the manufacture of non-conforming products. Examples of prevention costs include: expenses involved with in-process quality control methods, training in quality control techniques, and adaptive control systems [Morse, 1987].

Second, appraisal costs are the costs of identifying poor quality products before such products reach the customer. Examples of appraisal costs include costs of product inspection and depreciation of inspection equipment [Morse, 1987].

Third, failure costs can be internal or external. Internal failure cost occurs when the product fails to meet specifications. The cost of rework, scrap and repair are typical internal failure costs [Morse, 1987]. External failure costs, on the other hand, arise once the product is in the field [Morse, 1987]. Typical external failure costs include field service, warranty repairs, product recalls, and product replacement [Morse, 1987]. Additional external failure costs include intangibles such as customer ill will and the cost of lost sales [Morse, 1987].

Often, external costs are more expensive than internal failure costs [Morse, 1987]. This can occur because of additional costs required to retrieve the product from the customer, or the costs to send repair personnel to the customer's facility. Therefore, detection of product irregularity as early as possible is very important, especially in the automated environment. Earlier fault detections usually result in less resources wasted, and lower repair costs. As discussed later, inspection costs can sometimes be lowered under automation because of fewer errors in production and the self-monitoring capability of some automated equipment.

Although management action may significantly improve product quality, at some point, further improvements in product quality usually become limited by the current level of technology. [Morse, 1987] Implementing automated manufacturing technology usually represents increased sophistication in the level of technology. Since cost systems are usually designed to accommodate the existing manufacturing technology, a change in the technology may suggest a corresponding change to the cost system. As firms shift from the traditional manufacturing techniques to increased automation, the technology can change significantly. Therefore, the methods for measuring quality costs should be analyzed to determine whether dollar costs should be used in order to more accurately gauge the cost of product quality.

2. Approaches to Measuring Quality Costs

Traditionally, in order to assess quality, most firms have used measures such as defect rate, or the number of items requiring rework [Howell, 1987]. While this approach can provide an approximate quality indicator, the weakness of this method is that it fails to accurately capture the dollar cost of poor quality. In a survey of over 100 manufacturers, Howell found that 91% of the respondents measure quality costs. Of this 91%, 57% measure quality as a by-product of their operating control system (i.e., number of physical units), 7% use their accounting systems and 29% use some other informal measure outside their operating or accounting system [Howell, 1987].

This suggests that only 7% are attempting to quantitatively measure the dollar costs of quality by using their accounting systems to track actual costs of scrap, defective output, and rework. This same survey cited product quality enhancement as the area of greatest potential for manufacturing improvement.

Since factory automation consistently produces high quality goods [Lee, 1986], any production costs of non-quality output should be investigated in order to determine the reasons for producing inferior products. Some companies have incorporated such measures as warranty costs and the costs of field repair into their quality cost measurements [Morse, 1987]. Including these costs helps to capture the real cost associated with producing an inferior quality product. Measuring and controlling quality costs is a vital management tool in the automated environment. Otherwise, it is difficult for management to accurately assess the cost effectiveness of their investment in automation.

3. Measuring Quality in Dollar Terms

There are several advantages of measuring quality costs in dollar terms instead of solely by numbers of production units [Morse, 1987]. First of all, when quality costs are measured in dollars, it is easier for management to determine the cost effectiveness of quality enforcement programs, and to make quantitative comparisons with other corporate programs. Dollar measures are usually more meaningful to top management than operational measures such as those based on lower scrap rates or reduced rework rates [Morse, 1987]. Secondly, the dollar measure helps to illuminate the stage at which the most significant dollar costs are incurred in the product's life cycle. This ability to focus on various stages of product quality can help management to more effectively target and eradicate the quality problems that carry the most adverse financial impact [Morse, 1987].

4. Summary

Accounting for quality costs should receive greater attention in the automated manufacturing environment. Since automation can normally reduce or eliminate random deviation from product specifications, quality standards should be reviewed and probably tightened under factory automation. The result will be an improved capability on management's part to assess factory efficiency and product quality. A positive side effect could be an increase in product demand and sales price as customers become more assured of receiving a high quality, dependable product [Kaplan, 1986]. The next section discusses the cost accounting changes that can arise under factory automation because of new treatment of inventories.

B. IMPROVED INVENTORY MANAGEMENT

In the survey by Howell (1987), respondents indicated reduction in inventory levels as the second potentially most significant area for manufacturing improvement. As long as customer demand can be filled, inventory reduction usually means saving money. Idle inventories require storage space, represent tied-up cash, and stand out as unproductive resources that jeopardize the firm's competitive position. Inventory management can sometimes be improved by better marketing forecasts. However, often inventory levels can also be more effectively managed in an automated factory than in a traditional manufacturing environment. In this section, three methods are discussed in which inventories can be more effectively managed in the automated manufacturing environment: manufacturing inventory reduction, inventory relocation, and inventory record keeping.

