METHODOLOGY FOR PROJECT MANAGEMENT CONTROL IN THE CONSTRUCTION INDUSTRY

BY

NEIL N. ELDIN

Bachelor of Science
Cairo University
Cairo, Egypt
1972

Master of Science
Concordia University
Montreal, Canada
1978

Master of Engineering
McGill University
Montreal, Canada
1979

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
December, 1987

Thesis
1987D
E37m
Cop. 2

OKLAHOMA STATE
UNIVERSITY
LIBRARY

METHODOLOGY FOR PROJECT MANAGEMENT CONTROL

IN THE CONSTRUCTION INDUSTRY

Thesis Approved:

Robert K. Hughes
R. K. Hughes (Thesis Adviser)

Phillip L. Manke

James K. Lee

Garold D. Oberlender

John P. Lloyd

Norman N. Durham
Dean of the Graduate College

1307075

PREFACE

This research was conducted to employ a new approach to evaluate the performance of construction projects. The new approach differs from the current common practice in two main areas. The traditional search for one integrated descriptor for the success or failure of the entire project is replaced by evaluating the performance of selected project components only. Next, a set of ratios analogous to the financial ratios used to appraise businesses was utilized to identify cost items having a potential for financial problems and to determine the monetary impact on the final project cost.

A set of control ratios capable of describing the progress conditions of each project's work items was selected. Forecasts and performance indices utilizing the selected ratios were computed by examining the relationships between the actual and budgeted value of the control ratios. A problem detection technique was formulated to detect areas in the project having potential financial problems. An algorithm was devised to identify the immediate causes of such problems and to determine their monetary impact on the final project cost.

An actual construction project was included in the study as a numerical illustration of and as a guide to the application of the developed problem detection technique. The technique was successful in identifying the cost items having financial problems, determining the causes of such problems, and assessing their monetary impact on the final project cost. This investigation was limited to evaluating and detecting problems due to labor costs, material costs, and extra costs due to low labor productivity.

The author wishes to express his sincere gratitude to Dr. Robert K. Hughes for his guidance and concern as the principle advisor during the course of this study. The author is also thankful to the other committee members, Dr. Philip J. Manke, Dr. Hamed K. Eldin, Dr. Garold D. Oberlender, and Dr. P. J. Lloyd. Special thanks are due to Dr. P. J. Manke and Mrs. Chris Aggour for their editorial comments.

My wife, Nagwa, my two daughters, Nancy and Nora, my mother and dad deserve my deepest appreciation for their constant support, moral encouragement, and understanding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

General

Construction is the largest industry in the United States. It accounts for twelve percent of this country's gross national product, employing approximately five million Americans and involving an annual expenditure of over three hundred billion dollars [39]. The construction industry is, by nature, a highly variable process with numerous risks and is considerably sensitive to the continuous upward and downward economic cycles. Studies have shown that more than ten percent of the construction enterprises in the United States fail annually due to poorly informed management and the lack of effective management tools [29]. Researchers, specifically investigating causes for contractors' failures, concluded that inefficient utilization of available capital to cover liabilities, improper use of construction management techniques, limited productivity improvement, and ineffective management are also major causes for contractors' failures [19,43].

Although the need to minimize potential failures in the construction industry has provided the impetus for the accelerated growth of project management systems, tools, and techniques,especially in the last decade, management problems in the construction industry are still far from being resolved. With current management concepts, usually more than one project control system is used simultaneously on a project to generate different pieces of necessary information. Systems such as accounting, cost estimating, and scheduling are typical examples. Consequently, a project manager is continuously facing the challenge of coordinating and analyzing various types of data in order to assess the project's performance to guide his decision-making process to determine any necessary corrective action.

The need for the timely processing of a huge volume of project data and the realization of its interdependency make the task of properly controlling a project quite difficult and sometimes impractical to accomplish with the available techniques. This may explain the apparent distrust of the current management tools and techniques. This distrust is manifested in the construction industry by the lack of interest in major investments to learn about or even to extend the utilization of such modern techniques [42]. Without adequate tools, managers are often forced to make decisions based on insufficient, or at least, not the best possible information [10]. The complexity and sophistication of today's projects add to the difficulty of the decision making process and increase the pressure imposed on project managers.

Management success depends to a large extent on focusing only on significant information, and on the effective utilization of such information. For tactical decision-making, a project manager having over all project responsibility requires accurate and current information.

Such information is necessary for making sound decisions. Therefore, it must be tailored to his needs, displayed in a format emphasizing clarity, and be problem oriented rather than project oriented. In other words, information systems should utilize the management by exception concept. This will assist the manager in focusing on potential problems where corrective actions may be needed.

Current Project Management Needs

A survey was conducted by Tenah in 1986 [51] to determine the information needs of key personnel at various levels of the management hierarchy. The survey suggested that, although the functions performed by these individuals may vary significantly, some information is commonly required by all of them regardless of their principle responsibilities.

Four common information elements were identified: cost summaries; scheduling status reports; overall reported progress; and trend forecasts. These four information elements are considered the basic requirements for successful construction management and project control [6]. The primary functions of a project management team are to monitor and control the cost of the work components, and the time of the project activities (scheduling), to assess the work progress, and to attempt to generate overall forecasts for project completion.

In performing these functions a project management team is faced with several challenges including determining the current project's status (in terms of cost, time, and progress), establishing adequate parameters to evaluate the project's performance, and projecting past performance into the future in order to generate project forecasts. These challenges are extremely complicated and encompass several serious problems which currently limit the usefulness and application of construction management and project control concepts. The problems encountered in meeting these challenges are due to unique characteristics of the construction process. Namely, that cost, scheduling, and progress (percent of work completed) are different functions by nature yet one intimately interrelated. Moreover, construction operations are time dependent which makes project data continually change in magnitude. Therefore, independent monitoring and reporting of any of the basic control elements (cost, time, and progress) has little or no value for project management.

The difficulties encountered in measuring and relating cost to time, and progress led to the development of project evaluation techniques based on comparing a project's actual costs and scheduling data to the preconstruction data (desired or expected). Cost performance for example, is evaluated by comparing the actual project cost to the estimated project cost. Similarly, scheduling performance is measured by comparing actual project execution time to the scheduled execution time. Commonly, work progress is assessed subjectively by senior construction personnel, and no real interface between these three control elements (cost, time, and progress) exists.

