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PERFORMANCE MEASUREMENT
IN THE
RAMP SMP FACILITY

by

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Management will require timely, accurate cost and operational data to evaluate the efficiency of the RAMP facility and its effectiveness in achieving program goals. Traditional accounting and performance measurement systems produce inadequate data in a CIM environment.

This thesis derives objectives for the facility from program goals and proposes measurements to assess the achievement of these. The measurements

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Performance Measurement
in the
RAMP SMP Facility

by

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ABSTRACT

The Rapid Acquisition of Manufactured Parts (RAMP) program is a Navy initiative to address the problems of high cost, growing leadtime and diminishing sources for spare parts. RAMP addresses this by developing digital parts technical data and computer integrated manufacturing (CIM) capability within the Navy and integrating this capability into the Navy's supply and weapons acquisition systems.

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This thesis derives objectives for the facility from program goals and proposes measurements to assess the achievement of these. The measurements emphasize flexibility, quality, efficiency and support of RAMP program goals.

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I. INTRODUCTION

A. BACKGROUND

The Navy often needs to procure very small lots of commercially unavailable repair parts. The parts may not be commercially available because they are used only in a limited number of military applications. The reasons that these parts are not readily available through the Navy's supply system include the following:

- The part was overlooked, or considered not likely to ever fail, during the initial supply support determination (provisioning) process,

- The part may have been stocked at one time but was disposed of because insufficient demand occurred to warrant continued stocking,

- The original manufacturer may have gone out of business or may be unwilling to provide the item except at an exorbitant price, or

- The part may be needed for an extremely urgent requirement, such as a fleet casualty report (CASREP), and normal procurement leadtimes would not be acceptable.

Any traditional manufacturer attempting to make such a part in very small lot sizes, using traditional labor intensive manufacturing methods would likely require a long leadtime and charge the Navy a price reflective of the manufacturing technology of manned job shops or the high costs of disrupting and re-tooling a fixed high-volume assembly line.

These problems of growing cost and lead time, coupled with the diminishing industrial base in the United States, led the Department of Defense to initiate several programs in the early 1980's to accelerate the introduction of advanced technology into logistics data and spare parts procurement systems. The Rapid Acquisition of Manufactured Parts, or RAMP program, under the management of the Naval Supply Systems Command (NAVSUP), is one of the Navy's initiatives in this area. RAMP facilities will use advanced methods and equipment to produce parts in two types of highly automated manufacturing cells: one for small mechanical parts (SMP) and one for printed wire assemblies (PWA).

Ultimately, RAMP facilities will be situated at several Navy Industrial Fund (NIF) activities and private sector contractors around the country. At this time, the RAMP Test and Integration Facility is nearing completion in Charleston, South Carolina, and is expected to be operational in the early 1990's. Here, the system hardware and software will be integrated and made ready for the first Navy site installations. The first SMP cells will be at the Charleston Naval Shipyard and the Naval Aviation Depot, Cherry Point, North Carolina. The first PWA cell will be at the Naval Avionics Center in Indianapolis.

RAMP will use part specifications in computer readable format in a computer integrated manufacturing (CIM) and flexible manufacturing system (FMS) environment to produce a wide variety of high-quality, low-cost parts with leadtimes which are about one tenth as long as current procurement channels. (Lotz, 1987) The availability of parts data in a standardized, non-ambiguous digital format is expected to be the key reason for the dramatic improvements in leadtime. (Interview-A)

CIM integrates computer aided design (CAD), computer aided engineering (CAE) and computer aided manufacturing (CAM.) An FMS consists of:

> ...two or more machine tools served by an automated materials handling system and controlled by a computer. An FMS is generally used in low to mid volume, mid variety production systems where a number of related parts are manufactured in varying quantities. (Bennett et al, 1987)

The program is expected not only to improve fleet readiness by reducing costs and leadtimes for spares, but to:

- Integrate advanced computer integrated manufacturing technology into Navy logistics systems,
- Establish procedures and capability to communicate parts requirements and specifications to automated manufacturing facilities, and
- Install flexible manufacturing cells in Navy industrial activities. (Lotz, 1987)

RAMP may also enable the Navy to reduce its wholesale spare parts inventory levels, providing a potential saving of Navy Stock Fund investment dollars. A viable RAMP system should allow the Navy to safely use a higher stockout risk level in inventory models, reducing the safety stock levels presently required. Currently, the Navy maintains large inventories of items for which little or no demand is anticipated. Reduction of these inventories will free funds for more productive investment in other areas.

Another RAMP goal is to encourage and assist private sector suppliers to adopt modern manufacturing technology. The private sector has been slow to adopt advanced manufacturing technology, citing high costs and a lack of knowledge of how to evaluate, implement and manage the CIM as primary reasons. (Peat, Marwick, Main & Co., 1987) Under the RAMP concept, the Navy assumes the risk of system development and then freely shares the technology with associated contractors, thus encouraging private sector industrial modernization.

In order to efficiently operate the facility and effectively achieve the goals of the RAMP program, management will need to devise a system of performance measurements or indicators. Current Navy Industrial Fund (NIF) and private sector performance measurements generally emphasize short-term financial results and labor efficiency. Many of these traditional measurement systems may lead to poor decision making in an advanced manufacturing setting. (Howell, 1986) Some new measurement concepts have been proposed in current management and accounting literature, but this is a new field of study and many issues are unresolved. (Kaplan, 1983) Most researchers expect a greater emphasis on improved quality, lower inventory levels and more responsive customer service in the new performance measuring systems. (Howell, 1986 and Hendricks, 1988)

While it is expected that the specific performance measurements will change, it is very clear that the methods of data gathering and compilation will be different. Most of the manually prepared material requisition documents and labor time tickets will become unnecessary in an FMS or CIM because the computer network that operates the automated factory will collect real-time data on virtually every relevant aspect of every job. In contrast to manual systems, this data will be much more accurate and timely.

More timely reporting will be essential in the automated factory. Dramatic reductions in manufacturing cycle times are expected. Rather than waiting for monthly reports from the traditional accounting system, management must be able to monitor quality, inventory position, delivery, and system utilization constantly. Performance measurement must become a real-time function in the automated factory, and not continue to rely on reports of data aggregated over weeks or months as in the labor-based traditional factory.

B. THESIS OBJECTIVE

This thesis explores the goals of the RAMP program and reviews current writings on management control and performance measurement in private sector CIM/FMS organizations. A model is proposed which outlines several measurements to consider for implementation, and some general considerations for designing the management control system for the RAMP facility. The objective of the model is to ensure that the performance measurement function will enhance, rather than frustrate the program's goals.

Detailed descriptions of the RAMP manufacturing facility, operational scenarios, and discussions of cost accounting issues have been presented by Gardner (1988), Bryant (1988) and Murphy (1988) and will not be repeated here.

The purpose of this thesis is to investigate the types of information required by management in a CIM environment, specifically the RAMP SMP cell, for effective management control. That is, how can management accurately monitor and facilitate efficiency and effectiveness as they attempt to achieve the organization's strategic goals?

The goals of this thesis are to answer the following questions:

- What information is required by management of a CIM factory to assess performance?
- The goals of the RAMP program are different from those of a private sector, profit making facility. How will these differences translate into different performance measurement systems?

- Once a system of measurements and controls is in place, how will management determine that they contribute to the program's efficiency and effectiveness?

C. SCOPE, LIMITATIONS AND ASSUMPTIONS

The scope of the thesis is to study the performance measurement requirements of a prototype RAMP facility. The focus is on the small manufactured parts (SMP) cell and not on the printed wire assemblies (PWA) cell. Applicability to the PWA cell will not be specifically addressed, although many of the issues considered are expected to be the same as those in the SMP cell. The differences in managing the two types of cells may be a productive subject for additional research.

The scope will be limited to the study of the RAMP facility itself, and will not directly include the interfaces with its prospective host site command. This thesis assumes that the RAMP facility is operating as a cost center within the host's command structure, receives administrative and support services from the host, and operates under the NIF accounting system, with some modifications as proposed by Bryant (1988), and Murphy (1988).

The thesis identifies some possible behavioral implications of measurements where they may influence the manager to act in a manner inconsistent with the organization's goals. There is a danger in any system of quantitative performance measurements that individuals will act to maximize only the measured attributes, to the detriment of the organization's broader goals. (Ridgway, 1956) Accordingly, the possible impact of given measurements on managerial behavior will be explored.

The cost accounting system is an integral part of the study, but the thesis does not specifically address investment justification of the RAMP program nor product costing issues, except where they affect performance measurement. These topics have been addressed in previous research by Gardner (1988), Bryant (1988) and Murphy. (1988)

Required data for the proposed measurements is identified, but the specific methods of capturing and recording the data with RAMP's computer local area network (LAN) are not addressed; that is the subject of a concurrent thesis. (Franklin, 1989)

D. RESEARCH METHODOLOGY

The research used three modes of investigation: archival research, interviews with selected individuals and analytical research. The archival research included an extensive review of accounting, management and manufacturing literature to define performance measurement as it is done in existing automated manufacturing environments. A computer literature search was used to ensure completeness. Interviews with RAMP program and facility managers were helpful in defining and clarifying program objectives. Analytical research was used to tailor the results of the performance measurement models to the specific objectives of the RAMP program and to draw conclusions.

E. THESIS ORGANIZATION

This thesis has five chapters:

Chapter I contains introductory and background material. The objective of the study and research questions are presented. The research methodologies used in the thesis are identified.

Chapter II develops the theory of performance measurement in a manufacturing environment and offers an explanation of how an inadequate performance measurement may cause a manager's behavior to diverge from the firm's goals. Examples of dysfunctional performance measures are presented. The chapter discusses the effect of advanced manufacturing methods such as automation on performance measurement systems. Finally, there is a discussion on the design and evaluation of control systems and performance measurements.

Chapter III reviews three recent field studies in the areas of performance measurement and factory automation. Current measurements are identified and related to the discussion of theoretical matter from Chapter II.

Chapter IV develops in more detail the RAMP program goals and objectives. Performance measurement systems introduced in Chapter II and discussed in Chapter III are adapted to this model of the RAMP, and evaluated for applicability and usefulness.

Chapter V summarizes the research and recommends, based upon the analysis in Chapter IV, some managerial performance measurements and offers considerations for the design of the RAMP management control systems. The specific questions listed in Section B of this chapter, Thesis Objectives, are addressed in this chapter. Topics for further research are proposed.

II. PERFORMANCE MEASUREMENT AND THE ADVANCED MANUFACTURING ENVIRONMENT

A. INTRODUCTION

The purpose of this chapter is to explore the literature on how to best measure performance in an advanced manufacturing setting. The chapter argues that the management control systems and performance measurements in use influence the actions of the manager in achieving an organization's goals. Several examples of commonly used financial performance measures are discussed. The chapter considers the effect of advanced trends in manufacturing practices, especially factory automation, on performance measurement and concludes with a discussion of some general considerations for the design and evaluation of performance measurement systems.

B. BACKGROUND

1. Definition and Purpose of Management Control and Performance Measurement

Anthony et al. (1984) describe a three-level model of the planning and control process in organizations which will be useful in understanding the context in which performance measurement is discussed in this thesis. This section describes this model and uses it to develop a working definition of performance measurement.

The three levels of planning and control are strategic planning, management control and task control. Strategic planning, is the process of determining the goals of the organization and broad strategies to achieve these. Management control is the process by which management assures that the organization carries out its strategies. Task control is the process of assuring that specific tasks are carried out effectively and efficiently.

Strategic planning, while a continual process, produces output (stated goals and broad strategies) relatively infrequently and often at irregular intervals. It typically involves only staff and senior management in a long-range, broad-scope planning effort resulting in the policies and programs which define top management's goals and competitive strategies for the organization. Management control on the other hand, is an ongoing process carried out by both senior management and operating line management. It takes as given the policies and programs from the strategic planning phase and seeks to implement them, using resources as effectively and efficiently as possible.

Task control seeks to control, in great detail, specific work and procedures. The concept of task control implies a schedule of specific tasks to be carried out, and predetermined standards (monetary and nonmonetary) for the resources and time allowed for each. Variance between the standard and actual resource or time used should be measured for each activity and corrective action taken. Much of this type of control can be automated, especially in a CIM environment. Management control, on the other hand, aggregates this task data by time period and by organizational subunit. While both task and management control are continuous efforts, management control has historically tended to aggregate data by week, month or year. Task control on the other hand is virtually a real-time process. Also, Anthony et al. (1984) write that task control is normally performed by supervisors rather than managers.

Management control is an ongoing process carried out by line and senior management using various indicators (generally financial accounting measures, but including some nonfinancial indicators as well) to ensure that the organization's resources are being used efficiently to accomplish its goals. (Anthony et al., 1984) It is a persuasive activity in that it seeks to influence behavior. It has a relatively short time horizon and focuses on the entire organization. (Euske, 1984)

The purpose of performance measurement is to decide what operational and financial data to measure, how to measure it, and how to gather this data for use in the management control process. It should provide data to evaluate efficiency and effectiveness. Performance measurement supports the management control function by providing the information needed to ensure that the organization achieves its goals.

2. The Design of Measurements and Managerial Behavior

a. Background

A review of the literature revealed two problematic aspects of the performance measurement process. First, the essence of performance is difficult to capture in any set of quantitative measures, no matter how carefully constructed. (Ridgway, 1956) Second, since the organization's reward structure is generally based on the performance measurement system, individuals attempting to advance their own interests will stress achievement of those attributes of performance on which they are evaluated and may ignore those attributes which have little bearing on their evaluation. (Kerr, 1975) This section discusses these two problems.

b. Relation of Measurements to Organizational Goals

Because of the difficulty in measuring abstract goals such as quality and productivity, surrogate measures are defined in order to conveniently represent the performance. Some specific, visible attributes of the performance are chosen for measurement and for management evaluation. (Euske, 1984) The selection of appropriate surrogates to be measured frequently poses a problem.

For example, if management of a firm decides that it should improve its market share by becoming a high quality producer, it might attempt to measure improved quality by computing production defect rates, warranty work expenses or it may survey customer opinion. None of these is a direct measure of the goal. "High quality" is very difficult to define, let alone measure. The firm will probably set quantitative goals for some attributes like the examples mentioned above, in an attempt to monitor its success in achieving its goal.

Lawler and Rhode (1976) list three considerations in selecting performance measures to correspond to an organization's goals: completeness, objectivity and influence.

Completeness means that the attributes measured in fact capture all the key elements of the desired performance. No attributes go unmeasured which, if ignored by management, would detract from the achievement of the firm's goals.