1. Manufacturing Inventory Reduction

In the automated factory, manufacturing inventory levels should usually be reduced to that level which just supports production flow. Traditional manufacturing environments have often been characterized by idle inventories maintained as a buffer against stockouts, or lost sales [Kaplan, 1983]. Maintenance of this buffer was intended to reduce sales that may be lost because of inaccurate sales forecasts, poor quality, or unreliability of suppliers.

In the automated factory, the concerns cited above do not require large buffer inventories. Technological advances reduce the time required in the production cycle [Lee 1987, p. 58]. This enables firms to respond more quickly to sales orders. Firms can reduce dependency on sales forecasts and respond more quickly to customer demand. Second, quality improvements are often realized when using automated manufacturing. "Although improvements in quality are difficult to measure, the ability with CAD to try more variations of a design before settling on a final version certainly has improved our quality" [Krouse, 1984, p. 96]. Proper, early design selection can reduce trial and error designs which result in more waste and require higher, supporting raw material inventories. Third, supplier reliability can be increased by qualifying vendors, and establishing long-term vendor relationships. "Qualifying vendors on the basis of quality and delivery performance eliminates the need for buffer stocks" [Howell, 1987, p. 23]. As the need for buffer stocks is reduced, inventory levels can be reduced.

2. Inventory Relocation

In the automated factory, inventory can often be relocated to the factory floor. Relatively large inventories often held in the traditional factory environment required large amounts of storage space. There are two factors that facilitate inventory relocation. First, as automation decreases the production cycle time and inventory levels are reduced, opportunities arise to reposition inventories closer to the actual production machinery. Lower inventory levels require correspondingly less space. Second, many firms which acquire factory automation, seem to simultaneously restructure their manufacturing flow along product lines instead of traditional departmental groupings [Howell, 1987]. This restructuring of the manufacturing flow, along product lines, offers opportunities to relocate inventory closer to the manufacturing location.

3. Inventory Record Keeping

Another improvement to handling inventory in the automated factory results from the ability to reduce and consolidate inventory record keeping. Reduction of inventory levels and record keeping should result in lower inventory management costs. This benefit arises from at least two characteristics of the automated factory.

First, as noted above inventory levels should usually be reduced when automated manufacturing technology is used. This reduction in the number of inventory items implies the ability to reduce or consolidate both the inventory record keeping documents and the record keeping function.

Second, automated inventory tracking systems have been devised to further improve inventory accounting in the automated factory. Before factory automation, inventory counts were often performed manually. For large inventories this process could be quite costly. In an automated factory, inventory tracking systems include such items as radio frequency devices and bar code scanners. "Automated reading devices make continuous tracking of parts possible" [Lee, 1987, p. 54]. For example, using bar code scanners, it is possible to automatically record movement of any coded item from one location to another. Automated tracking devices provide enhanced inventory accountability in the automated factory.

An example of more efficient inventory control under automation is illustrated by the K2 Corporation of Vashon Island, Washington. K2 is this country's largest manufacturer of high performance fiberglass snow skis [P&IM Review, 1987]. The company had used a manual inventory tracking system comprised of hand written "movement tickets" in order to follow materials through the production process. Inventory data gradually accumulated, and eventually led to two major problems: 1. Too many unordered skis existed in inventory, and 2. Not enough "ordered" skis were available in inventory to ship to retailers.

K2 Corporation solved their inventory problems by incorporating a bar code inventory system under computer control. The result has been a $75,000 savings per year [P&IM Review, 1987].

Inventory accounting changes often occur in the automated factory. These changes occur because of the ability to reduce inventory levels, relocate inventory to the factory floor, and to reduce, or automate, inventory record keeping. In the next section, the accounting changes are discussed that arise because of increased factory flexibility.

C. INCREASED FLEXIBILITY

Production flexibility, like inventory and quality, assumes new dimensions in the automated manufacturing environment [Lee, 1987]. In contrast to the traditional assembly line process, CAD/CAM facilitates mass production requiring less lead time, less changeover time, and greater variety in product output [Lee, 1987]. Each of these characteristics suggests corresponding changes to the firm's product costing system.

1. Changes in Lead Time

Factory automation enables products to be produced requiring less lead time [Howell, 1987]. For example, in an extreme case, an automated link from the customer, through the manufacturer, to the supplier could enable the customer to place the order, draw the materials directly from the supplier, and automatically pull the materials through the manufacturing process. Although this scenario is highly unlikely because of the virtual loss of control by the manufacturer, it illustrates how far automation could go. In this case, lead time would be very small. A more likely situation is described by the same set of circumstances except that the manufacturer controls the manufacturing technology instead of it being automatic.