Some of the identified problems with current construction management procedures and techniques are:

1. Dissatisfaction with the available monitoring, scheduling and costing systems and procedures was reflected by a general trend to revert back to simple managerial tools providing only partial benefits instead of using formal quantitative methods and analysis. For example, the use of bar charts as the principle scheduling control document is preferred over CPM networks; work progress is subjectively determined rather than by the use of quantitative methods; mathematical and programing models are not generally used for project budgeting [35,42].
2. Improper interface of cost and scheduling systems is a major cause of failure in the implementation of adequate project tracking systems [45]. This has resulted in a tendency to increasingly use management techniques only as legal and contract administrative instruments rather than as project control tools [41].
3. Little written information is available pertaining to actual job progress including the absence of practical effective techniques for quantitative work progress measurements. Also, the devotion of considerable time to data collection and routine information processing by senior project personnel at the expense of time required for analysis and decision-making, and an inability to generate forecasts with reasonable accuracy until the project closeout phase have been repeatedly reported [15,42].
4. A lack of an integrated project tracking system capable of adequately tracking cost, time, and progress throughout the entire life cycle of a project [2,8,13,22,44,48,53].

5. A need for a sound problem detection technique to identify causes of poor performance, based on facts rather than perceptions [43,47].

Current Project Evaluation Approach

The purpose of a project control system is to provide management with the information necessary for decision making regarding time and costs. The current practice is to meet one date, the completion date of the entire project, to prove successful time management of the project. Similarly, management focuses on completing the project within one cost figure, the total project budget, as proof of successful financial management [6,47]. But since these two performance measures are certain only at the completion of the project, attempts are made to determine the project's progress and to measure its performance at intermediate completion stages. In doing so, major problems with existing management evaluation techniques arise. The two basic problems are the lack of a sound quantitative method for measuring work progress (percent completion of a project) that is acceptable across the industry; and the problems encountered in interfacing cost and scheduling. In the following sections, a detailed discussion of these two problems is provided.

Measurements of Work Progress

Some of the essential requirements for determining realistic quantitative measurements of work progress are:

1. The definition of the lowest level of detail at which progress is to be measured, and
2. The selection of the basis upon which progress is to be assessed.

Definition of Level of Control

The work breakdown structure (WBS) concept is the latest management tool for defining the lowest level of detail on a project at which progress will be measured [24,25]. The WBS is a concept by which the project work is grouped in a meaningful way to establish hierarchical relationships among the different types of work and the total project, as shown in Figure 1.1.

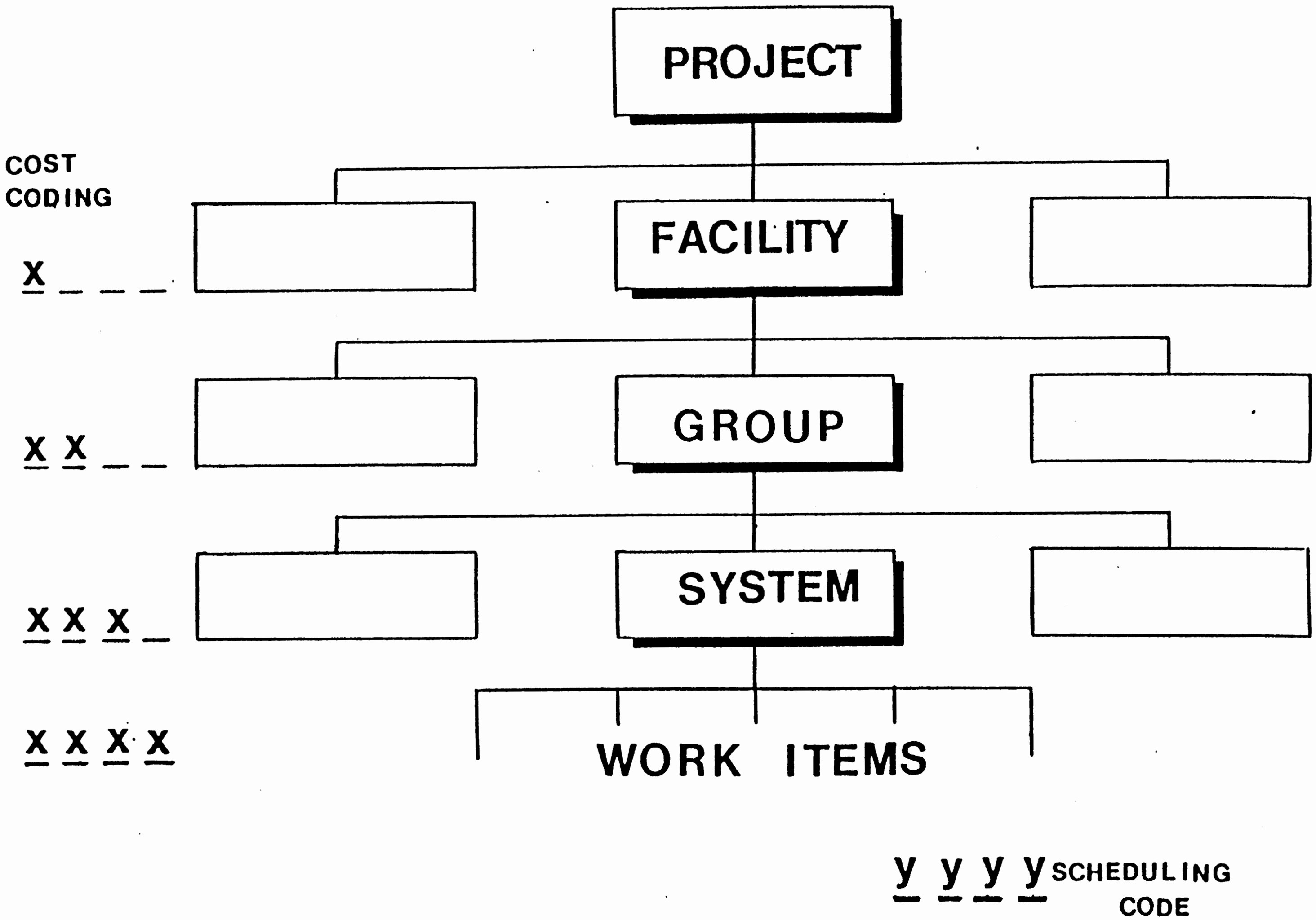

Figure 1.1 - Typical Project Work Breakdown Structure

It has been claimed that this technique is the clue to the integration of cost and scheduling control systems [14,50,52]. This integration is achieved by structuring the WBS so that the work items represent scheduling activities, and by assigning unique cost codes to each level and its subcomponents on the WBS. In this manner the cost of each activity can be tracked for control purposes and cost /scheduling integration can be achieved.