Objectivity means that the measure is impartial and cannot be manipulated. This chapter examines some accounting measures which are subject to manipulation by management to achieve goals.

Influence refers to the ability of the person evaluated to accomplish the actions needed to change the level of the measure. There is no point evaluating a manager against a budget comprised mainly of costs arbitrarily allocated to the department or which is otherwise beyond the manager's control.

c. The Divergence Between Action and Goals

The management control system seeks to ensure that the firm's policies and strategies are being carried out, using performance measurements as yardsticks. Further, the firm's reward system is typically based on achievement of goals as defined by the performance measurement system. (Lee, 1987) A manager's compensation and chances for promotion are based to a large extent on how favorably the individual is evaluated according to the measurements used. (Lee, 1987) The manager therefore has a substantial personal interest in producing favorable measurement data. Unless the measurement system accurately and completely reflects the firm's strategies, the manager's personal incentives may diverge from the goals of the organization, and this non-congruence of goals may unintentionally lead the manager to act in a manner that maximizes personal welfare to the detriment of the organization. The agency model of organizations offers an explanation of how this divergence may occur.

The agency model of organizations, in its simplest form, views the firm as a series of two party quasi-contractual relationships, between principal and agent, or owner and manager, over a single, finite period of time. The principal supplies resources and delegates to the agent the task of coordinating these in the achievement of the principal's goals. Each is presumed to be motivated only by personal interests, and seeking to maximize personal utility from the firm's activities. (Baiman, 1982) Although the assumptions appear to be so tightly constructed as to render the model impractical, Baiman demonstrates that they can be relaxed to allow for multi-person organizations and multiple time periods. This simplifies use of the model and enables it to be used to explain performance measurement.

The returns or rewards to both principal and agent are a function of the extent to which the firm achieves its goals. The return to the owner is the residual increase in wealth to the organization. The contractual relationship between principal and agent defines the terms of the agent's compensation function and the attributes of performance to be measured in determining compensation. An example of this type of function would be a base salary plus a bonus based on reported earnings per share.

The concept of moral hazard describes how the owner's and manager's goals may diverge. Moral hazard is a term used in economic and behavioral literature to refer to the tendency of one party, pursuing personal interest, to take actions which alter the outcome for other parties. A common example is an individual who having purchased burglary insurance does not bother to install door locks. Neighbors act similarly and the frequency of robberies increases causing insurance premiums to rise. The individual is eventually robbed and suboptimal outcomes accrue to both the individual and the insurer. Welfare to society would be increased if everyone acted "irrationally" by installing locks in spite of having insurance coverage. (Baumol, 1983) This phenomenon is used in agency theory to explain the dysfunctional behavior that can result when the functions that define the reward for principal and agent differ. The agent acts "rationally" by maximizing personal utility, but in doing so may sacrifice competitive advantage and organizational success, unless individual interests can be made congruent with the owner's. The following paragraphs provide examples to illustrate this concept.

The manager, as agent for the firm's owners, may have a set of interests not entirely congruent with the owners'. The manager's goals may be oriented toward maximizing current year operating results to increase his bonus, while the owner may desire maximization of the firm's wealth and long-term competitive position. This divergence of interests will widen as the manager's incentives come to be based on measures not identical with the owners' goals.

For example, Rappaport (1981) argues that a manager's focus has a relatively short time horizon, corresponding with the relatively short periods of time over which performance is measured. This phenomenon may occur regardless of the stockholder's presumed desire for long term wealth maximization. This is frequently alleged to lead to the manager's increasing current reported earnings, while sacrificing long term competitive advantage. (Lee, 1987)

Further, it appears that managers will pay attention to those aspects of performance which are measured by the management control system, in the belief that this will further their own interests. The attributes measured become the performance realized, because they are tied to the organization's reward structure. The reward system reinforces those behaviors. (Euske, 1984) However, because of problems in defining and measuring performance, and in designing the control systems, the attributes measured may not correspond to the organization's goals.

For example, if increased productivity is an organizational goal and is measured (and the plant manager compensated) according to the ability to meet an increased production quota, managers may sacrifice quality, incur overtime costs or defer equipment maintenance in order to produce units of output to meet the new quota.

The management control system therefore should measure those attributes of performance most likely to lead to accomplishment of the firm's goals. Also, the system must consist of coordinated and balanced measures that complement each other and do not promote the achievement of one goal at the expense of others. A better measure of productivity for instance, might relate quantity of output to efficient use of inputs, and reduced scrap rates, in addition to merely measuring units of output.

C. MEASUREMENT INFORMATION SYSTEMS

1. Introduction

Performance measurements are often divided into two categories: financial and nonfinancial. The financial measurements are generally products of the accounting system, while the nonfinancial measurements are derived from formal operating control systems or informal methods of measurement.

2. Financial Measurements

Organizations specify many of their goals in terms of financial measures. Goals are often set for annual income, gross margin and return on investment (ROI). Standard cost systems are frequently used in manufacturing organizations, producing variances which are analyzed for signs of manufacturing efficiency. These measurements of performance receive extremely heavy emphasis. (Peat, Marwick, Main and Co., 1987) The term "bottom line" has even come into popular use in conversation.

The use of financial accounting information (as opposed to technology driven, operational data) for management control seems to have originated in the United States after

World War I, with the rise of the large multi-divisional industrial firm and the need for external reporting to capital markets and tax authorities. (Johnson and Kaplan, 1987) Before then, the owner/manager of the typical single-activity firm could directly relate cost information to the underlying production process (which the manager understood well) and manage successfully. With the rise of large, complex multi-product firms, the manager grew farther away from the technical process and began to use accounting based performance measures to "manage by the numbers."

Unfortunately, financial accounting records, while satisfactory for external reporting and tax purposes, led to poor managerial decision making. (Cooper and Kaplan, 1988) Arbitrary cost allocation rules led managers to mistakenly change product mix to emphasize products which appeared profitable under the existing allocations. A fixation on the annual external and tax reporting cycle led to development of performance measurements constrained artificially to a single year, regardless of product life cycles. (Johnson and Kaplan, 1987)

The performance measurements derived from this financial accounting system encouraged managerial action which would maximize reported income, as management compensation was often based on current year performance in reported earnings. (Lee, 1987) Cost reductions and localized (individual worker or machine level) efficiency improvement measurements were emphasized. However, maximizing reported income often involved sacrificing long-term competitive advantage, as is illustrated in the next section of this chapter. Furthermore, the underlying assumptions of the traditional accounting model (long life, design stable products and labor driven production) are becoming less valid as manufacturing moves to a more automated environment and more sophisticated products. (Berliner and Brimson, 1988)

Accounting-based measurements do have the advantage of being comprehensive and coordinated throughout the firm. The monetary measures of the accounting system provide a standard basis for comparison of one division with another. Departmental costs are measured by uniform rules which allow them to be aggregated at the plant, divisional and corporate levels. Corporate earnings can, with some caution, be attributed to lower levels, to compare one manager with another.

3. Nonfinancial Measurements

Two frequent complaints about accounting based measures are that the reports are not timely and that they are aggregated at such a level as to provide measures that are of little practical use. The preceding paragraphs described how financial accounting data came to be used for performance measurement, and some of the problems arising from this use of accounting data. Recall that this data came to be used for performance measurement as a surrogate for operational data when the firm's organizational structures and product lines grew more complex. Practitioners and academicians see a need for a return to more emphasis on nonfinancial, or operational measures. (Howell et al., 1987 and Kaplan, 1983)

Information for nonfinancial measures comes from either formal operating control systems or from informal systems. Operating control systems are statistical records of data such as departmental output, customer service and scrap rates. With the availability of microcomputers and spreadsheet software, this information is easy to gather and analyze. Line managers at all levels are designing their own measurement systems, often quite sophisticated, based on nonfinancial, process-related data. The managers contend that this type of data is more useful than the official accounting reports in administering their departments; it is immediately available and is designed expressly for the manager's unique needs.

These ad-hoc systems furnish relevant, timely data but there are several drawbacks to their use. They are not necessarily comprehensive nor coordinated. The informal measurements designed at one level may not "roll up" to higher organizational levels. They use independent and often contradictory departmental databases. It may not be appropriate or even possible to compare such things as scrap rates or delivery performance among different departments because of different measurement specifications.

The challenge seems to be to combine the comprehensiveness and coordination of the accounting system with the timeliness and relevance of the line manager's operating control system.

D. MEASURES WHICH MAY ELICIT DYSFUNCTIONAL PERFORMANCE

1. Background

The following paragraphs discuss several examples of performance measurements and how they may diverge from organizational goals.

2. Return on Investment

The most widely used financial accounting based measure is return on investment, or ROI. (DeCoster, Schafer and Ziebell, 1988) ROI is defined as profit divided by assets committed, or as the product of margin on sales and asset turnover:

$$ROI = \frac{Profit}{Sales} * \frac{Sales}{Assets}$$

The best known early examples of the use of ROI as a managerial performance measurement were the Du Pont and General Motors corporations in the early twentieth century. General Motors in particular used ROI to ration capital among divisions, and to assess manager's performance and desirability for promotion. Each division manager sought better ways to meet the ROI goal. (Johnson, 1983) More than eighty percent of manufacturers surveyed recently measure some variation on return on investment and use it as a measure of performance. (Howell et al., 1987)

However, ROI as measured by most accounting systems may be subject to manipulation by a manager. For example, by postponing (or neglecting) discretionary expenditures such as preventive maintenance on production machinery, a manager may increase a given period's accounting income, and raise ROI. Or, the manager may defer investment in newer, more productive machinery. Depreciation charges will then over time reduce the book value of assets. This reduces the denominator and increases ROI. In each case, the measurement may induce the manager to act in a manner inconsistent with the firm's long term success. (Johnson and Kaplan, 1987) Appendix A contains some simple illustrations of these manipulations.

3. Standard Cost Systems

a. Background

Full, or absorption standard costing provides another set of widely used measures. (Howell et al., 1987) Products are costed at predetermined standard amounts for materials, labor and overhead. The differences between these standards and actual resources consumed are recorded in the accounts as variances. These variances, "favorable" and "unfavorable", are then investigated to determine their cause and then are allocated to current year income and to inventories. (AICPA, 1953 and Usry et al., 1988) They are also analyzed and used as measures of manufacturing performance.

Standard costing has its roots in the scientific management movement of the late nineteenth century. Industrial engineers developed the idea of setting formal time and material standards for each task in their search for the most efficient way to use resources in a complex process. (Johnson and Kaplan, 1987) Manufacturers began analyzing variances very early in the twentieth century to evaluate and control their operations, but it was not until after World War II that standard cost information was generally integrated into the firm's financial accounts. (Johnson, 1983)

The following paragraphs briefly discuss some of these measures and the dysfunctional managerial response they may elicit.

b. Materials Purchase Price Variance

Materials Purchase Price variance measures the difference between predetermined standard prices for raw materials and the actual prices the firm's purchasing agent was able to negotiate. A favorable variance means that the agent paid less than standard price for a given item, and has presumably performed well.

However, the agent now has an incentive to ignore vendor quality and delivery performance in order to get the lowest possible price. These could be someone else's problem. The agent may also increase quantities procured to qualify for volume discounts. These actions can lead to excessive scrap rates, due to the rejection and rework of substandard materials, and excess inventory, which must be financed, stored and moved around the factory, incurring needless costs. The lower quality material may eventually result in unfavorable material usage and yield variances. Ironically, total materials cost may be higher than ever.

Consideration must be given to more than just materials purchase price. In this case, investigation of the variances may reveal that greater materials usage and lower yields more than offset the price savings. Here, measuring purchase price variance creates incentives for the purchasing agent which are inconsistent with the firm's total cost efficiency.

c. Labor Efficiency and Rate Variances

Labor efficiency and rate variances evaluate the use of direct labor in the production process. Conceptually, there seems to be nothing wrong with this except that direct labor is a decreasing component of total cost in today's manufacturing environment. Overhead, on the other hand is a much larger (and an increasing) component of total cost.

Howell et al. (1987) found that direct labor accounted for only about 15 percent of total product cost, while overhead exceeded 33 percent. Focus on labor may direct management attention away from overhead, where more cost is incurred, and may cause a manager to miss opportunities to reduce non-essential costs.

Also, maximizing output per worker may lead to over-production and excess inventory if productive capacity is not balanced throughout the production process. For example, assume a worker can potentially process eight units per hour, and the next stage in production can handle only six units per hour and will not be expanded in the near term. In the short run, there is no reason to try to motivate the first worker to raise output beyond six units per hour. The additional output cannot immediately be processed and will begin to accumulate in front of the second stage. Performance measurements should direct managerial attention to these imbalances, so that productive resources can be allocated most effectively.

d. Fixed Overhead

The treatment of fixed overhead costs such as factory rent and depreciation may also pose a problem in an absorption cost system. Fluctuations in production and sales volume can in some cases affect income because of the method used to account for fixed costs. Using income as a performance measure may be misleading in these instances. The following paragraphs discuss this problem.

The firm's annual budgeted fixed overhead cost is divided by a planned base level of productive activity (frequently direct labor hours) for that same period, to develop a fixed overhead application rate. Fixed overhead costs are then assigned to each unit produced by multiplying the application rate times the proportionate amount of the base. A higher production level results in a lower unit cost, since fixed overhead costs are spread over a larger number of units.

If not all of the year's production is sold during the year, the unsold units (and their share of the year's fixed costs) remain capitalized in ending inventory. Since those costs are not charged to the current year's operations, net income will increase over what it would have been had the firm produced only what it sold. Changes in inventory levels must be analyzed along with net income to understand the performance achieved. Appendix B contains simplified illustrations of these phenomena.

Many standard cost systems contain an allowance for scrap either as an overhead cost item to be spread over all production or in the form of inflated standard materials quantities. If exactly the predetermined amount of waste occurs, the standard cost system reports no variance. This procedure does not isolate the cost of the scrap and therefore does not focus management attention on the amount of waste. The result is to reinforce the notion that a certain amount of scrap is expected and acceptable and therefore no attempt to become more efficient is indicated. (Hendricks, 1988)

4. Efficiency and Utilization Measures

Traditional measurement systems have emphasized measures of direct labor efficiency or machine utilization. In order to maximize performance for these measures, a supervisor had an incentive to keep workers and machines busy, producing units of output for inventory. As firms have come to recognize the costs of carrying inventory, their management has realized that it is more important to produce according to accurate forecasts of requirements than to pursue localized measures of efficiency. Holding inventory results in the incurrence of significant cost. Producing units to keep machines and workers busy, if sales cannot be similarly increased, results in higher inventory levels. This is inconsistent with the goals of inventory and cost reduction.