This automated, short-lead-time environment suggests that records could be created and processed automatically. Inventory accounts could be automatically measured, parts could be tracked through the manufacturing process by "bar code" scanners, and the product could be assembled and inspected, again using bar code devices, mechanical grippers, or vision systems. As lead time is reduced, product cost information must be accumulated and efficiencies determined more rapidly because of less time spent in the manufacturing process. Therefore, as lead time decreases, the time available to produce accurate product costing information decreases, and can be better accomplished under computer control.

2. Changes in Machine Preparation Time

Accompanying the decrease in lead time, is a second feature of increased flexibility, a decrease in machine preparation, setup and changeover times. Lee (1987) illustrates the difference in changeover time between a yypical automobile plant and the automated Toyota plant. He notes that a typical automobile plant requires six hours to changeover the metal stamping process from one model to another. By comparison, the Toyota plant requires only 3-5 minutes [Lee, 1987]. This decrease in changeover time represents a decrease in overall product manufacturing time, and usually, decreasing time results in decreasing costs. The product costing system must accurately reflect this cost adjustment if management is to receive useful decision making information. Accounting measures based on transaction activities, as discussed earlier, can be helpful in capturing the effects of changes in machine preparation time by relating changeover time to the transaction cost.

3. Changes in Product Variety

Third, under automation, decreased lead time and changeover time allow more focus on product variety. Quicker changeover implies the capability to produce a greater variety of products without inhibiting overall throughput. Different products require a different resource mix, and incur differing costs. The product costing system should capture the cost changes caused by the greater variety of products enabled in the automated factory environment.

One way to capture these changes is by use of specialized computer software which integrates the accounting information system to the manufacturing process. An example of this type of specialized integration system can be seen at General Motors, where Manufacturing Automation Protocol (MAP) has been employed. The objective of MAP is to adapt all factory and data processing machines to a common protocol specification [Data Communication, 1985]. Other examples of cost measurement and control software tools used to improve factory flexibility decision making capabilities in automated factories include:

- Standard Assembly-Line Manufacturing Simulation (SAMIS) developed at California Institute of Technology Jet Propulsion Laboratory [Ayers, 1985]. This system was created to support research and development efforts for new technology.

- Economic Assessment Model (EAM) developed by Bell Helicopter [Ayers, 1985]. This system was created to financially analyze development plans for productivity improvement projects.

In summary, the increased flexibility of automated manufacturing suggests changes to various aspects of traditional costing techniques. Faster production cycles enable shorter manufacturing lead times. Quicker machine changeover times enable greater production variety. Increased production variety should enable satisfaction of a larger customer base. The effects of these changes can be captured by the cost accounting system by use of transaction measures, and by advanced computer software packages.

D. FACTORY PHYSICAL LAYOUT

Bringing automated manufacturing into the factory often results in some changes to the way in which the factory is arranged [Koelsch, 1985]. These changes affect the manufacturing equipment locations, relationships of service departments and the product inspection procedure. This section discusses each of these changes, and their impact on the product costing system.

1. Manufacturing Equipment Location

Introduction of factory automation seems to affect the way in which manufacturing machines are arranged in the factory. Traditional factories were often arranged in a functional manner [Howell, 1987]. This meant that similar machines were grouped together, and resulted in extensive work in process inventories, and material handling as production proceeded from one line to the next.

As firms transition to automation, many seem to be arranging their factories along product flow lines [Howell, 1987].

> In a product flow line, all the different types of equipment required in the manufacturing process are brought together, splitting up large groups of similar equipment, creating multiple miniature product line factories. This layout minimizes material handling and inventory. [Howell, 1987, p. 23]

The result of the product flow line is a reduction in traditional product cost categories.

2. Service Departments

Service departments are those departments, such as legal and data processing, which exist to provide specialized service to other departments. In order to maximize operating economics of scale, traditional manufacturing organizations evolved with centralized service departments to support the production departments [Johnson, 1987]. This logic was based on the notion that it was more economical for a centralized purchasing department or centralized quality control department to service several production departments rather than have each production department individually dedicated services [Johnson, 1987].

Under factory automation, the trend is towards multiple product flow lines, as discussed above [Johnson, 1987]. This product line approach may call for a reduction of some centralized service departments, and reassignment of personnel with specialized skills. These specialists can sometimes be assigned directly to the product lines. This reassignment may only be feasible if some product lines do not require the services of all centralized departments. For example, a mature product may not require the services of the engineering department, or some other centralized product development service. Therefore, to apply overhead containing engineering department costs to a mature product line may distort the product cost for that item.