What has not been addressed by researchers in this area is a problem in the application of this management technique. If a work item (the lowest level of detail on the WBS) satisfies the criteria for being a scheduling activity as proposed above, it cannot satisfy the criteria for being a cost item. For example, placing a footing for a certain building or installing the foundation for a specific piece of equipment is a common scheduling activity on a network diagram, and a typical work item on a WBS. Either of these work items satisfies the criteria for being a scheduling activity since it involves an amount of work that is definable, controllable, measurable, and compatible with the actual field operations and work assignments, but it does not satisfy the requirements for being a cost item. In this example (a footing foundation) the work item or scheduling activity may involve excavation, formwork, reinforcement steel, concrete work, hardware, and backfilling operations. Each of these operations (subactivities) will have a different cost code and belongs to a different major cost item. Costs simply do not exist at the subactivity level because cost and man-hours are never kept at this level of detail.

An attempt to keep cost records at the subactivity level results in an inefficient and unmanageable control system [45,48]. Attempting such a detailed system means issuing purchase requisitions, purchase orders, and keeping cost records for each subactivity.

Basis for Progress Measurement

Review of the attempts to quantify work progress to date reveals that three bases for progress measurement were utilized. These are expenditures, quantities in place, and earned value. The principle assumption in using expenditures as a progress measurement tool is that if the total budget for a project is 150,000 dollars and if the todate cumulative actual expenditure is 75,000 dollars, then the project must be 50 percent complete since one half of the budget has been spent. It was not long until it was realized that much of the budget can be spent with little significant progress being realized.

This directed attention to the fact that progress should be tied to the actual quantities being installed. This principle sounded promising in the beginning until it was discovered that the differences in the units of measurement, i.e., lb, cu yd , ft, ton, etc. for the different work items and their subcomponents are major obstacles in the application of this method. The different units prevent the summation of the progress achieved at the subcomponents level to arrive at the progress achieved at the component level. Similarly, it was also realized that the summation of the progress achieved on the different work items to obtain overall project progress was not achievable without assigning weight factors to each item and calculating what became known as weighted percent complete which entailed lengthy and cumbersome calculations [23].

Other complications surfaced when it was understood that even items having the same units of measurement needed extra qualifications that were not based on quantities or units of measurement. For example, it was realized that although the quantity of concrete placed on the first floor of a skyscraper was equal to that placed on the top floor of the same building, the cost and time for accomplishing each of these two work items was significantly different. Similarly, although all piping work is measured in units of linear feet, the cost and time required for one weld on a 48-60 inch pipe may be 20 times as much as that required for a 2.5 inch pipe. This difference in cost and time is attributed to differences in the diameter, thickness, and metallurgy of the pipes.

All these difficulties in measuring work progress, whether based on either expenditures or quantities in place, created the need for another method which resulted in the earned value concept [12,37]. The earned value is the amount budgeted or planned to reach a specific goal regardless of the actual expenditures incurred in reaching that goal [3]. Under this concept, subactivities are assigned certain percentages of the total amount budgeted for an activity (work item) instead of actually pricing each subactivity. Pricing or budgeting a whole activity and assigning estimated percentages of its total cost to its subactivities is easier than pricing each subactivity to develop the total budget for the activity, especially when actual cost is kept only at the activity level. This is due to the fact that the smaller the cost component the smaller the price margin it can tolerate, and the more accurate its estimate has to be. This may explain why the differences in total bid prices quoted by different contractors are usually very small, while significant differences often exist when comparing costs of the same components quoted by different bidders.

Although the earned value concept is a step in the right direction, its application still suffers from the following three shortcomings:

1. The cost of an activity (work item) is still a "guesstimate" since no accurate pricing of its subactivities exists.
2. Tracking the actual cost of the subactivities and hence the whole activity is not possible since actual costs are not collected or maintained at the subactivity level.
3. Accepting the two facts stated above requires maintaining two cost systems on the project: one based on actual cost at the cost item level; and the second based on the "guesstimated" cost at the activity and subactivity levels. This makes the control functions more complex, requires additional effort, and defeats the idea of true cost and scheduling integration.

   Perhaps more importantly, it raises the question of whether the earned value and hence the work progress should be based on cost or on time. If it is based on cost, the earning rules for an activity may be:

Excavation	5 %
Formwork	35 %
Reinforcement	15 %
Concrete	40 %
Backfill	5 %
	100 %

Assuming that at the time the project update work was completed on the first four subactivities, i.e., excavation, formwork, reinforcement, and concrete, the percent of completion for this work item will then be equal to the summation of the earned percents on these subactivities. Therefore, this work item is 95 percent complete.

However, if the earned value is based on time, the earned percentages allocated to the subactivities may vary significantly from the above percentages since they became percentages of the total duration of the activity. These earned percents may take the following values:

Excavation	20 %
Formwork	10 %
Reinforcement	20 %
Concrete	5 %
Curing	35 %
Backfill	10 %
	100 %

Calculating the progress based upon time will result in significant variance in the percent complete from the above calculated figure. Based on time, the work item will only be 55% complete, i.e., equals to 20 + 10 + 20 + 5, rather than 95% complete when based on cost percentages.

As can be seen from the above example, differences in the percent earned by each subactivity and the number of the subactivities needing to be considered may vary depending on the basis for applying the earned value concept. Thus, the resulting percent complete of an activity may vary significantly which in turn has a measurable impact on the project's overall percent complete.