E. PERFORMANCE MEASUREMENT IN THE ADVANCED MANUFACTURING ENVIRONMENT

1. Introduction

Howell and Soucy (1987) identify six major trends in manufacturing which they see as critical for a company to embrace in order to become or remain competitive:

- Higher quality,
- Lower inventory,
- Flexible flow lines,
- Automation,
- Product line organization, and
- Effective use of information.

As the titles suggest, this manufacturing "revolution" involves more than merely robots and computer integrated manufacturing, although automation is certainly a visible and important part of the change. Many of the changes are subtle, yet are perhaps more important than automation. Together, the trends reflect a fundamental strategic change in thinking about manufacturing. The advanced manufacturing firm will require new performance measurements that de-emphasize the traditional low-cost production and localized efficiency measures. The following sections discuss these trends and their impact on performance measurement.

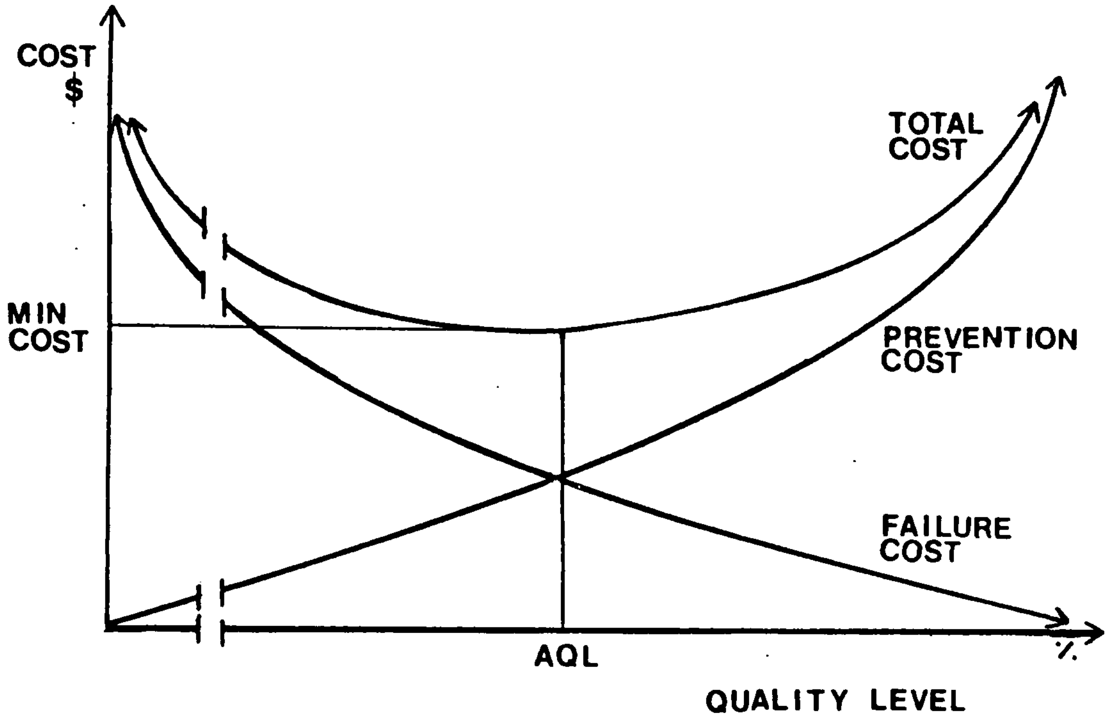
2. **Higher Quality**

The trend to higher quality begins with a realization that high quality is not inconsistent with other organizational goals. In fact, Howell and Soucy (1987) attribute increased attention to quality to the realization that poor quality may be a significant cost driver to the firm in terms of rework costs, warranty work, scrap, and equipment breakdowns.

Lundvall (1974) suggests a four-part quality cost measurement model, which captures quality costs and classifies them as either internal failure costs, external failure costs, appraisal costs or prevention costs. Internal failure includes costs of rework, repair and loss on sale of scrap. External failure costs include warranty work and lost customer satisfaction as measured by some surrogate. Appraisal includes inspection time, both manual and automated. Prevention costs includes training and engineering and design quality effort. Appendix C is a simplified example of a quality cost report based on this model. The four-part model is used in this section to contrast and then reconcile the traditional and the advanced views of quality management.

The traditional model assumed that as the level of quality increases (number of defects decreases), the costs of failure (internal and external) will decrease and the costs of prevention and appraisal must increase. The model is represented graphically in Figure 2-1, and appears to be a classic cost minimization problem.

This model implies that there is an optimum, acceptable quality level (AQL) which minimizes cost, and that it would not be rational (economical) to pursue improvement beyond that cost minimizing point. Many writers, particularly those who have studied modern Japanese firms, argue that as firms pursue a "zero-defects" approach, their total costs actually decrease, their market share increases, and their products command a premium price in the market (Lee, 1987). Many Japanese firms, they assert, have reduce defect rates to the point where they measure flaws in parts per million, rather than by per cent.



Source: (Lundvall, 1974)

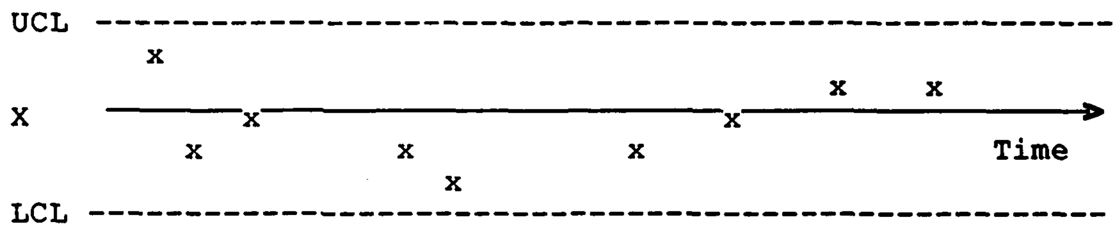
Figure 2-1 Graphic Representation of Quality Cost Model

The zero-defects concept appears to be inconsistent with the model presented above. The apparent inconsistency can be explained by the fact that the cost curves are static with respect to a given level of technology. Improvements in manufacturing methods should shift the cost curves down and to the right, implying that the pursuit of quality improvement should always continue, and not become fixed on some acceptable quality level, or AQL. (Morse et al., 1987)

This involves a fundamental shift in thinking about quality and the acceptance of some assumptions which are not intuitively obvious. Perhaps the key lies in beginning to think about quality effort as a value-adding activity, rather than a non-value added cost and activity.

Kaplan (1983) suggests this apparent contradiction is a fruitful field for future empirical research. In any event, there appears to be agreement on the general importance of improved quality for economic success and on the need for increased emphasis on the measurement of quality. An emphasis on quality measurements would be appropriate in an advanced manufacturing environment. Measuring defect rates and quality cost by product line have been widely recommended. Kaplan further suggests that defects be analyzed qualitatively as well as counted, to identify and eliminate sources of the defects.

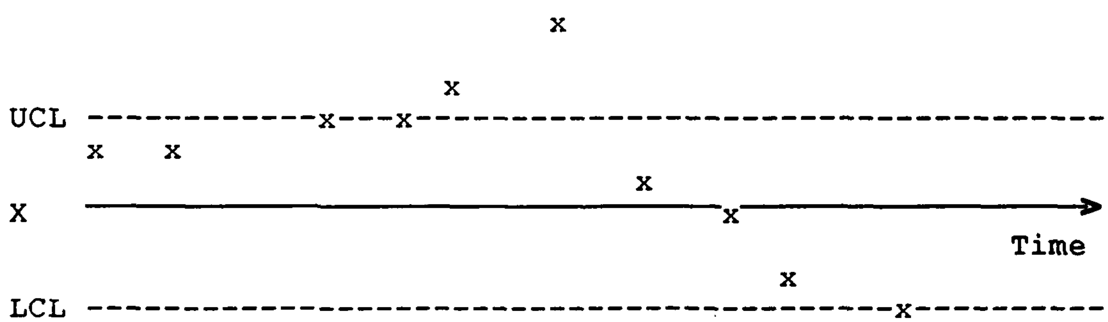
Statistical process controls (SPC) are widely recommended as tools to isolate sources of defects and to determine when a process is in control. (Deming, 1981) SPC involves sampling output periodically and measuring the variability of critical attributes (diameter, weight, etc.) around the designed value. The sample values are plotted on control charts similar to Figures 2-2 and 2-3.



Source: (Adapted from Deming, 1981)

Figure 2-2 SPC Control Chart, Process "In Control."

In Figure 2-2, the process depicted is "in control." The variability shown is a result of common causes inherent in the process as designed. The upper and lower control limits (UCL and LCL) are generally three standard deviations above and below the mean (X).



Source: (Adapted from Deming, 1981)

Figure 2-3 SPC Control Chart, Process "Out of Control."

This process in Figure 2-3 is "out of control." The increased variability results from some unusual cause such as a maladjusted machine tool or poor quality raw materials. The unusual cause should be corrected first, to bring the process into control, then the inherent variability should be addressed by process refinement, additional training and the like.

In addition to implementing statistical process controls in house, Deming encourages purchasing managers to require vendors to submit statistical evidence of quality with raw materials supplied to the firm.

Performance measures should reflect the general strategic importance of quality improvement. If higher quality is a strategic goal, the measurement system should reflect this fact by specifying measures which encourage managers to pursue higher quality. Care must be taken not to develop measures which penalize quality while encouraging short-term cost savings.

A potential criticism of quality cost measurement is that the conversion of operational data such as defect rates and customer complaints into financial terms introduces the potential distortions of the accounting system into the process (a bolt is supposed to be five inches long, but was cut at four and fifteen/sixteenths inches, how does one assign a cost to that defect?) If management believes that the elimination of defects is a strategic necessity, then excessive effort to find and track defect costs is superfluous.

3. Lower Inventory

Inspired by the success of such Japanese firms as Toyota, American manufacturers are coming to view inventory as a sign of inefficiency and waste in their processes. Inventory ties up working capital and causes storage and handling costs. New inventory management systems such as Just-in-Time (JIT) are being implemented to reduce inventory levels, and are achieving dramatic improvements in such measures as inventory turns. (Lee, 1987)

Just-in-Time is a philosophy of constant pursuit and elimination of waste in a process. Work is "pulled" through the factory; output is produced only to satisfy the immediate demands of the next stage of production. Smaller deliveries are ordered from suppliers and scheduled to arrive on the shop floor, literally, just in time. Practitioners urge smaller lot sizes, close coordination with a limited set of reliable suppliers, reduced set up times and a "make it right the first time" attitude in order to drive inventories, defects and schedule interruptions to zero. (McIlhattan, 1987)

Kaplan (1983) cites three reasons for firms to hold inventory. First, the simple economic order quantity (EOQ) model presumes setup costs to be fixed and will specify production run quantities in excess of immediate needs in order to minimize total setup costs. Second, uncertain demand and poor quality raw materials cause a requirement for backup inventory. Finally, there is a need for buffer inventory of work in process to enable the assembly line to continue when one or more stations have been interrupted because of poor scheduling, machine breakdowns or to rework substandard output.

Traditional inventory models are based on the economic order quantity (EOQ) model which balances inventory holding costs and production setup costs in order to minimize total inventory costs. In the FMS environment, greater manufacturing flexibility and better scheduling will significantly reduce set up times. As setup times and costs are reduced, the EOQ model will specify shorter production runs, lowering the inventory requirement. In the extreme case, if setup were perfectly costless, the model would specify that no inventory be held at all and the EOQ would be a production lot of one.

The inherently more consistent and reliable manufacturing process of the FMS and the better process scheduling made possible by computer integration will reduce uncertainty and buffering as reasons for holding inventory. Close coordination with vendors, small frequent deliveries and the improved quality discussed in the preceding section will reduce the need for backup inventories of raw materials and work in process.

The automated factory then supports and is consistent with the inventory reduction and manufacturing simplification strategies discussed in the preceding paragraphs. To evaluate success in inventory reduction, measuring inventory turnover ratios is recommended. (Hendricks, 1988) These inventory turnover ratios, should be kept by product line, manufacturing cell or by other strategic categories. (Hendricks, 1988) Inventory accuracy statistics may also prove valuable.

Close tracking of vendor performance becomes imperative to eliminate the need for buffer inventory. Timeliness and quality of raw materials supplied should be carefully evaluated, in order to identify and terminate low quality, unreliable vendors. Statistical process control requirements should be invoked in purchase documents in order to document material quality. (Deming, 1981) Materials price variances should be de-emphasized or even ignored. (Howell et al., 1987)

4. Flexible Flow Lines

This strategic trend involves physical reorganization of the factory floor. Rather than the traditional grouping of machines by similar function, they are arranged by natural process flow. An example is the flexible manufacturing cell where machinery is grouped into a compact arrangement that minimizes the distance traveled by product from raw material to finished goods. The result is that product flows more directly through the factory. Material movements are minimized and simplified. Materials handling costs are reduced. Excess inventory levels, especially work in process, become more visible.

Since manufacturing flexibility is one of the principal advantages cited of FMS technology, firms should develop measures to record and analyze machinery set-up or change over times. Queueing time, or the wait between one process and another should be measured. These times should be analyzed to identify bottlenecks in the flow of production. Optimized production technology (OPT) seeks to balance production flow by removing bottlenecks, rather than by maximizing the utilization of individual machines and workers. (Hendricks, 1988) Success in this area will result directly in lower inventory levels and costs.

5. **Automation**

This is a relatively new and unsettled issue among practitioners and academicians. Clearly, automation of a process significantly affects the requirements for performance measurement, but at this time there is a lack of consensus on how to resolve the varied issues. Most of the literature to date has been descriptive in nature and has not specifically recommended measures except in the most general of terms. (Kaplan, 1983)

Berliner and Brimson (1988) discuss several criteria for the automated firm's new measures. They must be consistent with the organization's goals. They should provide a link between the firm's strategy and its activities. They should be established at the activity level and reflect those activities that are significant to the company. They should be adaptable to changing business needs and easy to apply and understand. Finally, they should be cost effective and timely.

Besides the rather intuitive considerations cited above, the new measures should be premised upon and incorporate the changed manufacturing technology and cost structure of the automated factory. The following paragraphs discuss some of the implications of this technological change on performance measurement.