In general, it seems advisable to remove any irrelevant service department costs from the overhead pool charged to a product. This is especially important in the automated environment, because the total manufacturing overhead will usually increase under automation as discussed earlier. [Howell, 1987] For product costing, making this change could result in more relevant indirect cost allocation and a more accurate product cost determination. The cost accounting system must then adapt to this new cost allocation structure because to continue using prior methods would distort product costs, and provide misleading management information.

3. Product Inspection

Additionally, under factory automation, there is usually a reduction in the number of product inspection points. In the traditional factory using large amounts of direct labor, multiple product inspection points were used throughout the manufacturing process to verify product quality. However, since machines tend to make each product within specifications, the need for multiple inspections points can usually be reduced [Kaplan, 1983]. This change has several effects on accumulating product cost. First, overhead allocation can be restructured. Overhead pools no longer need to contain the previous amounts allocated to production inspection costs. Secondly, inspection costs can be reduced as the amount of time and equipment spent on inspection is reduced. [Kaplan, 1983] For example, one of Ford's engine plants runs four times faster than traditional lines and is capable, through an automatic self-monitoring process, of automatically performing product inspections during the manufacturing process [Production Engineering, 1986]. Another example is Allen-Bradley's integrated assembly line which automatically assembles motor starters. The production process is fully automated, with no direct human labor, and achieves an error rate of 15 parts in one million.

Automation often results in steady production consistency. This consistency of output reduces the need for the number of inspection activities that were typically required in the traditional, manual labor oriented manufacturing line.

4. Summary

Manufacturing automation usually results in modifications to the factory layout. These modifications affect the physical layout of the manufacturing equipment, the relevance and application of service department costs, and the amount of product inspection points. In the next section, changes to the firm's cost structure which may arise in an automated environment are discussed.

E. COST STRUCTURE CHANGES

It appears that automation introduces changes to the firm's cost structure. Bennett et al. (1987), in a study of manufacturing firms, found that the total manufacturing cost for their respondents consisted of 53% material costs, 32% overhead costs, and 15% direct labor cost. As firms automate more of their manufacturing processes, Bennett predicts, "...that a cost structure of 55 percent material, 5 percent labor, and 40 percent overhead is a fair representation of what advanced manufacturing will bring to some automated facilities" [Bennett et al., 1987 p. 12]. This decrease from 15% to 5% in direct labor, and rise from

32% to 40% in overhead, may lead to practical changes in the way manufacturing costs are calculated.

One such change may be replacement of the two cost categories of direct labor and overhead with the single cost category of conversion cost [Seed, 1987]. This procedure has been in effect for some time in process type industries, such as the chemical industries and the oil industries [Seed, 1987]. As the number of workers and the direct labor cost decreases with increased automation, it may be more economical, and equally effective, to continue measuring direct labor for certain purposes if desired, but to formally track and report conversion costs. [Seed, 1987]

Another cost structure change in the automated factory is the increase in fixed conversion costs caused by automation. Direct labor, material handling, and quality control are examples of costs that often change from variable to fixed in an automated factory [Seed, 1987]. For example, direct labor becomes more support oriented, and MHS machines usually require a fixed initial investment cost which varies little with system use. The result is that these types of costs do not vary with production as they did in the traditional factory.

Introduction of factory automation can introduce changes to the firm's costs structure. Whether the machine involved is an industrial robot or an FMS, the firm's product costing system should reflect any relevant cost structure changes.

F. CONCLUSION

In summary, factory automation appears to introduce changes to the manner in which products are produced. In order to assess and portray the cost of product manufacturing, the cost accountant should ensure that the cost accounting system reflects the changes caused by factory automation.

In this chapter, several changes were discussed which may affect the manufacturing environment as a result of the introduction of automated production technology. First, product quality should increase in the automated factory. Second, the literature suggests that manufacturing inventories may be reduced. Third, under factory automation, increased manufacturing flexibility may be possible, which should be reflected in the firm's accounting system. Fourth, modifications may occur in the factory physical layout, and to the firm's cost structure. Manufacturing automation brings diverse changes into the factory, and also provides opportunities for production improvement. What are some of the changes that could be made to incorporate these new concepts into traditional cost accounting systems? The next chapter discusses some recommendations for improving product costing in the automated manufacturing environment.

VI. CONCLUSION

This chapter consists of four parts. Part A presents recommendations for improving cost accounting in the automated factory environment. Part B lists related questions for potential future research. Part C provides a summary of the main points of this thesis. Part D is the conclusion to the thesis.

A. RECOMMENDATIONS

1. Introduction

The preceding chapters have discussed weaknesses in traditional product costing techniques when employed in the automated manufacturing environment. Although some significant weaknesses seem to exist, many of the basic tenets of traditional cost accounting appear sound. The changes required in order to more accurately reflect the manufacturing processes in the automated factory seem to be primarily evolutionary changes which can be made either by: (1) additions or modifications to existing accounting practice, or (2) establishment of a separate costing system as an adjunct to current systems now in use. What suggestions can be offered to improve cost accounting under factory automation? This section discusses some of these recommendations.