Current Problems in the Cost/Scheduling Integration Concept

In the current management approach, the status of a project and its performance evaluation are commonly described utilizing the cost/time envelope diagram or similar techniques to integrate cost and scheduling data [5,16,17,34]. The cost envelope diagram is a graphical presentation of the project's preconstruction cost profile based on early start (ES) and late start (LS) schedules, as shown in Figure 1.2. As the project progresses, actual project costs are plotted on the same graph as indicated by the dashed curves in the figure. If the actual project cost is described by curve 'B' or a similar one, i.e., the points describing the total project cost fall inside the planned cost envelope the performance of the project is judged to be satisfactory. If the actual project performance follows a curve similar to curve 'A' or 'C', i.e., falling above or below the planned

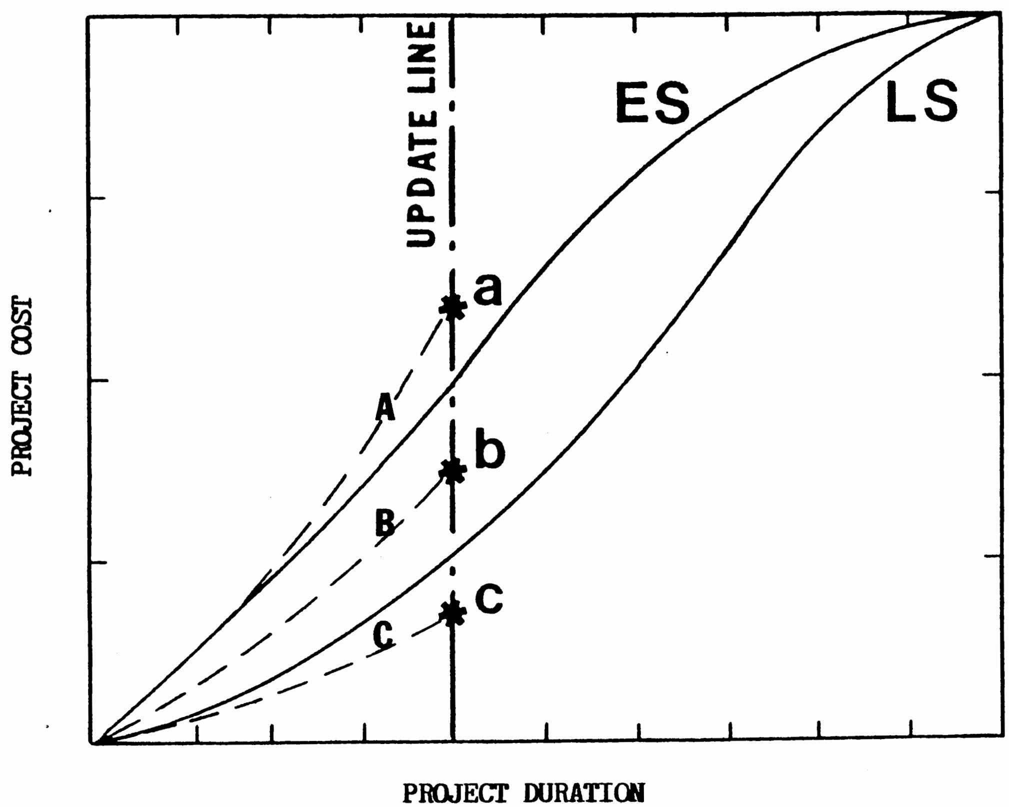

Figure 1.2 - Typical Project Time-Cost Envelope

cost envelope, the project performance is judged to be unsatisfactory. Curve 'A' is usually interpreted as an indication of an overrun situation, while curve 'C' is interpreted as an indication of a behind schedule situation.

Further analysis of the three possible actual performance curves suggests that none of these trends is conclusive, and all could be misleading or provide false information to top management. At any fixed time such as the update period shown in Figure 1.2, points 'a', 'b', and 'c' could be a result of poor performance or excellent performance depending on their causes.

Point 'a', for example may indicate overspending and hence poor performance. It could also indicate excellent performance resulting from getting more work accomplished than scheduled, or early arrivals of material or a major piece of equipment for which cost was incurred earlier than anticipated. Similarly, point 'c' may indicate slow progress which is reflected by an underspending situation, or it may mean excellent performance resulting from getting work accomplished under budgeted cost. Causes for getting work done under budgeted cost such as an overinflated estimate; a bad distribution of the control estimate's components (front-end loading); efficient management; implementation of a productivity improvements program; tight project control system; and price deflation due to economic recessions or scarcity of jobs such as experienced since the early 1980s are not at all uncommon. On the other hand, point 'b', the supposedly desired and acceptable performance, may in reality be a result of poor performance if it meant achieving the same progress represented by curve 'C' but at a much higher cost.

In recognition of these problems, and in an attempt to improve such a widely used management concept in project evaluation, Stevens [47] offered a major modification to the above approach. He recommended plotting only the target project's cost profile and including the project's accomplishments curve on the same graph as shown in Figure 1.3. In order to arrive at a conclusive judgement regarding project performance, Stevens devised the following method:

1. For any update period, project the cumulative actual accomplishment (A) on the planned accomplishments curve (B). If this requires going back on the time scale, the project is behind schedule. The scheduling slippage is equal to the distance between point A and point B on the time scale. In arriving at point B if it is required to advance ahead of the update time, the project is ahead of schedule. The scheduling gain is equal to the distance between point A and point B on the time scale.
2. A cost overrun situation is detected by determining the cost corresponding to the level of accomplishments projected on the planned accomplishments curve (C). This cost is compared to the actual cumulative cost at the time of the project's update (E). If the actual cost expenditure (E) is greater than the planned cost (C), an overrun situation is detected. The magnitude of such a cost overrun is equal to the difference between the two points (C and E) on the cost scale. Similarly, if the actual cost expenditure (E) is less than the planned cost (C), an underrun situation is detected. The magnitude of a such cost underrun is equal to the difference between the two points (D and E) on the