Standard cost systems and variance reporting in general may be less important in automated environments because the manufacturing process can be expected to become more consistent and reliable. The traditional labor based cost allocations and variance analysis become less significant as the amount of direct labor decreases. Seed (1984) suggests using engineered machine hours in place of standard direct labor hours for costing and performance analysis purposes. It will be useful to measure actual versus planned or engineered time in the manufacturing cell as an indicator of system efficiency, and as a check on the quality of the planning and estimating function.

Writers disagree on the value of the contribution margin and of direct (variable) costing in advanced manufacturing environments. Cooper and Kaplan (1988) and others promote activity based costing systems which, among other things, focus on those overhead costs traditionally thought of as fixed. Activity based costing recognizes that "fixed" costs do vary with such things as the diversity of product line, the number of categories of raw materials, and the number of required marketing channels. This diversity, they argue, is where much cost (and waste) occurs. Since the contribution margin focuses on the variable costs (a shrinking portion of total cost), it can then distract management attention from the problem and can give inaccurate product cost information.

Howell <u>et al.</u>, (1987) on the other hand regard the contribution margin as important information because they believe the distinction between fixed and variable costs is widening and, as a result, the value of using contribution margins is increasing.

Dilts and Russell (1985) visualize a need for new type of variance measuring the product mix though a flexible manufacturing system (FMS). To achieve the greatest benefit from the FMS, a certain diversity of product through the system will maximize the use of the system as a whole. Too narrow a mix of product may indicate under-utilized capacity within the FMS, suggesting that a more fixed automation environment may be appropriate. A mix that is too wide may imply that excessive set up time is consumed. Their suggested formula is:

$$\frac{\text{Actual Average Utilization}}{\text{Standard Average Utilization}} - 1 * \text{Contribution Margin}$$

This will produce a negative variance whenever the production mix is too narrow and the system is under-utilized, and a positive variance when the production mix is too great and excessive set up time is incurred.

Dilts and Russell note that this variance is not a material mix or yield variance as conventionally defined. Also, they do not suggest including this variance in the financial accounts.

Reymann (1988) proposed a performance measurement methodology for use in a CIM environment at a Naval Aviation Depot (NADEP). He proposed no specific measurements beyond those discussed in this chapter. He did, however, recommend combining eight or so measurements into a single "performance index", using perhaps a Delphi method to select the measurements and to assign weights to each. (Reymann, 1988) This seems attractive; most managers weight factors intuitively in any system. However, the plan is still subject to all the problems of completeness, objectivity and influence discussed in the first half of this chapter. In fact, the performance index may even encourage manipulation. It is possible to lose ten points on quality, but make up twenty on cost control, and come out ahead on the total index value.

6. **Product Line Organization**

This trend involves focused production on a narrower range of products. The advantage is the ability to more directly identify the resources, especially those consumed in activities traditionally considered as overhead or indirect costs, and trace them to particular product lines. Howell and Soucy (1987) believe that more limited product lines will require fewer types of support resources. Further, the ability to more directly trace additional costs to products will alleviate some of the costing and profitability measurement problems which arise from allocations of overhead. Activity-based costing systems can be more easily implemented to accurately analyze the profitability of the product mix.

7. **Effective Use of Information**

Automation of the manufacturing processes will provide several new sources of timely, accurate data to use in performance measurement. The local area network (LAN) communication technology upon which ties the FMS together collects system data for scheduling production and maintenance. Bar coding and automated materials handling systems, besides improving inventory accuracy and saving labor, provide a potential source of data on materials usage, inventory levels and the location and stage of completion of each job throughout the manufacturing process. This data should be very accurate, and easy to access. Manually collected data on the other hand are subject to more error and cannot meet the timeliness needs of an automated process. (Brimson, 1986)

The obvious benefit is that this data will be available on a nearly real-time basis, and will be available to the accounting and management control functions as well as to production and planning systems. This will improve the accuracy of the costing function by making it feasible to directly trace more resources to products. It will also provide an ideal database for the performance measurement function as well. Accurate data, from a single database are made available to the accountant and manager at virtually no cost on every aspect of the manufacturing process.

This makes it feasible for management to design virtually any measurement needed and have it immediately, with less regard for the cost of gathering data. The measurements can be aggregated at the plant, cell, machine or even at the individual job level if that level of detail is considered valuable. There is a potential pitfall in this, however. It is possible that managers will initially be overwhelmed with so much data that sifting out the really critical attributes of performance will be a significant problem. Managers must carefully select that information which they need to control the organization and avoid being burdened with more data than they can digest.

F. EVALUATION OF THE PERFORMANCE MEASUREMENT SYSTEM

How can one tell if an installed system of performance measurements is operating as intended? That is, does the system produce the measurements needed to ensure that the organization is achieving its strategic goals and using its resources efficiently? There is not a satisfactory answer in the literature because the process of control and performance measurement involves influencing the behavior of humans, and the multiplicity of relationships involved places the absolute understanding and the precise prediction of behavior beyond our current ability. (Euske, 1984)

Models of management control and performance measurement generally describe iterative processes. Goals are set, the desired performance defined, attributes of the performance measured and evaluated. Rewards are issued and the standards adjusted or goals redefined to reflect changed conditions. The set of measurements must not remain static, because it can never be perfected, strategies change over time and because the environment in which the organization functions is continually evolving. Management must continually review the performance measurement system to ensure that it supports, rather than frustrates the firm's strategic goals.

Product life cycles are growing shorter and technology, both of product and the process by which it is manufactured are advancing at an accelerating rate. Firms that continue to pursue labor efficiency when that is clearly inappropriate, or that play accounting "games" to boost return on investment while ignoring those fundamental factors from which they derive competitive advantage may not survive the 1990s. (Lee, 1987)

III. A REVIEW OF THREE RECENT FIELD STUDIES OF PERFORMANCE MEASUREMENT

A. INTRODUCTION

This chapter reviews three recent studies of automation and performance measurement systems used in American manufacturing firms. Attitudes of management toward the measurements, and current trends are discussed.

B. BACKGROUND

The three studies were conducted to gather information on the current state of factory automation, cost accounting practices, capital investment justification and performance measurement techniques in the American manufacturing sector. This chapter has two goals. First, it seeks to determine the similarity of the firms under study to a RAMP facility. Second, it considers the finding with regard to performance measurement.

The earliest of the surveys, by Howell, Brown, Soucy and Seed, was performed in the spring of 1986 under the joint sponsorship of the National Association of Accountants (NAA) and Computer Aided Manufacturing-International (CAM-I). (Howell et al., 1987) It is the most comprehensive and detailed of the three. The findings were based on 350 responses from manufacturers of various sizes in various geographic areas. In addition to the survey, the team conducted on-site interviews at selected manufacturer's plants. For brevity, this chapter refers to this study as the NAA survey.

The second study was performed in late 1986 by Peat, Marwick, Main and Company. It consisted of a survey of 200 manufacturing executives in the northeastern United States. The findings discussed in this chapter were published in a summary booklet. (Peat, Marwick, Main and Co., 1987) This is referred to as the Peat Marwick survey.

The most recent study was conducted in the spring of 1988 by Hendricks, and was based on responses from 85 controllers of Fortune 500 manufacturers (Hendricks, 1988) and is referred to as the Hendricks survey.

Appendix D presents a tabular summary of the relevant findings of each survey.

C. LEVELS OF AUTOMATION

Chapter IV considers the findings in light of the theoretical discussion in Chapter II, and the RAMP program's goals. In order to consider the potential applicability to RAMP of these findings a comparison will be made between the firms under study and the RAMP SMP facility. Chapter II argued that different management control concepts and methods of performance measurements are necessary in an automated factory. Any measurements of performance that RAMP adopts should have proven themselves effective in an environment similar to RAMP, or at least be reasonably likely to be effective in this environment.

All three surveys contained questions as to the types of automation in place at the respondents' plants, and reported the frequency of affirmative replies for each type of automated function. Because of variations in wording, it was not possible to compare directly the frequency of automation of each function in each survey to validate the results or to establish that a trend existed between the earlier and later studies.

It appears initially that the frequency of automation of the functions discussed did increase between the 1986 (NAA and Peat Marwick) surveys and the 1988 (Hendricks) survey. A composite (weighted average) of responses of the 1986 surveys was compared with the 1988 survey for functions where meaningful comparisons were possible:

TABLE 3-1

REPORTED LEVELS OF AUTOMATION

Function	1986	1988
CAD/CAE	91%	98%
Automated Stowage/Retrieval	29%	64%
Computer Aided Inspection	29%	60%
Flexible Mfg Systems	12%	31%
Computer Integrated Mfg	16%	17%

Source: (Howell et al. , 1986; Peat, Marwick, Main and Co., 1987; Hendricks, 1988)

Part of the apparent increase may be explained by the fact that the Hendricks survey was mailed to only large (Fortune

500) manufacturers, while the earlier surveys, as Appendix D shows, were sent to manufacturers of various sizes, including some small firms. It may be that the larger firms have superior access to capital markets, have more sophisticated investment analysis techniques or can better afford the risk of investing in the new technology. Further, the firms selected for the Hendricks survey came from industry groups considered likely by the researcher to have factory automation installed. For these reasons, it is not possible to unequivocally conclude from these data that the levels of automation in industry have increased over the period between the studies.

Table 3-1 does show that the percentage of firms reporting "stand alone" automation of various functions is quite high relative to the percentage of firms that have taken the next step to more integrated types of automation such as CIM and FMS. Hendricks suggests that they may be carefully evaluating the benefits of stand alone automation before making the substantially more heavy investment in CIM. Berliner and Brimson (1988) suggest that capital investment analysis techniques which do not quantify the intangible benefits of automation may be understating the value of integrated manufacturing systems, and therefore making them appear to be less attractive investments. This would deter a firm from investing in CIM.

The firms studied, particularly those in the Hendricks survey, have automated several stand-alone functions (islands of automation), but have not moved heavily into the more integrated systems of automated manufacturing. As RAMP will be more fully automated and computer integrated than the typical firm studied, it would not be prudent to presume that whatever works for these firms will be applicable to RAMP. There is enough experience in the private sector, however, to begin planning RAMP's system by examining what these firms consider valuable.

D. PERFORMANCE MEASURES USED IN THE PRIVATE SECTOR

1. Introduction

This section discusses the performance measurements used in the firms discussed above. In most cases, data from two surveys is cited and compared to validate the findings.

The Hendricks survey provided only data on the frequency of use of various measures and concentrated on operational measures. The NAA study segregated the responses for each measure into three categories: always used, often used and occasionally used. It provided extensive data on financial as well as operational measures. The data summarized in Appendix D represent the sum of the percentages who responded "always used" or "often used" for each measure. Neither of these two studies, however, provided any data on relative weights attached to each measure. For example, neither survey indicated whether firms emphasize return on investment more than sales growth.

2. Sources of Data for Measurement

With few exceptions, the source data for the financial measurements came from the accounting systems and the data for the nonfinancial measurements came from the operating control system or were measured informally. (Howell et al., 1987) Exceptions to this generalization are noted in the discussion in Sections 3 and 4 below.

The use of financial accounting systems for performance measurement was discussed in detail in Chapter II.

Howell (1987) describes the operating control system for this purpose, as a system of departmental statistical records to assess manufacturing performance, customer service and departmental performance. He further notes that informal measurements are not necessarily undisciplined, citing scheduled program and forecast reviews as examples of structured but informal measurements.

3. Financial Measurements

This section draws on the NAA study and the comments in the Peat Marwick study.

As suggested by the discussion in Chapter II, the firms studied made extensive use of measurements drawn from the financial accounting records. The majority of the executives surveyed in the Peat Marwick study indicated that they evaluate performance by first looking at the financial results for the total business, then at the results for individual plant locations. Their emphasis on financial measurement of performance is consistent with the short term, income oriented view of performance discussed in Chapter II.

The financial measurements in use were almost exclusively oriented toward income statement data and accounts. Sales and sales growth (used by 89 and 82 percent of respondents) were the two most prevalent indicators, followed by cash flow (73 percent), and several variations of profitability measures (68 to 76 percent.) Several rate of return measures were reported, with frequencies of 47 to 62 percent. This seems inconsistent with the popular conception that return on investment (ROI) is the single most often used measure. (DeCoster, Schafer and Ziebell, 1988) Perhaps the several variations of the wording of the questionnaire choices split the responses and may account for the lower than expected response rates for return on investment. Contribution margin was used as a performance measure by 59 percent of the firms surveyed. That there is no consensus on the use of contribution margin is consistent with the conflicting opinions on the merit of variable costing in the advanced manufacturing environment discussed in Chapter II.

4. Nonfinancial Measures

As suggested in Chapter II, various nonfinancial measures are used to complement, and overcome the deficiencies of accounting based measures of performance. This section draws on data from the Hendricks and NAA studies.

Quality oriented measures were most frequently cited. Nearly everyone surveyed (91 percent) formally tracked quality as part of the performance measurement system. Only seven percent used the management accounting system to assist in quality management. The rest used a nonfinancial operating control system or informal measures of quality. Few prepared formal quality cost reports similar to the four-part model discussed in Chapter II and illustrated in Appendix C. Howell suggests that a report of this type would represent a significant opportunity for accounting data to provide additional, useful data to complement the operating control system. Of those surveyed by the NAA, 36 percent felt that additional quality information would be useful.

Inventory levels and inventory turnover were measured formally by approximately 75 percent of the firms in both studies, and were the second most frequently measured area after quality. This finding seems reasonable given the significant potential gains to be achieved through, and the trend toward inventory reduction. This area is measured primarily with data from the management accounting system. As inventory reduction is one of the more significant benefits of automation (Bennett et al., 1987), it is consistent that measurements of this nature be given emphasis.

One factor noted by Howell which has historically limited the usefulness of inventory measures based on accounting systems is that they have been generally limited in detail. That is, the turnover ratios are aggregated at such high organizational or commodity levels that they are not useful in pinpointing specific problems. Inventory turnover rate and level information becomes more useful as it is broken down by product line, production process and material type. Given advances in information technology, Howell notes that this is a likely area for the accounting system to provide more useful analyses by isolating slow moving categories of inventory for management attention.

Labor productivity measures were the third most frequently used item in both surveys (Hendricks 73 percent, NAA 76 percent.) This occurs despite the fact that both showed labor to be by far the least significant element of total product cost (Hendricks thirteen percent, NAA fifteen percent). There does not appear to be anything intrinsically wrong with measuring labor productivity in an automated environment. Since fifteen percent of total production cost is still a substantial expenditure, direct labor still needs to be managed efficiently. A firm should not be too eager to disregard labor costs as irrelevant unless direct labor is truly an insignificant cost or does not pace the production process, as in a true CIM setting.