2. Recommendations for Overhead Application Techniques

There are two aspects of overhead application that should be reviewed when automated manufacturing machinery is brought into the factory. First there is the issue of formulating the overhead pool. Secondly, there is the issue of overhead cost application. First the formulation of the overhead cost pool is discussed.

a. Overhead Cost Pools

Recommendation: When the work force structure changes, as automation is brought into the firm, an in-depth analysis of the contents of existing overhead cost pools should be conducted.

Discussion: As discussed previously, use of automated manufacturing equipment suggests that it may be advantageous to modify the composition of traditional overhead cost pools. These modifications may be needed in order to structure overhead cost pools so that homogeneous costs are grouped together.

When factory automation is introduced, the nature of some manufacturing costs change. For example, variable indirect labor, and personnel supervision costs, usually decrease, while indirect fixed capital costs generally rise. The result can be that once homogeneous pools are no longer homogeneous. Overhead cost pools, once composed of costs caused by similar manufacturing activities, may now be composed of costs which are not driven by similar manufacturing activities. For example, consider the costs associated with plant, property and equipment. In the traditional manufacturing environment, plant, property, and equipment utilization often varies with production activity. Increased production frequently means more direct laborers. Expanded work forces result in increased usage of plant, property and equipment and increased demands on support services, all of which contribute to increases in indirect costs of production. However, in the automated factory, such as the Allen-Bradley plant, the labor force, and hence, building occupancy costs, may vary only slightly with changes in production. In contrast to the traditional plant, building occupancy costs in the automated factory may no longer be driven by changes in production activity. If building occupancy costs remain in a cost pool that is predominantly driven by production volume in an automated manufacturing environment, misleading product cost data may be computed. Without analyzing, and possibly restructuring the contents of the aggregated overhead cost pools which were previously formed under a direct labor intensive system, distorted cost data may result under automation.

b. Overhead Cost Allocation.

Recommendation: Conduct an in-depth analysis of the existing procedures for allocating indirect manufacturing costs.

Discussion: When automated manufacturing technology is brought into the factory, the existing procedures for allocating indirect manufacturing costs should be re-analyzed. The purpose of this analysis is to determine the accuracy of the cost allocation procedures. As discussed earlier, costs should be allocated in a manner which reflects the circumstances under which they were incurred. In the traditional manufacturing environment, direct labor was often an appropriate allocation base. However, in an automated manufacturing environment, machine or transaction oriented bases may be a more effective means of allocating indirect manufacturing costs. The results of this analysis may indicate that it is important to establish machine standards, measure machine usage, and analyze machine cost factors.

A review of overhead collection and allocation procedures should be performed when automated manufacturing is brought into an organization. Organizations which evolve from traditional manufacturing processes to automated manufacturing processes and do not also modify their indirect cost allocation bases, may jeopardize the accuracy of their product cost system. Next, recommendations for inventory handling in the automated factory are discussed.

3. <u>Recommendations for Inventory Handling</u>

Another major aspect of manufacturing that requires careful analysis in an automated factory is the treatment of inventories. Inventory location, inventory categories, inventory detail and cost are all areas which are likely to be affected by factory automation. This section discusses some recommendations that relate to product costing due to the changes automation brings to inventory management.

a. Inventory Reduction

Recommendation: Inventory levels should be reduced to the minimum level needed to support the production flow.

Discussion: In the automated manufacturing environment, where advanced technology enables shorter production cycles, holding large inventories may be unnecessary. This may be especially true if long-term relationships are maintained with reliable suppliers. Shorter production cycles and reliable deliveries of raw materials suggest that manufacturing inventory levels may be reduced for two reasons. First, manufacturing inventories represent tied up capital which may be invested elsewhere for a better return. Second, large inventories require storage space, security, insurance, and are sometimes vulnerable to spoilage and obsolescence. The benefits of inventory reduction may be diminished under certain circumstances, such as potential labor disputes with suppliers, or excessively high order costs. Yet, the automated manufacturing process can respond more quickly to customer demand, and may decrease the need for large buffer inventories. When this need for buffer inventories decreases, inventory levels should usually be reduced.

b. Inventory Relocation

Recommendation: Inventories should be maintained on the factory floor in the automated environment. [Howell, 1987]

Discussion: After giving due consideration to such factors as space requirements, security costs, shorter lead times and lower inventory level requirements, it may be possible in the automated factory for materials to be placed closer to the manufacturing cell or machine where they will be processed. Additionally, organizing the factory floor to facilitate product flow, an apparent trend with automated processes, increases the likelihood that raw materials can be relocated nearer to the actual manufacturing location. Relocation reduces materials handling expense and total handling time, especially if inventory items can be delivered to the factory floor by the vendor. This factory consolidation of machine and inventory can accelerate manufacturing throughput, and contribute to more efficient production.

c. Inventory Record Reduction

Recommendation: As traditional factories transition to automation, traditional inventory record keeping functions may be reduced or consolidated.