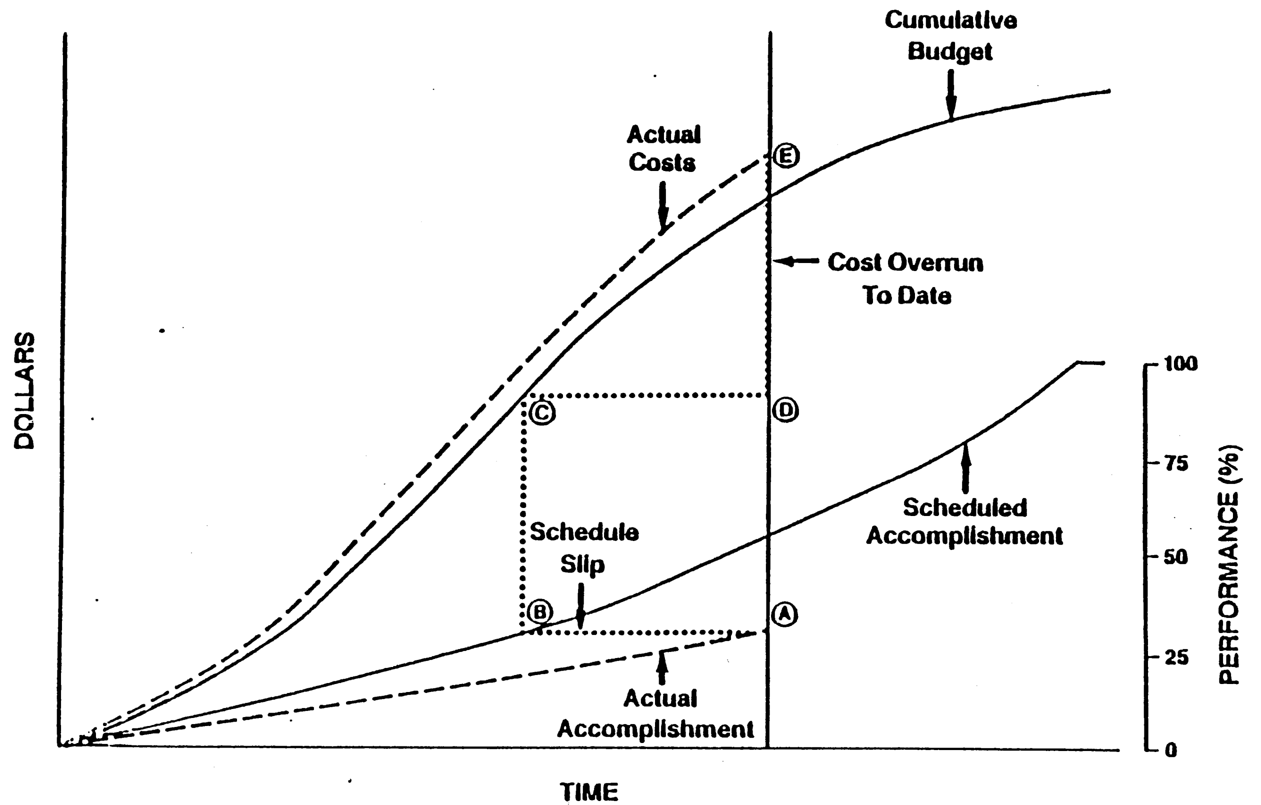

Figure 1.3 - Integrated Cost/Schedule Diagram
[Stevens, 1986]

cost scale. Even with the modified concept there are some less obvious problems:

1. The new approach still assumes that a realistic quantitative method exists for measuring work progress (performance percent, percent complete, or accomplishments).

2. The planned target cost profile is an applicable baseline only if the preconstruction scheduling network is an exact simulation of the actual project conditions incurred during the execution phase which is rarely the case.

The construction control budget (estimate) is only a model to forecast the project costs prior to the actual start of the project. This model is usually based on historical cost data from other projects. Similarly, a scheduling network is just a model of the possible time structure or sequence of construction events which is developed before the fact and, thus, contains measurable uncertain circumstances. Uncertainties such as imposed by adverse weather, labor strikes, limited availability of certain resources, unexpected site conditions, and similar circumstances.

During the actual execution phase, there are continuous changes in the preconstruction scheduling network imposed by factors such as limited resources, late material delivery, design changes, optimization of equipment utilization, prolonged downtime, adverse weather conditions, and any other unforeseen factor. Selecting one possible sequence of field operations (schedule) as the only acceptable performance baseline leads to erroneous conclusions and imposes unnecessary constraints.

Schedules developed with the limited information available in the preconstruction stage often ignore other sequences, which are equally capable of delivering the whole project on time.

3. Even under the assumption that a preconstruction schedule is an accurate presentation of the actual project's condition, measurable differences between the planned cost profile and project's actual cost profile can result from the differences in the basis upon which cost is reported, hence the basis for generating the two cost profiles. Costs may be reported based on charges committed, invoiced, or actually paid; each method of reporting costs has its advantages, disadvantages, and proper uses.

The definition of committed cost is often vague enough to cause variations between the two cost profiles (the planned and the actual) depending on an individual's subjective interpretation. To identify when costs are committed may also depend on the type of work, type of contract, the volume of work, and duration of the subject item and its components. With the current typical organization of construction companies the individuals responsible for generating and maintaining actual cost profiles are not the same individuals who develop estimates.

Using the invoiced cost as the cost reporting method and the basis for generating cost profiles may increase the distortion of the project's status picture due to the time lag between work actually being accomplished and the cost invoiced. At project level, management has little or no control over the invoicing cycle which may range from a few weeks to a few months. Invoice processing is a corporate function that is usually placed within the accounting and fixed assets departments. The time lag between work progress and invoiced cost will always result in reporting a lower cost than was truly incurred to reach a certain progress level resulting in an overly optimistic impression of actual performance.

Using actually paid charges as the cost reporting method will obviously result in a greater time lag and will increase the distortion in the cost/progress relationship. In summary, it can be concluded that until an industry wide agreement is reached regarding the basis upon which work progress should be based and until fundamental problems in the interface of cost and scheduling are resolved, project evaluation as a part of project controls cannot be approached successfully at the macro level.

Impetus of the Thesis

Recognition of the shortcomings of the current management concepts in the evaluation of project performance at a macro level and the need for a more successful evaluation procedure utilizing a problem detection technique to identify causes of poor performance and calculate their monetary impact have prompted this study.

The apparent similarity between a construction project and a commercial organization and the success of financial analysts in evaluating companies' performance and identifying symptoms of poor financial structures without apparent problems have directed the author's attention to analyzing such methods in an attempt to utilize their concepts in evaluating construction projects.

A financial ratios analysis technique is one method used successfully by financial analysts in evaluating a company's performance. With this technique, ratios between different items on the balance sheet and profit and loss statements are used as indicators of the overall performance of the firm. The emphasis is placed on understanding that none of the ratios individually is a good indicator of a firm's performance, rather, the values of many ratios collectively, and the correlations among them, contribute in evaluating a firm's performance [31,40,46]. Performance evaluation in the financial business sector, unlike in the construction industry, has been accomplished at a micro level. Instead of searching for one numerical value to describe the success of the entire business, up to fifty different ratios are generated to attempt to evaluate each separate aspect that affects the overall performance. The relationships among related aspects are also described by determining their correlations.

The other important concept in this technique is the use of ratios of data elements instead of the absolute values of such data. The use of ratios was found to eliminate problems in appraising companies of different sizes or in different locations where different prices or currencies exist. It was also found that the use of ratios expedited the analysis, reduced the large numbers of items to a relatively small set of readily comprehended and economically meaningful indicators, and overcame the common deficits in financial statements due to the time lag in reporting costs [33,36,49].