However, labor productivity is a less relevant and useful measure than some others, and it may distract attention away from the analysis of overhead, which is a much larger and faster growing element of cost. Hendricks notes a trend away from labor based cost allocation and performance measurement. Thirteen percent of his respondents indicated that they had recently discontinued this measurement.

Delivery performance to customers was measured by a majority of firms in both studies (Hendricks 55 percent, NAA 75 percent). This data is collected almost exclusively via the operating control system or by informal means. Hendricks suggests that even more key characteristics related to delivery be formally measured, because of their potentially large impact on revenue. For the firm to compete, it must be responsive to the factors its customers value most. An emphasis on delivery may become more important as more of the firm's customers adopt Just-in Time practices.

Slightly more than half of the firms reported that they formally measured materials yield (Hendricks 61 percent, NAA 55 percent). Most of those measures were output of the management accounting system, reflecting wide use of standard cost systems. As many standard cost systems contain an allowance for scrap built into the standards, the interpretation of materials usage and yield variances may be difficult. Howell (1987) notes that a zero materials variance does not imply that there is no waste of materials, but that a predetermined, "tolerable" amount of material is being wasted. As direct material is the most significant element of cost, even in the capital intensive settings studied, Hendricks observes with some concern that this area is less often measured than even labor efficiency.

Approximately half of the firms in both studies measured equipment productivity. The data for this purpose comes largely from operating control systems and informal measures. Both surveys noted the importance of measures of equipment utilization rates and downtime because of the large investment in automated equipment.

Manufacturing flexibility was measured by less than half of the firms in both studies (Hendricks 47 percent, NAA 39 percent). The data for these measures were gathered about equally often from the management accounting system, the operating control system and from informal measurement systems. Hendricks notes that flexibility is formally measured most often in firms with an FMS or CIM. This seems to support the notion that flexibility is one of the primary strategic advantages to automation, hence those firms pay closer attention to flexibility than the firms with only isolated functions automated. Neither study elaborated on how these firms actually measured flexibility.

Of the firms surveyed, 82 percent used the same system of performance measurements for their automated and their non-automated functions. No different methods were used in spite of the different manufacturing process and cost structure. Some possible explanations for this are considered in the next section.

E. DISSATISFACTION AND DESIRED IMPROVEMENTS

Both the Peat Marwick and the NAA studies reveal that users generally feel that the performance measurement systems need improvement, but that obstacles to change exist. The NAA study found that 69 percent of those who used performance measurement statistics were either dissatisfied with their system, or felt that it needed major improvement, suggesting a clear need to re-evaluate measurement systems. Most of the desired improvements were in matters of emphasis of one measure over another, rather than any need for new types of measures.

Certain areas for possible improvement of the performance measurement systems were suggested and the respondents were asked to indicate whether or not they change would be desirable. The most frequently cited specific improvements needed were in the areas of increased emphasis on variance analysis (48 percent), responsibility accounting (47 percent) and exception reporting (44 percent), all features of classic standard cost systems. This does not seem consistent with current writings which suggest that standard cost systems will become less important in advanced manufacturing environments. (Howell, 1987)

Thirty seven percent cited a need for a longer-term focus in measuring and evaluating performance. This reflects some level of concern over the problem of short run orientation widely cited for declining American competitiveness. (Lee, 1987)

Twenty eight percent desired a simpler measurement system that focuses on key results. Other frequently cited improvements included productivity measurement (39 percent), inventory cost measurement (37 percent), quality cost measurement (36 percent) and capacity utilization (27 percent).

Significantly, while there is widespread perception of a need for change, none of the suggested improvements received a fifty percent desirability rating; most were rated desirable by less than half of those surveyed. This may suggest that while industry acknowledges that a problem exists, there is general confusion over how to measure performance in an advanced manufacturing environment. This perhaps reflects the general lack of understanding of the problem discussed in the next several paragraphs.

Several obstacles to change were noted. Most significant was the emphasis on short term financial results and a management compensation system which reinforces and rewards this emphasis. Habit and lack of understanding of options were also cited by significant percentages.

Howell notes in the NAA study that lack of understanding is probably a much more significant source of reluctance to change than the survey revealed. He concludes that the manufacturing sector is clinging to obsolete management accounting systems which are not keeping pace with its modern factory methods. The continued extensive use of single overhead rates, inappropriate application bases, excessive focus on labor analysis and short-term cost savings are cited as examples of this. Recall that fewer than one firm in five modified its performance measurements to account for automated production activities.

F. SUMMARY

The surveys describe current performance measurement practices in American industry. The measurements are, for the most part, traditional ones that emphasize short-term financial performance, and that would be appropriate in a labor intensive environment. Some firms are attempting to develop new ways to measure performance, appropriate for an advanced manufacturing setting, but those firms are in the minority. There is general agreement that measurements need substantial improvement, but no consensus in industry of how to change the system. Finally, the surveys indicate that the main obstacles to improved performance measurements are the existing reward and compensation system and a lack of understanding of the options available and their implications.

The findings support the assertion in Chapter II that models of management control systems and performance measurement for the advanced manufacturing firm are still evolving. There is not a wide base of private sector experience to draw upon in the design of control systems for the prototype RAMP facility. RAMP technology is state-of-the-art manufacturing and will require the development of performance measurements suited to its unique role as a CIM manufacturer within the Navy.

IV. PERFORMANCE MEASUREMENTS FOR THE RAMP SMP CELL

A. INTRODUCTION

The purpose of this chapter is to specify the goals and objectives of the RAMP program, develop critical success factors for these goals and suggest appropriate performance measurements for the RAMP facility which will facilitate the achievement of these goals.

B. BACKGROUND

Chapter II presented two themes. The first is that performance measurements should be carefully designed to support the organization's goals and objectives. Secondly, advanced manufacturing technologies require different types of performance measurements from those used in traditional, labor-intensive settings. A greater emphasis on operational, nonfinancial measurements is appropriate. In Chapter III, it was established that there is no consensus on performance measurement techniques for advanced manufacturing technology in the private sector. Most firms employing FMS or CIM use similar performance measurements in the automated and nonautomated sections of their organization. Instead of adapting a proven control and measurement system from the private sector, the Navy will be required to design much of RAMP's management system.

This challenge was not unexpected. In fact, one of the program's goals is to develop advanced manufacturing systems and transfer the technology and "lessons learned" to the private sector, strengthening the American industrial base. (NAVSUP, 1989) Fleet support problems traceable to outdated and unresponsive American manufacturing facilities were the impetus for the RAMP program. (Lotz, 1987)

RAMP means several things. In the broadest sense, RAMP is a twenty year program to integrate digital logistics technical data and advanced manufacturing technology into the entire Navy logistics network and to strengthen America's industrial base by sharing these proven technologies with the private sector. More narrowly defined, RAMP is a flexible manufacturing cell which produces mechanical parts or printed wire assemblies while operating as a cost center within a host Navy Industrial Fund (NIF) activity. This chapter discusses the broader RAMP program strategic goals with activity level objectives being developed from these program goals. Finally, recommended performance measurements for the facility are presented.

The success of the program rests on the effective and cost efficient operation of the individual cells. Management must demonstrate the value of RAMP technology in the Test and Integration Facility and the prototype cells before full scale implementation and the dissemination of the technology to private industry. Well designed performance measurements will facilitate this process by documenting successes, rewarding effective performance and drawing management attention to areas where improvement is required.

C. RAMP GOALS AND OBJECTIVES

1. Ramp Program Critical Success Factors

The RAMP program's broad goals of cost and leadtime reduction, high quality and a stronger national industrial base are articulated in seven critical success factors:

- Standardize digital data packages and communications,
- Successful demonstrations,
- Cost/benefit justification,
- Integration into supply system,
- Optimization of supply response time,
- Integration into weapon system acquisition, and
- Transfer of technology to the private sector. (NAVSUP, 1989)

The first critical success factor is being addressed by RAMP support of the Product Data Exchange Specification (PDES). PDES is a nonproprietary specification intended to be interpreted directly by advanced application programs such as CAD systems and the RAMP operating software. PDES is being developed by a consortium of private sector firms and government activities, chaired by the National Institute of Standards and Technology (formerly the National Bureau of Standards). Eventually, PDES will be the language used to procure parts technical data from suppliers and used within the RAMP facility and for engineering, planning, scheduling and manufacturing. (Interview-B)

Successful demonstrations of the entire process, including PDES data communication, and cost/benefit justification using data from the prototype cells will quantify the cost savings of RAMP technology and gather support from other Department of Defense agencies and from industry. As discussed earlier, American industry has been slow to adopt integrated manufacturing technology in part because its benefits are poorly understood. These two critical success factors are closely related to the seventh, which is to transfer the technology to the private sector, in order to improve fleet support via a strengthened American industrial sector. It has always been the Navy's intent to rely on the private sector for vast majority of its spare parts requirements. (NAVSUP, 1989)

The full benefits of the program cannot be realized until RAMP is integrated into the Navy supply system. Effective software must be developed to permit the interface of RAMP's computer network with the appropriate Inventory Control Point's (ICP) computer systems. This integration will lead to the anticipated reductions in procurement leadtimes. Once leadtimes are reduced and communications networks established, supply response time (an important measure of supply system effectiveness) is optimized. Shorter leadtimes also allow the supply system to safely operate with smaller levels of insurance and safety stock items, thus realizing saving of Navy Stock Fund dollars.

Digital parts technical data is not currently a contractual requirement in most weapons systems acquisitions. (Interview-B) Consequently, most repair parts are not supported by data that can be readily used in the RAMP system, and the maximum benefits of the RAMP program will not be achieved. To obtain digital parts data for RAMP use, the Navy will initially select limited sets of candidates and "reverse engineer" them to provide the data. As PDES data becomes more universally available and equipment standardization efforts continue, RAMP technology will be support a larger portion of the Navy's requirement for parts.

2. Ramp Facility Goals and Objectives

a. General

Many organizations are involved in the RAMP program, providing policy guidance and system-wide integration, but success rests on the ability of a RAMP facility to manufacture high-quality parts with shorter leadtimes and at significant cost savings over conventional procurement. If the RAMP facilities cannot demonstrate this ability to Department of Defense management and to industry, then the program will not receive adequate support to survive.

The objectives at the facility level should therefore consider demonstration and justification and be consistent with the program's goals. Recall that the prototype

RAMP cells are research and development efforts to refine and demonstrate technology. Even if the facility is not profitable initially, it can still be effective in achieving its program support goals. In the following paragraphs, the author proposes some goals for the RAMP facility, keyed to the strategic goals of the RAMP program. Some objectives are admittedly vague, and not all of them are easily measurable, but they represent the facility's contribution to the strategic success of the program.

b. Standardize Digital Data Packages and Communications

The facilities should utilize their CAD capability to participate in the reverse engineering process in the conversion of drawings and paper parts specifications to digital format, accurately and at minimum cost. The facilities should be able to communicate accurately with inventory control points (ICPs).

c. Successful Demonstrations

The facilities should demonstrate the ability to operate using PDES and to achieve the anticipated reductions in average production leadtimes. This must be done while achieving specified quality levels and cost savings over conventional procurement methods. The ability to operate while holding minimal inventories (Just-in-Time) should be demonstrated. The ability to assure quality through process controls and automated inspection while minimizing manual inspection should be demonstrated.

Navy Industrial Fund activities are expected to break even financially. (NAVCOMPT, undated) This thesis presumes that RAMP SMP cell will attempt to operate at this break-even level. The RAMP facilities should be able to set prices so as to achieve cost savings and should manage costs so as to break even at this price level.

d. Cost/Benefit Justification

The facilities should support the RAMP effort to develop cost justification and accounting models for CIM within the NIF environment. Gardner (1988), Bryant (1988) and Murphy (1988) presented detailed discussion of these issues. They should support the RAMP effort to build a model to quantify the benefits of CIM, including quality and flexibility.

e. Integrate into Supply System

The facility should, through demonstrations, prove itself able to communicate with ICPs by responding to electronic invitations for bid, and requests for supply status.

f. Optimize Supply Response Time

The facility should establish leadtime goals for each homogenous family of parts to be manufactured. Goals should be set by part family for each critical phase of production, such as procurement administrative, manufacturing administrative and manufacturing leadtimes. These terms are defined in Section D of this chapter.

g. Technology Transfer

The facility should effectively document its experience and "lessons learned" and disseminate this knowledge to other RAMP sites, program management, ICPs and others as appropriate. They should be key participants in technology transfer symposia. This technology development and transfer role does not apply to the firms studied in Chapters II and III.

D. RAMP FACILITY PERFORMANCE MEASURES

1. Background

This section develops performance measurements or indicators to gauge the level of success in meeting the facility level objectives presented in the previous section. As discussed in Chapter III, there is limited private sector experience on performance measurement in an advanced manufacturing environment, and the RAMP objectives developed above differ somewhat from a private sector manufacturer. While many of the specific measurements proposed in this section are drawn from the current literature, they must be adapted carefully to the context of the RAMP program.

For the purpose of organizing this thesis, the measurements have been grouped into five broad performance areas: delivery performance, cost and processing performance, quality performance, materials management performance, and program support performance. Appendix E summarizes the recommended measures in tabular form.

2. Delivery Performance

Improvement of fleet support through reduced lead times is RAMP's ultimate goal. (NAVSUP, 1989) The demonstrated ability to deliver requested parts on time is thus critical to RAMP. Figure 4-1 illustrates the program's anticipated average time savings over traditional procurement methods, based on RAMP time goals stated by NAVSUP.

← Total Cycle Time →

	Procurement Administrative Leadtime	Manufacturing Administrative Leadtime	Manufacturing Leadtime
Traditional Manufacturing	150 days	189 days	59 days
RAMP Manufacturing	3 days	20 days	7 days

Source: (Adapted from NAVSUP, 1989)

Figure 4-1 Anticipated Leadtime Savings With RAMP

A brief definition of the terms in Figure 4-1 is necessary to understand the measurements proposed. Total cycle time (TCT) is the total time from the date RAMP receives an invitation for bid (IFB) from an inventory control point (ICP) until the date the part is ready for shipment to the customer.

Since the actual shipment of the part is anticipated to be the responsibility of the host's supply department, the time between completion of the part and its shipment is not under the control of the RAMP manager, and should not be part of the manager's evaluation.

Total cycle time is divided into three stages. Procurement administration leadtime (PALT) is the time from the date the RAMP facility receives an IFB until the ICP awards a contract. Notice that PALT includes the time required by the ICP to evaluate bids and make a contract award. The only part of PALT for which the facility is accountable ends with bid submission to the ICP and it is this period to which the three day standard applies. That is, the facility has three days to turn around an IFB.