Discussion: There are three factors which suggest that inventory record keeping functions may be reduced or consolidated in the automated factory. First, the reduction in inventory volume may enable a reduction in inventory record keeping requirements. Second, as inventory volume decreases, it is possible that some inventory categories can be consolidated, or even disappear. For example, in an extreme case, there may be only one inventory account, Raw Materials in Progress [Walden, 1988]. This rearrangement of the inventory account structure offers opportunities to reduce inventory record keeping. Third, automated inventory tracking devices, such as bar code scanners, can automatically track individual inventory items from location to location during an automated manufacturing process. This tracking data can be monitored by a central computer, resulting in the potential for decreased inventory record keeping in the automated manufacturing environment.

The means by which direct materials are brought into, and tracked during, the manufacturing process are areas that can often be improved when shifting from traditional to automated manufacturing techniques. Next, a recommendation for conversion costs is discussed.

4. Recommendation for Tracking Costs to Convert

Recommendation: Consideration may be given to replacing the two cost categories, labor and overhead, with the single cost category of "cost to convert."

Discussion: In automated factories, there may be a significant decrease in the number of direct laborers commensurate with the increase in machine production capability. Since the distinction between labor and burden may not always be clear in the machine paced environment, it may be advantageous to simply combine the two. This combination has been common in paper, chemical, and food processing industries for some time [Seed, 1984]. In an automated manufacturing environment, this procedure may decrease accounting complexity and cost, without losing any necessary information.

Two primary features of the cost to convert concept should be appealing to cost accountants in an automated environment. First, using a single cost eliminates the necessity to distinguish between direct labor and indirect labor, and hence burden. Secondly, "cost to convert" can be based on direct labor, machine usage, numbers of transactions, or process time, whichever is more appropriate for the particular function [Seed, 1987]. Both of these features should result in less complexity and less cost associated with the product costing system. A recommendation for reporting quality costs is discussed next.

5. Recommendation for Reporting Quality Costs

Recommendation: Formalize reporting of quality costs.

Discussion: As discussed earlier, factory automation introduces new manufacturing dimensions to production output. These new dimensions need to be quantified to facilitate management decision making. One area where such new measures are most relevant is in the area of quality cost measurement. New reporting for the cost of quality should be devised because, when compared to traditional processes, quality improvement is often attainable in an automated factory. Many manufacturers spend from 20% to 40% of sales dollars on tasks related to correction of product deficiencies [Walden, 1988]. While quality measures expressed in operational terms (i.e., number of defective units per batch) may be useful information, quality costs should usually be measured in dollar terms for overall management analysis. Reporting methods should be used to clearly focus on the cost of producing a deficient product. With accurate quality cost information, managers will be better equipped to make the overall manufacturing decisions which are affected by production costs.

6. Recommendation for Investment Justification

Recommendation: Use realistic decision parameters in the CIM acquisition process.

Discussion: New methods to justify investment in CIM technology need to be devised [Kaplan, 1986]. Today, managers often make the decision to acquire automation based partially on subjective feelings. Data to evaluate some of the historically hard to quantify categories of CIM benefits need to be accumulated. Unrealistically high discount rates need to be brought more closely in line with the projected cost of capital [Kaplan, 1986].

It is potentially misleading to use hurdle rates of 15%, and exclude formal consideration of improved quality, increased flexibility, and quicker response to customer orders. These criteria should be included in the investment decision as quantitatively as possible. Huang (1984) has devised one approach for evaluating and selecting industrial robots from different vendors. This approach advocates the use of a large number of selection criteria. Each of these criteria can be individually classified under three major headings: (1) Critical Factors, (2) Objective Factors, (3) Subjective Factors. By establishing quantitative weighting scales for each category, including subjective factors, Huang offers a comprehensive procedure which can be useful in the selection of automated manufacturing equipment. In the next section, a recommendation for multiple cost systems is discussed.

7. Recommendation for Multiple Cost Accounting Systems

Recommendation: Consider the establishment of two cost accounting systems to present better cost data.