This micro approach in which the traditional concept of searching for one integrated descriptor or indicator for the success or failure of the whole project is replaced by an attempt to evaluate the performance of individual components and to determine their impact on the overall project, and in which ratios of control data elements are used instead of the absolute amounts, has apparently never been attempted on construction projects.

Objectives and Scope of the Study

The objective of this study is to employ a new micro approach to evaluate the performance of construction projects. This includes development of a performance evaluation technique based on a set of ratios analogous to the financial ratios used to appraise businesses. The technique addresses identifing of key control ratios that describe work performance and devising an analytical procedure to detect potential problem areas where management corrective action is needed on a construction project.

This research attempts to achieve these objectives by addressing the following scope of work:

1. Review of the business financial ratios analysis technique - The review includes definitions, calculations, and limitations of these ratios in order to understand the essence of and the basic concepts used in applying the ratios technique. This review also

establishes a basis for application of an evaluation technique to construction projects.

2. <u>Assessment of the applicability of the ratios analysis technique</u> The applicability of existing business financial ratios and the ratios analysis technique is assessed as a performance evaluation technique for construction projects. This involves the analysis of the structure of a company's operations in contrast with a project's operations to identify the similarities and differences between the two types of operations.

3. <u>Identification of key control ratios</u> - This includes the selection of a set of control ratios (simple and complex) capable of describing the progress conditions of each project's work items. The ratios focus on evaluating the financial performance of each item which can affect the overall project performance. They also involve the identification of some key ratios which have special significance in the performance evaluation process. Forecasts and performance indices utilizing some selected ratios are computed based on the relationships between their actual and budgeted values.

4. <u>Development of a problem detection technique</u> - Since the identified key project control ratios describe the conditions of the cost items, their values are used to detect areas in the project having potential financial problems. A procedure is established to identify the immediate cause(s) of such problems and to determine their monetary impact on the overall project cost. This includes organization of the required input data, design of a systematic calculations algorithm, and formultion of

comprehensive management reports emphasizing cost analysis rather than cost accounting.

5. Assessment of the application of the detection technique - This includes the application of the technique using a sample project highlighting its advantages over the traditional approach.

The scope of this study will be limited to evaluating and detecting problems classified as direct costs. Only labor costs, material costs, and costs due to low labor productivity are addressed. Although equipment costs are classified as direct cost, they are excluded from the scope of this research. Handling of equipment costs is a major research area in itself.

Organization of the Thesis

This thesis consists of six chapters. A general introduction has been provided in Chapter I to state the nature and importance of the problem being investigated. In Chapter II, literature pertinent to the problem area under investigation has been reviewed with emphasis on the financial ratios analysis technique and utilization of ratio analysis techniques in the construction industry in general.

In Chapter III the assessment of the applicability of the financial ratios analysis technique to construction projects is presented. The selection criteria for a set of project's key control ratios which are capable of describing the performance conditions of cost items and evaluating their performance are established.

In Chapter IV, a problem detection technique has been employed utilizing selected key control ratios to identify areas of a project having potential financial problems, determine their immediate causes, calculate their monetary impact on the overall project, and generate total project budget variance predictions.

An actual project is examined in Chapter V to illustrate the mechanics of the ratios approach.

A summary, a conclusion, and recommendations for future research are presented in Chapter VI.

CHAPTER II

LITERATURE REVIEW

General

The purpose of this chapter is to summarize some of the literature pertinent to the problem being addressed. This chapter is presented in two parts. The first part establishes the necessary background on the financial ratios analysis technique being used in the commerce. The second part reports previous attempts to utilize ratios and ratios analysis on construction projects.

Part One - Financial Ratios Analysis Technique

Definition and Significance

A ratio is a mathematical expression describing the relationship between two variables. In the case of financial ratios, these two variables are obtained from the two primary types of financial records, the balance sheet and the income statement.

Since the 1800's, the ratios analysis technique has been a major management tool in the interpretation and evaluation of enterprises, using their financial statements for decision making. Ratios are among the best known and most widely used techniques of financial analysis. The use of financial ratios marked the beginning of the scientific approach to the analysis of financial data [33], i.e., the initial application of analytical tools and techniques to financial data in order to derive measurements and relationships that are significant and useful for decision makers [9]. In this way management uses ratios analysis to recognize symptoms indicating financial deficiencies. The sooner recognition of a potential problem takes place the greater the possibility for recovery and the lower the costs to rectify the problem [1]. Ratios analysis allows management to collect data in order to learn from the past and to bring the future under control.

Ratios have been used in the financial business for diagnosis, monitoring, and planning [55]. Utilization of this evaluation approach experienced its greatest growth after 1920. This was due to: 1) the emergence of corporations as the main organizational form of business enterprise which resulted in an increasing need for management to underrstand the more complex financial conditions of their enterprises in order to survive fierce competition; 2) the ever increasing roll of financial institutions as major suppliers of capital, which has imposed considerable pressure on guarantors of credits to develop a formal evaluation system of borrowers worthiness and to understand in depth the financial conditions of their customers; and 3) the passing of the Income Tax Law of 1913, requiring the preparation of balance sheets and income tax statements, which insured the availability of reliable data from which ratios could be calculated [4,28]. In order to monitor and control these corporate needs an alarm system has evolved in the form of ratios analysis which identifies trends and symptoms and alerts management so that action may be taken.

Although the concept of using a simple, integrated set of ratios was tried by the Du Pont company in 1919, the results were not publicized until 1949 [55]. Further developments took place during the 1960's when extensive studies were made to assess the usefulness of the financial ratios in predicting financial failure [26]. Utilizing thirty ratios, the findings indicated that the failure status of firms can be correctly predicted based solely on knowledge of the financial ratios.

Usefulness of Ratios Compared to Absolute Accounting Data

The usefulness of using ratios comes from the fact that financial statements and other sources of financial data are whole numbers presented in isolation in a specific standard format. Comparison between these figures is not achieved within the rigors of prepared financial statements. In order to give more meaning to a figure presented on a financial statement it must be compared with other figures. The result is a ratio expressing the relationship between the two items [55]. Ratios cast light on the interrelated parts of business operations. They are analytical tools that indicate symptoms of underlying conditions. When properly interpreted, ratios can also point out areas requiring further investigation. An in-depth analysis of ratios can disclose relationships and trends that cannot be detected by inspecting the individual components of the ratios, and this is a critical step in the corrective process [11,55].