Manufacturing administrative leadtime (MALT) begins with contract receipt and ends with the issue of the shop order to begin fabrication. It encompasses such actions as material procurement, shop scheduling and numerically controlled (N/C) machine programming.

Fabrication, or manufacturing lead time (MLT) begins with the issue of the shop order and ends with turnover of the part for packaging and shipment. It includes the manufacturing and testing functions.

The time goals in Figure 4-1 for each phase are broad averages for the RAMP program. The specific parts manufactured will take significantly more or less than the average time depending on raw material requirements, the number of machining steps, the complexity of the manufacturing process and any unique quality control requirements. Plant-wide average times will fluctuate from month to month depending on the product mix during the month. In order to provide measurements more useful to management, parts should be grouped into several homogenous families and time standards established and measured for each phase, by part family. These will prove more useful than plant-wide averages.

The facility should measure, by family, average total cycle time and its three components: procurement administrative leadtime, manufacturing administrative leadtime and manufacturing leadtime, and compare these with family standards. For example, an average total cycle time for part family group could be computed as follows:

$$\text{Average TCT} = \frac{\text{Sum of Individual Job Cycle Times}}{\text{\# Jobs for Period}}$$

Separate line graphs clearly showing the standard and actual time taken for total cycle time and its three components for each family in each evaluation period would be a clear, straightforward means of illustrating this performance. Monthly reports should be appropriate initially. Averaging over a shorter period may exaggerate the effects of short term fluctuations while a longer periodicity would smooth these fluctuations but would be slow to indicate the trends which require management attention.

In addition to these averages, management will need to track individual jobs which are overdue for shipment or delayed at some point in the process listed by age and by customer requisition priority, along with the reason for each delay. Management will also want status on high priority jobs such as jobs for fleet casualties (CASREPs) in process (a "Hot Sheet") to ensure they are being given appropriate attention. This report of late and critical jobs should be produced daily.

In order to evaluate the facility's performance, program management should establish criteria for delays beyond the control of the facility, and should segregate these delays from the delivery performance computations. For example, jobs delayed because incomplete or inadequate parts specifications were furnished or because of defects in the PDES data should be coded in the RAMP database so these delays, which are not controllable by RAMP, do not count toward the average computations. They should of course be included on the overdue lists with the appropriate reasons noted.

The data for these measures should be available from the RAMP order manager data system. The system will record information on the status of each job order (i.e., completed, current stage of production or delayed with reason for delay). Further, a record of the dates each of the jobs was in process in each stage (procurement administration, manufacturing administration or fabrication) is required in order to calculate average times.

One potential problem is that unusually small or large values will skew the averages in a small population. For example, a small number of jobs delayed because of material unavailability could skew the average manufacturing administrative leadtime to the right and raise the period's average above the standard value for that family of part. To recognize this phenomenon, the system should identify in an exception report each month those jobs significantly above or below the average time, using statistical techniques. To do this, average times and standard deviations would be calculated by part family for each evaluation period. Management could use exception reporting to isolate those jobs that take greater or less than an established standard (e.g., two standard deviations from the average). This would give management an indication that a very large or very small value may be skewing the average. This report may also indirectly highlight problems such as material procurement delays for management attention.

Another problem concerns the exception reports on critical and overdue jobs. The criteria for a critical job must be carefully controlled to prevent an unmanageable number of items from becoming "hot." These criteria will be somewhat arbitrary initially. For example critical jobs could be limited to only severe CASREPs. Once the system's operating procedures and protocols are optimized, the system will work best with minimal human disruption. In a well-run CIM environment, expediting will have less effect than in a traditional setting, and will cause greater disruption to the rest of the system, slowing average cycle time. The number of expedite, or intervention actions should be tracked and minimized, to allow the system to use its rule base to schedule production in the sequence it determines will minimize total production time.

These measurements are simple and straightforward. There is nothing complicated in their computation or analysis. Yet, they are probably the single most important set of indicators to be proposed in the thesis, as improved average leadtime is the most important goal of RAMP. (Interview-B) Particularly important are the anticipated savings in administrative leadtimes. (Interview-A) The quality of the data and the ability to write the numerically controlled (N/C) machine programming are critical to the greatest portion of the leadtime saving which the RAMP program offers.

3. Cost/Processing Performance

To evaluate cost and processing performance, an appropriate cost accounting system must be established which will accurately measure the resources consumed in the production of a product. Bryant (1988) and Murphy (1988) discussed this issue in some depth and suggested that indirect costs be allocated over several bases. Time in the FMS is an appropriate allocation base for some costs such as administrative and security costs, and the others should be allocated over a basis which resembles the underlying cost-driver, as in an activity based system. There seems to be overwhelming agreement that direct labor based allocation systems produce inaccurate cost data in an automated manufacturing environment (Cooper and Kaplan, 1988). Meaningful cost management is impossible if accounting systematically distorts product costs. If inaccurate cost information is used, pricing will be distorted. The ability to demonstrate savings is suspect without accurate cost and pricing data.

As discussed earlier in this chapter, the greatest portion of RAMP's anticipated leadtime savings will accrue due to the availability of high quality PDES data on parts to be manufactured, and the ability to import this data directly into RAMP's computer systems. It is anticipated that, over time, the RAMP SMP cell will accumulate and perfect more and more manufacturing "rules" and procedures in its database. (Interview-A) The system will eventually be able to identify material requirements and perform the design and N/C programming for routine parts with no costly or time consuming manual intervention, thus achieving the savings in administrative leadtime More complex parts will require the manufacturing engineer to intervene more frequently in the process to write machine coding for unique features of complex parts. This inhibits the speed of the computer based process, adds cost and leadtime and possibly compromises the integrity of the designed-in quality control features of the RAMP system. The percentage of parts that go through the engineering process without this manual intervention should be measured. The higher this percentage, the higher will be the benefit realized from the computer integration. It is also useful in explaining the facility's costs and leadtimes, since manual intervention is expected to slow the system and to drive up engineering costs. This will initially be a low percentage which should grow over time.

This measure should be used with some caution because the complexity of the mix of products will determine the amount of manual intervention, but this product mix is not under the control of the RAMP cell manager. To that extent, the measure may also give an indication of whether the cell is being tasked to produce an appropriate mix of parts.

A weekly summary showing this percentage along with exception listings of the job numbers, reasons and total hours required for manual intervention would allow management to quickly spot trends and identify types of parts which may be too complex for the existing RAMP technology. Management would then be able to identify required enhancements.

Some of the features of a standard costing system will be useful in the RAMP setting. For example, it would be desirable to measure and record for each job order number the actual time spent in the FMS and compare this time with engineering estimates of fabrication time for the part. The fabrication time for all jobs in a period would be summed and compared with the total estimated time for the same jobs. This could provide data for investigation to determine whether the FMS is physically operating at designed velocity, whether the engineering estimation process is inaccurate or whether some combination of the two problems exists. Consistently low or high variances, assuming the FMS is mechanically operating as designed could indicate problems in the engineering estimation process. If the estimates are considered reasonable, then a growing variance might indicate that the system is mechanically slowing down, perhaps due to a need for specialized maintenance.

The concept is similar to a standard cost system's labor and overhead efficiency variances, although no cost figure need be attached to this variance between actual and estimated time. There is no compelling reason to express the variance in financial terms since the RAMP does not presently intend to use a standard costing system. The important thing is to first minimize the physical variance, which will indicate that the process is in control, and then to reduce the time required by improvements in the engineering process and adjusting the machinery to its optimum specifications.

Related to this is the measurement of processing efficiency. The idea here is to measure the proportion of production time (actual time spent machining parts) to the sum of production time plus material handling time plus queue time, and to express this as a percentage. The times for each job spent in handling, in queue and in production should be recorded and totaled for each month, and the efficiency percentage calculated by dividing this into total the total production hours for the period.

$$\text{Efficiency \%} = \frac{\text{Production Hours}}{\text{Production + Handling + Queue Hours}}$$

Production adds value to the product. However material movement and idle waiting time are examples of non value-added activity. As this efficiency percentage increases, this "non value-added" time is minimized. Low efficiency percentages indicate wasted time, which should be located and eliminated. The causes of excessive material movement and queue time include delays due to inaccurate scheduling, rework of defective output, delays in procuring material or equipment breakdowns. An improving efficiency percentage indicates progress toward a Just-in-Time operation.

Reduction of queue times is achieved through more accurate scheduling, and through reduction in machinery set-up time. Machinery set-up time should include the time required to unload a completed job, install the correct fixtures and tools, select and position the next job to be machined. The local area network (LAN) can measure and record the time taken by a machine to accomplish these tasks, for each set-up. As discussed in Chapter II, several Japanese firms have made dramatic improvements in efficiency and in inventory reduction by focusing attention on reducing set-up time. Where some American auto makers took six hours to change over sheet metal stamping equipment from one model to another, Toyota accomplished a similar changeover in five minutes. (Kaplan, 1983) Set-up time is another non value-added activity, which should be isolated for management attention in performance measurements. The ability of an FMS to produce the optimum product mix discussed in Chapter II hinges on quick, efficient tool changeovers and set-ups. Average set-up time should be measured for each major machine as an indicator of flexibility. To be consistent with a Just-in-Time philosophy, the goal for average set-up time is zero. It may never be physically achievable, but a commitment to continual improvement is desirable; every minute saved is valuable in the FMS.

Direct labor hours have diminished in value as a basis for performance measurement and cost allocation in a RAMP cell. Although the facility is manned by several workers who tend the machines and stage materials, labor does not pace the production process. There is little likelihood that increasing the productive hours of an individual worker will increase the throughput or total system efficiency of the RAMP facility. For this reason, direct labor hours are not expected to be a worthwhile measure of performance.

Because of the substantial investment in capital equipment, researchers have recommended an emphasis on equipment related measurements for the FMS. (Hendricks, 1988) FMS system availability statistics would be relatively simple to compute as the percentage of system available time (uptime) divided by total scheduled available time. System downtime is comprised of hours down for preventive and for corrective maintenance. Further, the ratio of hours of preventive to hours of corrective maintenance will indicate system reliability and maintainability.

Budgets for corrective and for preventive maintenance plans must be developed, expressing the maintenance plan in fiscal terms. Execution performance of a flexible preventive maintenance budget would be an essential indicator of whether maintenance is being accomplished as scheduled. In general, maintenance cost control would be measured against a flexible budget. Preventive maintenance costs should follow a volume-adjusted flexible budget almost exactly and budget variances, adjusted for price level changes, should indicate whether maintenance is accomplished. Total expenditures below budgeted costs may indicate that maintenance is not being accomplished according to plan, and higher expenditures may indicate poor cost control. Careful analysis of this budget variance will indicate the specific reasons.

Formal tracking of planned preventive maintenance will help to ensure that the work is accomplished, and not deferred as a "cost saving" device. A trend toward an increasing ratio of preventive to corrective maintenance is desirable since it indicates that attention to preventive maintenance is paying off in terms of fewer breakdowns.

Since the third shift is currently scheduled as downtime for system maintenance, downtime statistics must be interpreted carefully. System availability statistics should be based on the percentage of available first and second shift time only. No downtime is expected during scheduled production shifts. If any occurs, it is of unusual interest and should get immediate attention.

These cost and processing performance measurements require a tremendous amount of detailed record keeping, which would render them virtually impossible to compute in a traditional manufacturing setting. The LAN technology in an FMS makes them possible. (Brimson, 1986) Data requirements for these cost and processing measurements would generally be provided by the RAMP's manufacturing cell control system. Specifically, performance measurement requires accurate logging of the time each job order spends in queue, in handling and in each stage of production, from the time a shop order is issued until the part is turned over to packing and shipping. Bar coding will enable accurate automated tracking of every part at every stage. Availability of these data, by job order number, in RAMP's common database makes the cycle efficiency calculations possible. A "clock" on each machining center can automatically measure and record setup times. A similar clock can measure overall system availability and utilization time.

Weekly summary reports of these measurements are possible with the data gathering capability of the LAN. Exception reports showing measurements significantly (as determined by management) above or below specified values should be available daily.

These cost and processing performance measurements are somewhat more complex than the delivery performance measurements proposed in the previous section and they focus on attributes of performance not frequently measured in traditional manufacturing environments. In summary, they de-emphasize labor as a cost allocation basis and a unit for performance measures. They emphasize efficiency of the entire FMS manufacturing cycle and the operability and reliability of the automated machinery. They include more nonfinancial measurements, and attempt to avoid expressing operational data in financial terms where doing so would be unnecessarily complicated or confusing. Non value-adding activities are isolated for management attention.

4. Quality Performance

The inherent consistency of automated manufacturing makes it possible for RAMP to make parts of uniformly high quality because machines do not become bored, or fatigued as humans do. Demonstration of this improved quality is one of the facility's most important tasks. The quality is assured by the clarity of the part descriptive data (in PDES format), the consistency of the N/C machine programming rules and the consistent performance of the automated manufacturing machines. As successful demonstrations proceed, the built-in quality should allow for reductions in manual inspection time and costs. (Interview-B) Chapter II discussed in depth how improved quality can lead to reduced inventory requirements and lower total costs, two of RAMP's goals. RAMP facilities should therefore emphasize quality measurements.

Defect rates should of course be measured, as should rework time and cost and loss on disposal of scrap. In addition to recording the rates, defective material should be analyzed qualitatively to ascertain the underlying cause of the defect. This causal analysis should occur at the time the defect is discovered by the operator or by the machine. The velocity of the RAMP manufacturing cycle requires that prompt corrective action be taken. This concept is somewhat related to the Japanese practice of Jidoka, or autonomous control of defects, where any person (or machine) in the manufacturing process can halt production to correct defects. (Lee, 1987)

The diversity of product in a job shop environment probably precludes the use of many of the common statistical process control techniques, which are more suited to production of a homogeneous product in a continuous process. Control techniques which focus on percentage deviation from design rather than on absolute values of a variable might be useful for process control in RAMP, that is the system could measure and record the percentage of deviation from the designed diameter of each hole drilled by a machine. Variability within certain control limits would indicate that the process is in control, and larger deviations would indicate an unusual flaw in the drilling process such as a worn adjustment on a machine tool.

A four-part quality cost report, similar to Appendix C is another helpful way to begin to organize the management of quality. (Morse et al., 1987) Its advantage is that it provides a complete and balanced view of quality management not available by concentrating only on defects. Its disadvantage is that collecting this cost data is difficult. In most accounting systems, including Navy Industrial Fund accounting, these costs are not explicitly reflected in the chart of accounts. To prepare this report, the RAMP system will have to capture and record time and costs expended in quality engineering, training, supervision, inspection, testing and the costs of correcting both internal and external failures.