Discussion: It appears that one cost system is not able to provide data that are accurate enough, and focused enough, to fill all the requirements of a product cost system [Howell, 1987]. Three requirements of a product cost system (i.e., external reporting, internal product costing, and operational production control) appear difficult to achieve with a single cost accounting structure. Two examples help illustrate these difficulties. First, external reporting does not require manufacturing overhead to be causally related to the manufacture of individual products [Kaplan, 1988]. Conversely, managerial product decisions and operating efficiencies may be improved by utilizing product cost calculations derived from causal relationships between the costs of resources consumed and the manufacturing expenses incurred. Second, for external reports, inventory valuation need only be reported on the date of the external report, usually monthly, quarterly, or annually. This time period can be too lengthy for relevant management decision making or accurate operational control. For operational control, managers need accurate, timely information which relates to their portion of the manufacturing process, and reflects costs over which they have control. The operational system should be less aggregated than the corporate inventory valuation system, and tailored more towards the short-term needs of the individual operational manager. [Kaplan, 1988]

Multiple product cost systems may improve a firm's ability to calculate production costs. It may be better to build a single, organizational data base, and then devise multiple cost systems to access this data base in order to address the needs of cost management and control, product cost determination, and inventory valuation [Howell, 1987]. Two primary systems could be developed, one to support inventory valuation, and the second to support measurement of operating efficiencies and improve managerial product cost decision making [Howell, 1987]. A costing framework composed of multiple cost systems may provide management with better cost data than a costing framework composed of only a single costing system. A recommendation concerning the accumulation of product cost data is discussed in the next section.

8. Recommendation for Accumulation of Produce Cost Data

Recommendation: Consider implementation of automated procedures for collection of product cost data.

Discussion: Factory automation can often result in acceleration of manufacturing throughput and a corresponding reduction in product manufacturing time. As this pace of production increases, there is less time available to manually accumulate product cost data. Automated product tracking devices, such as bar code scanners and vision systems, can quickly and accurately record product transfers from one point, or manufacturing process, to another. These automated tracking devices can feed information to the computer data base management system, which can constantly provide real-time product cost information. As the manufacturing process becomes automated, it may become advantageous to automate the linkage between the manufacturing system and the product cost system.

9. Recommendation for Service Department Cost Analysis

Recommendation: Analyze the treatment of service department costs when automated manufacturing equipment is brought into the factory. Remove any irrelevant service department costs from the overhead pool charged to the product.

Discussion: When organizations shift from traditional manufacturing to automated manufacturing, potentially irrelevant service department costs can remain in overhead cost pools. The treatment of service department costs should be re-examined for at least three reasons. First, most organizations originally established procedures for handling service department costs when older, more traditional manufacturing technology was used. Any major change in the manufacturing process suggests possible changes to the treatment of service department costs. Second, as discussed earlier, total manufacturing overhead is likely to increase in the automated manufacturing environment as compared to the traditional plant. As the total cost increases, it becomes more critical to eliminate any irrelevant costs. Third, the trend in many firms incorporating automated manufacturing techniques seems to be movement away from functional machine groupings and towards product flow lines. These three factors can affect the relevance of centralized service department costs.

When firms shift to automated manufacturing technology, the treatment of centralized service department costs should be re-examined. Any irrelevant service department costs should be considered for possible removal from the overhead cost pool charged to the product.

10. Conclusion

This section discussed recommendations for improving product cost measurement in the automated factory environment. Changes to factory overhead structure, inventory levels, production quality, along with changes in other aspects of manufacturing under automation suggest that a corresponding evolution in cost accounting should occur.

B. SUGGESTED AREAS FOR FURTHER RESEARCH

During the research process for this thesis, questions arose which, although outside the scope of this particular thesis, suggest areas where more research may lead to additional improvements in manufacturing product cost techniques. In this section, these questions are discussed.

1. Question: How does one most accurately quantify the justification criteria for automated manufacturing equipment?

Discussion: Factory automation offers many possible improvements for manufacturing capability. However, some of the most significant of these improvements seem to be extremely difficult to capture in quantitative terms. This weakness in the justification process results in subjective values weighing heavily in the automation justification decision. The outcome of the justification process, can be heavily influenced by personal biases. How should a firm objectively quantify the important qualitative benefits during the acquisition justification process for automated manufacturing equipment?

2. Question: What is the most meaningful way to measure the cost of quality during the product life cycle?

Discussion: Automated equipment appears capable of consistently producing high quality goods. Yet, when a poor quality item occurs during production, or is discovered in the field, how can the cost of neutralizing the defect by best measured? Dollar measures seem to be only part of the answer.

3. Question: What can be done to improve the interface between accounting information systems, and the automated manufacturing process?

Discussion: With powerful computer systems available to drive automated production machinery, it is important that compatible computer software programs be developed to interface the manufacturing process with the accounting system. As discussed earlier, several systems are available today to help capture the economics of operating automated manufacturing technology. Many of these systems, such as Manufacturing Automation Protocol (MAP) or Material Resources Planning II (MRP II), are new and do not appear to fully provide all the data which management needs. How can the accounting information and control system be structured to take better advantage of the capabilities of automated manufacturing equipment?