Ratios are used to identify shifts in financial conditions that impact operations. These shifts cannot be seen when using a mere balance sheet or another financial data reports which is a static snapshot of financial conditions at a point in time. The static type of financial statements are sensitive to the time span of the business activity, the accounting method used, and the legal requirements for such documents [27,36].

Ratios were also found to expedite analysis by reducing large numbers of items to a relatively small set of readily comprehensive and economically meaningful indicators [33]. The major objective of ratios analysis is to facilitate the interpretation of financial data, ascertain symptoms of an organization's economic conditions, provoke control questions, and guide the decision making. The relationships of various items to each other or to their magnitudes in previous years represent a viable management tool. Presentation of data in ratio form makes the analysis of an enterprise easier by overcoming problems due to a time lag in reporting charges, differences in accounting methods, and the required degree of accuracy [49].

Significant Ratios and their Interpretation

There are a multitude of different ratios that can be devised. Management may select several that would benefit their organization and after testing could put them in use. A list of such common ratios may include [46]:

1. Cash Flow/Sales
2. Net Income/Sales
3. Current Liability/Net Plant
4. Current Liability/Net Worth
5. Long Term Debt/Net Plant
6. Long Term Debt/Total Capital
7. Total Liability/Net Worth
8. Working Capital/Total Assets
9. Total Assets/Net Worth
10. Receivables/Inventory
11. Cash/Total Assets
12. Cash/Current Liabilities
13. Current Assets/Total Assets
14. Current Assets/Current Liability
15. Inventory/Current Assets
16. Inventory/Working Capital
17. Quick Assets/Total Assets
18. Quick Assets/Current Liability
19. Receivables/Sales
20. Cash/Sales
21. Current Assets/Sales
23. Inventory/Sales
24. Quick Assets/Sales
25. Quick Assets/Operation Expend
26. Cash/Operation Expenditures
27. Total Income/Sales
28. Cash Flow/Total Assets
29. Cash Flow/Net Worth
30. Total Income/Total Assets
31. Net Income/Total Assets
32. Net Income/Net Worth
33. Net Worth/Sales
34. Sales/Working Capital
35. Sales/Total Assets
36. Cost Goods Sold/Inventory
37. EBIT/Total Assets
38. EBIT/Sales
39. Sales/Net Plant
40. Cash Flow/Total Capital
41. Total Income/Total Capital
42. Sales/Total Capital
43. L.Term Debt/Total Assets
44. Total Liab/Total Assets
45. Current Liab/Total Assets
46. EBIT/Interest Expense
47. Stocks/Total Assets
48. Cash Flow/Total Liability
49. Net Worth/Net Plant
50. EBIT/Net Worth
51. Sales/Net Plant+W.Capital

Note: EBIT is Earnings Before Income Tax

Of this complete list only twelve financial ratios, i.e., Quick Ratio, Current Ratio, Fixed/Worth Ratio, Debt/Worth Ratio, Unsubordinated Debt/Capital Funds Ratio, Sales/Receivatles Ratio, Cost of Sales/Inventory Ratio, Sales/Working Capital Ratio, Sales/Net Worth Ratio, Profits Before Taxes/Worth Ratio, Profits Before Taxes/Total Assets Ratio, and Cash Flow/Current Maturating Long Term Debt Ratio, were selected by major national financial associations to be included in the annual industries financial ratios reports.

The selected ratios as well as the others listed above can be grouped under four main categories of performance measures. The four categories are discussed below using the twelve selected ratios for illustration. These categories of performance measures are:

1. Liquidity Measures - These include the Quick Ratio (summation of cash, short-term securities, and net receivables divided by total current liabilities), and the Current Ratio (total current assets divided by total current liabilities). Liquidity measures are of particular interest to creditors since they indicate the availability of short term liquidity to cover current liabilities and the ability of a firm to meet its current debts.

2. Stability Measures - These include the Fixed/Worth Ratio (depreciated value of plant and equipment divided by tangible net worth), the Debt/Worth Ratio (total debt divided by tangible net worth), and the Unsubordinated Debt/Capital Funds Ratio (summation of current and senior long-term debt divided by the summation of tangible net worth and long term subordinated debt). Stability measures describe the relationships between owners and junior and/or senior creditors. In other words, they determine the proportion of capital invested in fixed assets and the owners' capital, the proportion of what is contributed by creditors, i.e., what is owed, to that contributed by owners, i.e., what is owned, and the proportion of capital invested by senior creditors to the sum of the capital invested by junior creditors and owners.

3. Efficiency Measures - These include Cost of Sales/Inventory Ratio (cost of goods sold divided by total cost of inventory), Sales/Working Capital Ratio (net annual sales divided by net working capital), Sales/Net Worth Ratio (net annual sales divided by tangible net worth), and Sales/Receivables Ratio (net annual sales divided by total accounts and bills receivables). Efficiency measures reflect the physical turnover, saleability and liquidating value of the inventory, the activity of the portion of capital not held in the fixed assets, and the effectiveness of the collection cycle.

4. Profitability Measures - These include Profit Before Taxes/Worth Ratio (total net profit divided by tangible net worth), Profit Before Taxes/Total Assets Ratio (total net profit divided by net total assets) and Cash Flow/Current Maturities Long-Term Debt Ratio (summation of net profit, depreciation, and amortization divided by the current portion of long-term liability). Profitability measures reflect the return on capital invested by owners and creditors, and the ability of a firm to retire debts that are maturing annually from the cash generated by its operation.

Standards of Comparisons

No ratio is a good indicator of performance by itself. Ratios, therefore, are compared with standard industry values, rules of thumb, and their own historical behavior [9]. Comparison with standard values shows if the enterprise is typical of, superior to, or inferior to industry competitors [28]; while comparison with its own historical behavior shows whether the enterprise's conditions are improving or deteriorating with time.

There are numerous sources of financial information available to the public. Examples of the most widely known sources are The Federal Trade Commission, Dun and Bradstreet, Robert Morris Associates, and Prentice-Hall, Inc.

Limitations of Ratios Analysis

Like any management tool, ratios can be misused. There have been situations where poor decisions were made as a result [55] of such misuse. It should always be remembered that financial ratios are generated from historical records of past operations. The use of these ratios assumes that past economical performance can be projected into the future. It should be understood that financial ratios are only indicators that give no literal explanations nor provide corrections for defects. The task of ratios interpretation is the responsibility of the user. Disagreement with past records or industry's norms is not exclusive evidence of the existence of a problem. On the other hand, financial ratios cannot indicate whether past success was due to certain individuals who are no longer with the firm or due to a new product discovery, etc.