Judicious selection of proxies for items such as failure costs should allow RAMP to approximate quality costs in the four-part report format. For example, defective material received by a RAMP customer is documented by a Quality Deficiency Report (QDR), a NAVSUP form which identifies defective material and requests a replacement or refund from the furnishing activity. In lieu of warranty costs, RAMP might track the time and costs of responding to these QDRs and use this as a proxy for external failure costs. Absolute precision is not as important as an awareness of general quality cost levels and trends.

A quality budget for prevention and appraisal can be developed and budget execution tracked. Tracking execution performance of prevention and appraisal budgets encourages management's plans in those areas to be carried out and not deferred as short-term cost savers. Costs greater than the budget may indicate poor cost control. Analysis of the budget variances will reveal the specific reasons.

In addition, management may find it useful to document costs of compliance with special Navy quality control systems such as the Level One and SUBSAFE programs. These programs require detailed documentation on material quality and more intensive inspection. (NAVSEA, 1984)

The quality of raw materials received from the Navy supply system and from vendors will be considered in the next section, on Materials Management Performance.

5. Materials Management Performance

NAVSUP's intent is that RAMP operate under Just-in-Time inventory concepts. (Interview-B) These were discussed in Chapter II. Several of the reasons for holding inventory were mentioned in this chapter, in the section on Cost and Processing Performance. In general, inventory is held to economize on set-up costs, to protect against poor quality materials and as a buffer against inaccurate schedules. (Kaplan, 1983) Since the FMS is designed to increase manufacturing flexibility, improve quality and provide superior information, inventory should by design be kept at very low levels. RAMP should carefully manage its inventory levels and inventory turnover rates, and should expect that these will improve as the manufacturing and scheduling processes become more efficient over time.

Inventory levels are simply the dollar values and quantities of materials held as raw material invent ry or as work in process. Inventory turnover rates are conventional accounting measures, calculated for work in process by dividing the cost of goods completed for the period under evaluation by the average work in process inventory value for the same period. To calculate inventory turnover rates for a raw material, divide the cost of that material entered into production during the period by the average value of the raw material's inventory for the period. These measures should be calculated for work in process, each raw material category, each product line or for any other important strategic category. Improved inventory management performance will be indicated by decreasing inventory levels and increasing inventory turnover rates. Inventory measures are not only useful in their own right, they also help to identify production inefficiencies. Practically speaking, raising work in process turnover from 20 to 25 times is in itself desirable. But, assuming the product mix remains roughly constant, it also may imply that some significant non-value adding activity has been eliminated. That is perhaps more important.

Monthly reports are probably frequent enough for these inventory reports. The relatively small facility, the designed low levels of work in process and exception reporting of overdue jobs should give an experienced manager sufficient real-time informal indication of levels and turnover between reports.

Turning inventory over should not be a problem for a RAMP facility. Procuring high quality raw materials within the specified twenty day manufacturing administrative leadtime window does seem to be one of the most significant challenges for a RAMP manufacturer. Generally, manufacturers who have been successful at Just-in-Time implementation have established close relationships with a very limited set of suppliers similarly committed to high quality and just-in-time deliveries. (Lee, 1987)

Traditional government contracting procedures are time consuming and constrained by price-based competition. Innovative contracting methods must be devised to permit rapid procurement from vendors who can meet RAMP's strict quality and delivery requirements. There is little or no slack in the twenty day time frame to allow for unreliable vendors. Invoking statistical process control requirements for vendors may be helpful in identifying qualified suppliers and in reducing receipt inspection requirements. RAMP program management is investigating procurement methods which increase the emphasis on quality and delivery, and decrease emphasis on price. (Interview-B) Improvements in contracting support to accommodate the RAMP facility, and required changes in procurement regulations would be a productive area for additional research.

This material risk is mitigated significantly by the inventories of material held in the supply system. The host site may be able to satisfy some of RAMP's material requirements from their shop stores stock. The supporting stock point may find it beneficial to carry a stock of materials tailored to RAMP's anticipated requirements, if forecasts are available. Optimal inventory support arrangements between the RAMP facility, its host and the supporting procurement and supply activities, including inventory levels, requisitioning channels and priorities, would also be a productive topic for further research.

Facility personnel should record statistics on the quality of incoming materials. Materials may come from a number of sources such as the Navy's supply system and direct vendor deliveries and there are a number of potential reasons that a material receipt may be rejected. Possible reasons for rejection include non-conformance to specification, damage in transit due to inadequate packaging or mishandling, inability to identify the material due to missing or inadequate shipping documentation or the receipt of incorrect material. Materials rejected should be recorded by supplier and by reason for rejection. The intent is to pinpoint sources of problems and eliminate them. These statistics should be kept in the RAMP facility's database, with summary reports keyed on material source, reject reason code or job order number provided to the supporting procurement activity for use in contract administration and in selecting those vendors who will be able to meet RAMP's needs. This feedback should occur very frequently, perhaps daily, so that the procurement activity can monitor contracts as frequently as possible to enforce contractor delivery requirements.

The data for these measures should be readily available in the production and inventory control systems.

6. Program Support Performance

The RAMP Test and Integration Facility and the prototype cells are research and development activities. (Lotz, 1987) In addition to the production of parts, their mission includes the demonstration and refinement of RAMP technology, in order to ultimately arrive at an effective manufacturing system to be made available for further Navy and private sector installations. (Interview-B) The measurements suggested thus far concentrate on manufacturing effectiveness and efficiency. In this section, some tentative indicators are proposed to help assess how effective the facility is in developing and disseminating this technology. This area is referred to as program support performance.

In the area of digital parts data development, RAMP facilities should track the number and quality of PDES data packages which they produce. While NAVSUP does not intend to task the cells with the bulk of the PDES preparation, the cells will assist in this conversion process by preparing some data packages (for example, a cell may develop a data package to satisfy a CASREP) and by reviewing the packages for parts tasked to their cell for manufacture. (Interview-B) An accuracy goal should be established for those packages developed.

The facility operators and management will certainly be the first to notice the inevitable design problems in RAMP machinery, computers and operating software. To solicit their input, quality circles, design review teams and beneficial suggestion programs (with tangible rewards) could be used. Management could track the number of ideas received and the number implemented. The goal is to encourage feedback from those closest to the problems. Management should ensure that these programs are taken seriously and not given mere lip service. Deming (1981), is extremely suspicious of slogans, productivity campaigns and the like. He warns that they:

> ...never helped anyone to do a better job....these... devices are management's lazy way out. They indicate desperation and incompetence of management. There is a better way....

He states that involvement by management and holding each worker responsible for his or her output will go further in improving quality and throughput.

The amount of assistance and information furnished to industry should be measured by some surrogate, such as number of inquiries answered, number of visits or tours conducted, briefings given to and leadership in local trade groups, Chambers of Commerce, etc. As NAVSUP develops a more specific "marketing plan" for RAMP, the facility can be evaluated on its support of those specific objectives.

These measurements are more vague than those proposed earlier. They are also less complete and objective, and therefore possibly subject to manipulation. The fact that these areas are not directly and immediately related to cost control or fleet support should not suggest that they are any less important than other measurements. Since this stage of the project is oriented toward research and development, this program support performance is critical. The desired performance is a complete and frank exchange of lessons learned, and regular, constructive input from the facility on needed hardware and software enhancements.

V. SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

A. SUMMARY

The purpose of this thesis is to analyze the objectives of the RAMP SMP facility and propose an initial system of management performance measurements which take into account the unique characteristics of the facility and the advanced manufacturing methods it incorporates.

Chapter I described the need for the RAMP program in general terms and introduced the problem of performance measurement in this setting.

Chapter II contained a review of the literature and theory of performance measurement and how the measurement function affects managerial action. Performance measurements, as a basis for reward, will tend influence managerial behavior. The chapter also considered the effect of advanced manufacturing technology on performance measurement. The first research question, to determine the types of information required by management of a CIM plant, was addressed in the framework of Howell and Soucy's (1987) model of the six characteristics of advanced manufacturing: high quality, low inventory, flexible flow lines, automation, product line organization and effective use of information.

Chapter III reviewed three recent field studies of performance measurement in American manufacturing firms with varying levels of automation. The chapter concluded that while some appropriate measurements are being used, a satisfactory, coherent system of performance measurements does not generally exist today. The Navy therefore needs to develop a set of indicators which are consistent with the state-of-the-art manufacturing that RAMP represents.

Chapter IV addressed the second research question, to contrast the goals of the RAMP program with a private sector plant and propose an initial set of performance measurements which focus management attention on those areas of performance critical to the success of the program. The measurements were divided into five performance areas: delivery, cost and processing, quality, materials management and program support performance.

In the remainder of this chapter, the recommendations made in earlier chapters are summarized and topics for further research are suggested.

B. RECOMMENDATIONS

1. Delivery Performance

Growing leadtime for spare parts was one of the primary reasons for the RAMP program. The ability to quickly deliver parts on demand is the single most important responsibility of the facility. (Interview-B) Management should measure average total cycle time and its components (procurement administrative leadtime, manufacturing administrative leadtime and manufacturing time) for each family of parts. Line graphs showing the current averages and the standards are a simple means of illustrating this area of performance. Exception reporting of the number and status of overdue jobs will be needed. The number of disruptions of the automated process should be measured to keep the system operating at its most efficient pace.

2. Cost and Processing Performance

The RAMP program is intended to reduce the cost of spare parts by introducing modern manufacturing methods into the spares acquisition process. Appropriate measurements to support this goal include the difference between actual and planned manufacturing time, the processing efficiency percentage and average set-up times. Because of the substantial investment in capital equipment in the RAMP facility, measurements of system availability, utilization and reliability are needed.

3. Quality Performance

Total quality management (TQM) is part of the design of RAMP. (Interview-B) Although the more common statistical process control (SPC) techniques do not appear to be directly applicable to a job shop setting, the facility should nonetheless use sophisticated, formal quality measurements. Perhaps SPC techniques could be adapted to measure the percentage variation, rather than absolute values of variables. Appropriate measures include defect rates, qualitative analysis of defects, quality cost reporting and budget execution for defect prevention and quality appraisal costs. Ratios of failure costs to prevention and appraisal costs will offer an indication of trends in quality.

4. Materials Management Performance

A well-run RAMP facility has no reason to hold high levels of inventory. An increase in work in process or decrease in inventory turnover rates may be cause for concern because it could signal that some aspect of the manufacturing process may not be functioning properly.

A high level of material support from reliable vendors with exacting quality standards is essential in order for RAMP to meet its time standards for customer service. Careful monitoring of incoming raw materials and invoking requirements for vendor statistical process control will contribute to RAMP's progress toward a Just-in-Time operation.

5. Program Support Performance

The purpose of the prototype RAMP facility is to refine and demonstrate the technology needed to improve spare parts logistics support. (Lotz, 1987) The exact measurements used in this area will take shape as specific responsibilities are assigned to the facility by headquarters level program management. Until that time the facility should measure informally such things as quality of data package development and the level of involvement in community and trade group affairs. These roles are not yet well defined and have no counterpart in traditional NIF or private sector activities, but this should not detract from their importance.

6. General Considerations

The third research question addressed how management will evaluate the effectiveness of the measurements used. The measurements proposed in this thesis represent an initial set of indicators to be used in addition to the financial operating results provided by the Navy Industrial Fund accounting system. Many of the measures are similar to output of standard cost systems, except that cost need not necessarily be attached to the variance between actual and engineered time requirements. If management is committed to continuous improvement as in the total quality management and just-in-time precepts, it is sufficient to find where waste occurs and to eliminate it. The accounting effort in converting the operational measure to a cost is not value-adding activity.

As discussed in Chapter II, the set of measurements should evolve over time as the facility matures, through a commitment to continuous improvement. The danger of adhering to a set of obsolete or irrelevant measurements or using those measurements as a basis for reward was discussed previously in detail. The iterative development of measurements and standards is key to a successful facility.

C. RECOMMENDED TOPICS FOR FURTHER RESEARCH

Several interesting issues arose during the research which were beyond the scope of this thesis and which may be appropriate for further research. The following paragraphs identity these topics.

This thesis and several previous papers (Gardner, 1988; Bryant, 1988 and Murphy, 1988) concentrated on the small mechanical parts (SMP) cell. The general principles of accounting and performance measurement should be the same in the printed wiring assembly (PWA) cell. They should, however, be investigated by a researcher familiar with the technology and process of that type of manufacturing. Some substantial differences exist between the two processes. For example, the PWA cell requires more direct labor in production. (Interview-A) It is tempting to assume that both cells can be managed by the same principles and measurements, but this attitude is the very essence of the "manage by the numbers" mentality which is blamed for many of the current problems of American industry. (Johnson and Kaplan, 1987)

The SMP facility will operate as a cost center within the command structure of a larger NIF activity such as a Naval shipyard. Several unique aspects of the RAMP facility will affect the relationship of the cell to the command. Murphy (1988) addressed the question of how indirect costs may be fairly allocated to the cell. Additional research will be needed to investigate other aspects of the relationship. For example, how does the shipyard commander evaluate the RAMP manager in comparison with other production center supervisors? How will RAMP's cost accounting system be integrated with the shipyard's labor-driven traditional NIF system? How will conflicts between the RAMP program management (NAVSUP) and the shipyard management be resolved?

The tools of statistical process control (SPC) are receiving a great deal of attention as a means to implement total quality management, however they seem to lend themselves better to repetitive processes. Potential use of SPC in a RAMP setting is a potential topic for future research. One possibility might be an adaptation of SPC focusing on percentage deviation or on attributes (such as reject rates), rather than on absolute values of physical variables.

Formal supply support arrangements for the cell should include the cell itself, the host command and the supporting stock point. Each activity could potentially hold some inventory in support of RAMP manufacturing requirements, but in so doing must consider a trade-off between service level and inventory holding cost and NAVSUP's inventory policies. The performance measurements used at each level will tend to encourage either one goal or the other. In order to furnish effective supply support to the cell at least total cost, an arrangement should be developed coordinating the levels of stock and the responsibilities at each level.

Contracting procedures developed to satisfy legislative and regulatory requirements are often cumbersome, time consuming and excessively concerned with price based competition. Quality and vendor reliability are at times secondary considerations. The twenty day goal for manufacturing administrative leadtime dictates that greater emphasis be placed on delivery and quality. Price alone is not an adequate basis for vendor evaluation in a Just-in-Time setting. Innovative contracting arrangements, such as incentives for quality and delivery, must be investigated to supply quality materials on time while satisfying existing procurement regulations. Perhaps some changes in or waivers to regulations will be necessary.