4. Question: Management information reports contains too much superfluous data. How can management reporting be made more concise and relevant?

Discussion: Much of the management reporting in the automated environment contain overwhelming amounts of data and details. Management information systems are capable of tracking and producing overwhelming amounts of production and accounting data. How can management reporting be restructured so that the most important information is quickly available for sound decision making?

5. Question: What elements should be included in the computation of total product cost in the automated manufacturing environment?

Discussion: Logically, value added costs, such as material, labor, and overhead, should be combined in order to determine the cost of manufacturing a product. However, during the automated production process, there may be occasions when some non-value adding costs are incurred. GAAP currently requires these non-value added costs to be inventoried for Income Statement and Balance Sheet purposes. These costs could be incurred for a number of unanticipated reasons, such as shifts in customer demand, new legislation, or even an unforeseen event like the oil embargo of the 1970's. When the firm incurs a manufacturing cost which does not add value to the product, should this cost be written off as a loss on the income statement, or inventoried as product cost to be matched against the revenue gained from the product's eventual sale? [Mecimore, 1988]

C. SUMMARY AND CONCLUSION

In the first chapter, the origin of modern product costing was traced back to its inception prior to the Industrial Revolution. It was shown how managers and industrial engineers between 1830 and 1930 created and implemented most of the product costing concepts which firms utilize in their cost accounting systems today. Product costing development reacted to advances in manufacturing technology. Firms and organizations perceived the need to revise their product costing systems to accommodate the technological strides made in improving manufacturing capabilities. These companies responded with the development of accounting measures and ratios, devised by managers, to enable more accurate measurement of the resources which they consumed in the production of their goods and services. Since 1930, some refinements to cost accounting have been introduced to streamline the existing concepts, but few accounting innovations have taken place to accommodate the technological strides made in the development of computerized, automated manufacturing systems. Firms are virtually using the same product costing procedures created over 50 years ago.

In the second chapter, the physical characteristics of the new manufacturing environment were described, including features of robotic and numerical control machines, flexible manufacturing systems and CAD/CAM. It was seen that the new manufacturing technology, coupled with computerization, enables significant reductions in direct labor, previously a major component of traditional product costing procedure.

In Chapter III, the basic principles of manufacturing cost accounting were discussed, and the distinction was made between job order costing and process costing, the two main methods of determining product costs. This discussion led to an analysis of overhead application, investment justification, quality measures, and flexibility in the traditional factory environment.

Chapters IV and V then built upon the background developed in the prior chapters to discuss some of the weaknesses in product costing in the automated factory. Chapter IV focused on the product costing changes suggested by utilization of the actual hardware. It was shown that: (1) The relative percentages of essential product cost elements change in an automated environment. Although material costs may not change significantly, the relative amounts of direct labor and overhead are likely to change noticeably. Direct labor can be expected to decrease from the 15% range to 5%. Overhead can be expected to increase from 32%, to as much as 40%. (2) Overhead composition also changes as factory automation increases. The indirect labor component can be expected to increase as more computer programmers, maintenance staff, and other support personnel become necessary. Likewise, depreciation expense may increase commensurate with the greater use of capital equipment. (3) Investment justification under automation takes on a much more qualitative nature.

Chapter V focused on product costing processes that change under automation. It was shown that: (1) Quality factors assume a greater potential for significant cost savings . (2) Inventory levels may decrease, and it may be cost effective to maintain only the amount of inventory on hand needed to support actual orders. (3) Flexibility increases, and lead time decreases.

Chapter VI presented recommendations for making product costing more relevant in the automated factory. These recommendations included proposals for:

1. Overhead application techniques.
2. Inventory handling procedures.
3. Conversion costs.
4. Reporting quality costs.
5. Investment justification.
6. Multiple cost accounting systems.

7. Automating the accumulation of product cost data.

8. Treatment of service department costs.

These modifications may help to enable more accurate product costing. Chapter VI then presented questions, related to this thesis, which are suggested for additional research.

The primary question of this thesis was, "Does the automated manufacturing environment suggest that accounting procedures for product costing be performed in ways which differ from traditional methods?" The answer to this question appears to lie in the affirmative. The primary reason for this result may be because of reductions in direct labor and the changes in overhead characteristics which occur when automated manufacturing technology is introduced. These new technologies seem to affect the ability of traditional manufacturing accounting procedures to capture product cost relationships. Computerized, automated manufacturing techniques imply that traditional manufacturing accounting must evolve if product costing methodologies are to provide relevant product cost information in the new factory environment.

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