D. CONCLUSION

The RAMP program directly addresses several serious problems which impact negatively on fleet readiness and national security. The growing costs of spares is intolerable in the present budget environment. The declining number of manufacturers in America, and their reluctance to modernize threaten the ability to sustain peacetime operations, let alone to mobilize for war. By developing advanced logistics and manufacturing systems, NAVSUP is making a substantial investment to offset these discouraging trends.

In order to justify the program and to help sell it to the private sector and other Department of Defense activities, RAMP must know how to evaluate its performance. This thesis has explored how the performance measurement system impacts on managerial behavior and the long-term success of an organization. RAMP's goals and unique manufacturing methods will require that the RAMP SMP cell measure its performance differently from a traditional NIF activity and from a private sector CIM firm. This thesis has proposed several measurements for initial use in a RAMP SMP cell. The measures focus on delivery, high quality, lower inventory, improved customer service and support of the broad program goals. They de-emphasize direct labor reporting and short-term cost savings. An advanced manufacturing system such as RAMP requires corresponding advances in its accounting and management control systems.

APPENDIX A

RETURN ON INVESTMENT (ROI) MANIPULATION

ASSUMPTIONS:

Current Assets		$50,000
Property, Plant & Equipment	75,000	
Less Accumulated Depreciation	- 25,000	50,000
Total Assets		$100,000
No Change in Beginning or Ending Inventories		

Sales	$300,000
Cost of Goods Sold	250,000
(Includes $2,000 of maintenance expense and $5,000 of depreciation on plant equip.)	

Gross Margin	$50,000
Administrative Expenses	30,000
Net Income	$20,000

ROI (Simplified) = $\frac{\text{Net Income}}{\text{Assets}} = \frac{\$20,000}{\$100,000} = 20\%$

Taxes are ignored

CASE I. MAINTENANCE DEFERRED

	Maintenance Performed	Maintenance Deferred
Sales	$300,000	$300,000
Cost of Goods Sold	250,000	248,000
Gross Margin	$50,000	$52,000
Administrative Expenses	30,000	30,000
Net Income	$20,000	$22,000
ROI	$\frac{\$20,000}{\$100,000} = 20\%$	$\frac{\$22,000}{\$100,000} = 22\%$

By postponing scheduled maintenance until the following year, the firm was able to increase income by $2,000 and to raise ROI from 20% to 22%. They do this at an increased risk of equipment breakdowns and increased future operating costs.

CASE II. INVESTMENT DEFERRED

Proposed Investment Outlay	$35,000
Reduced Operating Expenses Resulting From New Equipment	$5,000

	Investment Made	Investment Deferred
Sales	$300,000	$300,000
Cost of Goods Sold	245,000	250,000
Gross Margin	$55,000	$50,000
Administrative Expenses	30,000	30,000
Net Income	$25,000	$20,000
Net Assets	$135,000	$100,000
ROI	$\frac{\$25,000}{\$135,000} = 18.5\%$	$\frac{\$20,000}{\$100,000} = 20\%$

In this case, the firm must decide whether to invest in more productive machinery. If the investment is made, it results in a $5,000 saving of labor costs, which is reflected in the higher income. The investment, however, lowers ROI as shown above. Considering only ROI, the investment appears unattractive even though it lowers costs, and may replace obsolete equipment which is labor intensive and produces poor quality products.

Note that by postponing the decision another year, more depreciation charges will be recorded, reducing the book value of assets, and raising ROI to:

$$ROI = \frac{\$20,000}{\$95,000} = 21\%$$

This effect should be considered when comparing two divisions, one of which has older plant and equipment. ROI may be higher for a time in the older plant. Higher operating costs will eventually drive profitability down.

APPENDIX B

EFFECTS OF FLUCTUATIONS OF SALES AND PRODUCTION VOLUMES ON THE INCOME STATEMENT IN AN ABSORPTION COST SYSTEM

ASSUMPTIONS:

	Year 1	Year 2
Sales (Units)	100	90
Production (Units)	100	120
No Work in Process		
Finished Goods Inventory, Beginning (Units)	0	0
Finished Goods Inventory, Ending (Units)	0	30
LIFO Cost Flow		
Taxes are ignored		

COST OF GOODS SOLD STATEMENT:

	Year 1	Year 2
Cost of Production		
Variable ($150/Unit)	$15,000	$18,000
Fixed ($15,000/Year)	15,000	15,000
Total Manufacturing Cost	$30,000	$33,000
Plus Beginning Finished Goods Inventory	0	0
Less Ending Finished Goods Inventory	0	$8,250
Cost of Goods Sold	$30,000	$24,750
Unit Costs		
Manufacturing Costs	$30,000	$33,000
Units Produced	100	120
Unit Cost	$300	$275

INCOME STATEMENT:

	Year 1	Year 2
Sales ($400/Unit)	$40,000	$36,000
Cost of Goods Sold	30,000	24,750
Gross Margin	$10,000	$11,250
Selling and Administrative Expenses ($5,000/year)	5,000	5,000
Income	$5,000	$6,250

Income increased in the second year by twenty five percent despite a ten percent decline in sales volume. This occurred because two things happened. First, production increased, spreading fixed overhead costs over more units, reducing the full cost per unit. Second, since not all of the second year's production was sold, some of the year's fixed cost was capitalized in the ending inventory, rather than being charged against income in the second year.

This increase in income was not necessarily desirable. Since the inventory must be stored, handled and financed, an additional outflow of cash will occur in subsequent years, if this level of inventory is maintained. The Naval supply system estimates a holding cost rate of 23 percent in its inventory models. (NAVSUP, 1988) Using that rate in this case, inventory holding costs would be approximately $1,900 per year.

APPENDIX C

SAMPLE QUALITY COST REPORT

PREVENTION:		
Quality engineering	$2,000.00	
Quality training	800.00	
System development	1,200.00	
Supervision	400.00	
		$4,400.00
APPRAISAL:		
Inspection	$8,000.00	
Testing	3,500.00	
Supervision	1,800.00	
		13,300.00
Total Prevention and Appraisal		$17,700.00
INTERNAL FAILURE:		
Scrap	$6,000.00	
Rework	4,800.00	
Reinspection	500.00	
Retest	200.00	
		11,500.00
EXTERNAL FAILURE:		
Warranty	$9,000.00	
Allowances	2,600.00	
Replacements	2,350.00	
		13,950.00
Total Failure		$25,450.00
TOTAL QUALITY COST:		$43,150.00

Source: (Morse et al., 1987)

APPENDIX D

SUMMARY OF MANAGEMENT ACCOUNTING SURVEYS

	Hendricks	NAA	PMM & Co
Date	Apr 1988	May 1986	Dec 1986
Surveys Mailed	168	2217	Unknown
Valid Responses	85	350	200
Response Rate	51%	16%	Unknown
Mailed to	Fortune 500 Mfrs.	Various Mfrs.	Northeast Mfrs.
Respondent Profile			
CEO/Div. GM		6%	50%
CFO/Controller	100%	75%	22%
Mfg./Oper. Execs.		15%	12%
Others		4%	16%
	100%	100%	100%
Manufacturing Cost Breakdown			
Material	54%	53%	
Labor	13%	15%	
Overhead	33%	32%	
	100%	100%	
Automation Installed			
CAD/CAE	98%	92%	90%
CAM	83%		
Auto Data Collection		33%	35%
Auto Planning, Scheduling		69%	67%
N/C Machines	85%	45%	
AS/RS	33%	33%	22%
Computer Aided Insp.	60%	32%	23%
Flexible Mfg. (FMS)	31%	10%	16%
Computer Int. Mfg. (CIM)	17%	13%	23%

	Hendricks	NAA	PMM & Co
Performance Measures Used			
Financial			
Sales		89%	
Sales Growth		82%	
Gross Margin		76%	
Cash Flows		73%	
Profit Margin		70%	
Inventory Turnover	75%	70%	
Return on Total Assets		62%	
Return on Total Capital		58%	
Return on Equity		47%	
Contribution Margin		59%	
Nonfinancial			
Quality		91%	
Labor Productivity	73%	76%	
Scrap Counts	72%		
Rework Costs	72%		
Delivery Performance	55%	75%	
Market Share		75%	
Throughput Rate	46%	56%	
Material Yield	61%	55%	
Product Development	16%	47%	
Equip. Productivity	54%	46%	
Equip. Downtime	48%		
Mfg. Flexibility	47%	39%	
Satisfaction with Performance Measurements			
Very Satisfied		6%	16%
Reasonably Satisfied		33%	Unknown
Needs Improvement		51%	Unknown
Dissatisfied		9%	34%
Desired Improvements			
Emph. Variance Analysis		48%	
Emph. Responsibility Acctg.		47%	
Emph. Exception Reporting		44%	
Emph. Productivity		39%	
Longer Term Focus		37%	
Measure Inventory Costs		37%	
Measure Quality Costs		36%	
Simplify System		28%	
More Nonfinancial Measures		27%	
Measure Cycle Time		23%	
De-emphasize Labor Measures		18%	
De-emphasize ROI		9%	

Source: (Compiled by Author from Hendricks, 1988; Howell *et al.*, 1987 and Peat, Marwick, Main and Company, 1987)

APPENDIX E

SUMMARY OF RECOMMENDED MEASUREMENTS

A. DELIVERY PERFORMANCE

1. Average Total Cycle Time

Purpose: To determine whether the average leadtime goal for a given family of parts is being met.

Computation: The sum of all job cycle times for a part family divided by the number of parts in the family completed in the period.

Periodicity: Monthly.

2. Average Procurement Administrative Leadtime

Purpose: To determine whether the RAMP SMP cell is responding to IFBs in the specified three day period.

Computation: The sum of all job procurement administrative leadtimes divided by the number of jobs completed in the period.

Periodicity: Monthly.

3. Average Manufacturing Administrative Leadtime

Purpose: To determine whether the RAMP SMP cell is completing all planning and procurement actions for a job in the specified period.

Computation: The sum of all job manufacturing administrative leadtimes divided by the number of jobs completed in the period.

Periodicity: Monthly.

4. Average Manufacturing Time

Purpose: To determine whether the RAMP SMP cell is completing all manufacturing actions for a job in the specified period.

Computation: The sum of all job manufacturing times divided by the number of jobs completed in the period.

Periodicity: Monthly.

5. Critical/Late Jobs

Purpose: To maintain management visibility of critical or late jobs.

Computation: Exception list of jobs which meet the management determined critical criteria, or which remain in any of the three phases of production beyond specified limits.

Periodicity: Daily.

B. COST AND PROCESSING PERFORMANCE

1. Accumulated Operating Results

Purpose: To measure whether the SMP cell is breaking even financially, as NAVCOMPT requires of NIF activities.

Computation: In accordance with NAVCOMPT Manual, Volume 5.

Periodicity: As required by NAVCOMPT and host activity.

2. Percent of Jobs Not Totally Automated

Purpose: To measure the percentage of jobs which required manual intervention and presumably slowed the computer automated process.

Computation: Divide the number of jobs which required manual intervention over the total number of jobs for the period.

Periodicity: Weekly.

3. Actual vs. Estimated Manufacturing Time

Purpose: To determine whether the FMS system is operating as desired, and to check on the estimating process.

Computation: Subtract the sum of actual job times from the sum of estimated job times.

Periodicity: Weekly.

4. Production Efficiency Percentage

Purpose: To measure the proportion of value-added time to total job time.

Computation: Divide the sum of production (machine) hours for all jobs by the sum of production, handling and queue hours for all jobs.

Periodicity: Weekly.

5. Average Set-up Time

Purpose: To measure the average set-up time for each machine, in order to minimize this non value-added time.

Computation: Divide the total set-up time for each machine center by the number of set-ups.

Periodicity: Weekly.

6. System Availability

Purpose: To measure the percentage of total system time available for production.

Computation: Divide system available hours (uptime) by total hours.

Periodicity: Weekly.

7. Maintenance Budget Execution

Purpose: To measure whether maintenance plans are being carried out to control maintenance costs.

Computation: Measure actual expenditures and compare with budgeted costs for preventive and corrective maintenance.

Periodicity: Monthly.

8. <u>Ratio of Preventive to Corrective Maintenance</u>

Purpose: To measure whether preventive maintenance is resulting in improved system reliability, since corrective maintenance should decrease as proper preventive maintenance is performed.

Computation: Divide preventive maintenance costs (or hours) by corrective maintenance costs (or hours).

Periodicity: Monthly.

C. QUALITY PERFORMANCE

1. <u>Defect Rates</u>

Purpose: To monitor the percentage of defective output.

Computation: Divide the number of defective jobs by the total number of jobs. Analyze defects qualitatively to ascertain source or cause of defect.

Periodicity: Rates, monthly. Qualitative analysis, ongoing, whenever defects are discovered.

2. <u>Quality Costs</u>

Purpose: To measure costs associated with quality factors: prevention, appraisal, external failure and internal failure.

Computation: Use costs measured by the accounting system, using surrogates when necessary, present in format illustrated in Appendix C.

Periodicity: Monthly.

3. <u>Quality Budget Execution</u>

Purpose: To measure whether quality plans are being carried out, to control inspection and engineering costs.

Computation: Measure actual expenditures and compare with budgeted costs for prevention and appraisal.

Periodicity: Monthly.

D. MATERIALS MANAGEMENT PERFORMANCE

1. Inventory Levels

Purpose: To measure the investment in inventories in order to provide information to assist in minimizing inventories.

Computation: Measure the quantities and values of inventories.

Periodicity: Monthly.

2. Inventory Turnover

Purpose: To relate the investment in inventory to the volume of production, measures the velocity with which inventory is converted.

Computation: For work in process, divide the cost of goods completed by the average value of work in process inventory. For raw materials, divide the cost of materials entered into production by the average inventory value of the material.

Periodicity: Monthly.

3. Raw Material Rejection Statistics

Purpose: To collect data on sources of and reasons for rejected material receipts.

Computation: Receiving and production personnel record data on material receipts rejected.

Periodicity: Daily.

E. PROGRAM SUPPORT PERFORMANCE

1. Data Development Support

Purpose: To assess the SMP cell's contribution to PDES development and quality.

Computation: Measure the number of errors in PDES package development.

Periodicity: Monthly

2. <u>Technology Transfer Support</u>

Purpose: To measure the cell's contribution to the broad program goal of technology transfer.

Computation: Unclear at this time. Should include such things as the number of system enhancements, participation in industry and trade groups and technical symposia.

Periodicity: As appropriate.

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