Generating these ratios is not an end in itself. It is rather a means by which management's capabilities can be improved. For a more successful utilization of this analysis some considerations should be taken in account [49,55]. These include:

- The need to differentiate between causes and effects is crucial for this type of analysis.
- In using figures subject to seasonal or more frequent fluctuation, it is advisable to use the periods' average.
- Data must be reliable since ratios are no more accurate than their source data.
- Care must be taken to choose ratios that are capable of identifying suspected problems with the knowledge of the relationships between different ratios.
- Decisions should be made only when true patterns and significant changes occur.
- Comparisons to both industry standards and to past performance (time series analysis) may be needed at times.
- Costs for obtaining extra data to generate more ratios must be justified.

Part Two - Use of Ratios in Construction

Articles that address the subject of uses of ratios in construction in general are limited in number. A review of the available publications has revealed that three types of uses for ratios exist in the pertinent construction literature. These include:

1. Ratios utilized for appraising construction companies.
2. Ratios adopted in reporting project status to top management.
3. Ratios used in preparing construction cost estimates.

Construction Companies Appraisal Ratios

Ratios analysis has been applied to the financial statements of construction companies the same way it was applied to manufacturing companies. In 1982 Warszwaki and Rosenfeld [54] attempted to evaluate the success of utilizing this technique, as known and used by financial analysts in evaluating manufacturing companies, to appraise the performance of construction firms. They pointed out that the direct application of the existing financial ratios analysis in construction may often result in misleading information due to special problems that characterize the construction environment. The authors listed several causes that could result in changing a firm's financial structure, and thus make the value of the financial ratios and their analysis misleading. A discussion of such causes can be summarized as follows:

1. Construction projects are executed as either contracted works (built by a contractor for an owner) or built by entrepreneur (builder-owner usually for subsequent sale). The first case involves a preordered project which is constructed on the owner's land and financed by progress payments for the work completed. The second case involves a project that is designed and constructed by the owner who usually seeks to sell it upon completion. Each case affects the capital structure of the firm under consideration and hence its financial statements in a different way. For example, in the case of a builder-owner lands and finished buildings are considered current assets while they are not in the contracted

work situation. This results in a noticeable change in the majority of the financial ratios.

Also, the market value of the land and the completed project will tremendously affect the profitability and all its related ratios of the owner-builder situation. Another factor that affects the financial structure of a construction firm is the speciality of the organization. Financial ratios of a general contractor with minimal assets will look completely different from another contractor, e.g., in heavy construction, highways, pile driving, etc.) engaged in activities requiring much higher capital investments. These problems may even multiply in magnitude if the activities of the construction company involve some manufacturing operations such as ready-mix concrete or prefabricated construction elements. Therefore, a comparison of financial ratios to industry standards or comparisons between two construction firms may yield meaningless results.

2. The choice of the method of financial accounting for a construction company has a considerable influence on the reported profitability and hence on the related ratios. The two commonly followed methods in construction are the percent-of-completion and the completed-contract [25]. Income and costs in the first method are recognized as they incur during the progress of the contract. Profits reported can thus be attributed to the portion of the work completed. Although this method reflects the state of present operations its weakness lies in two points.

These weakness are the difficulty and possible error in estimating the value of work accomplished, and hence influences the reported profitability. In the second method, completed contract, the reported profitability of a business is certain since income is recognized only when the contract is completed. However, the reported data has much less relevance since progress payments are considered liabilities and costs incurred are accumulated as work in progress until the contract is completed.

3. Construction is highly susceptible to upward and downward economic cycles and the accompanying financial inflation and deflation of project costs. The distorting effect of inflation is considered one of the biggest difficulties facing the use of the ratios analysis technique. This affects not only current projects costs but also the value of the fixed assets. The longer the duration of a project in times of inflation or recession the larger the difference between its real and book values. A project duration spanning several accounting periods is common for medium and large projects.

In their study, Warszawski and Rosenfeld [54] recommended that a new approach and a different methodology are required to resolve the preceding problems. They also attempted to devise a new approach utilizing discounted cash flow and the time value of money to overcome the problems in ratios analysis related to inflation.

Utilization of Ratios in Top Management Reports

Several ratios of data elements were developed and adopted by major construction firms and government agencies, e.g., Metier Management Systems Company, U.S. Air Force, DOD, NASA, in an attempt to ease some of the problems of reporting integrated cost and scheduling information [14,38]. These ratios may be expressed in terms of work hours and/or dollars, and can be calculated as shown in Equations 2.1-5 below:

1. Cost Performance Index (CPI) - This index describes the relationship between the budget costs of work performed to date (BCWP) and the actual costs of work performed to date (ACWP). A value of less than 1.0 reflects a performance lower than anticipated while a value higher than 1.0 indicates a superior performance.

Cost Performance Index (CPI) = BCWP / ACWP EQ. 2.1

2. Scheduling Performance Index (SPI) - This index determines the ratio between the budget costs of work performed to date (BCWP) and the budget costs of work scheduled to date (BCWS). Similar to the cost performance index, a value less than 1.0 indicates poor performance, while a value greater than 1.0 indicates higher performance than expected.

Scheduling Performance Index (SPI) = BCWP / BCWS EQ. 2.2

3. Percent Overrun/Underrun (PO/U) - This index was developed to avoid some of the false impressions that can result from comparing actual and budget costs for any time period during construction. It displays the relationship between the actual cost variance of to date work (ACWP - BCWP) and the budget (BCWP).

Percent Overrun/Underrun (PO/U) = (ACWP-BCWP)/BCWPx100 EQ. 2.3

4. Planned Percent Complete (PPC) - This index compares the budget value of the work scheduled to date (BCWS) with the project's total budget at completion (BAC).

Planned Percent Complete (PPC) = BCWS / BAC x100 EQ. 2.4

5. Percent Complete (PC) - This index expresses the relationship between the budget value of the to date actual accomplishments (BCWP) and the current budget at completion (BAC).

Percent Complete (PC) = BCWP / BAC x100 EQ. 2.5

The cost and scheduling performance indices (CPI and SPI) can be plotted over time as shown in Figures 2.1-2 as two useful reports for top management. A third useful report can be produced by plotting the two indices against each other as shown in Figure 2.3. This report provides management with information on whether the overall project performance is currently favorable, unfavorable, or marginal. It can also display whether a performance trend is being established with reference to these three conditions. For these indices to be more meaningful, they must be generated from a network based cost control

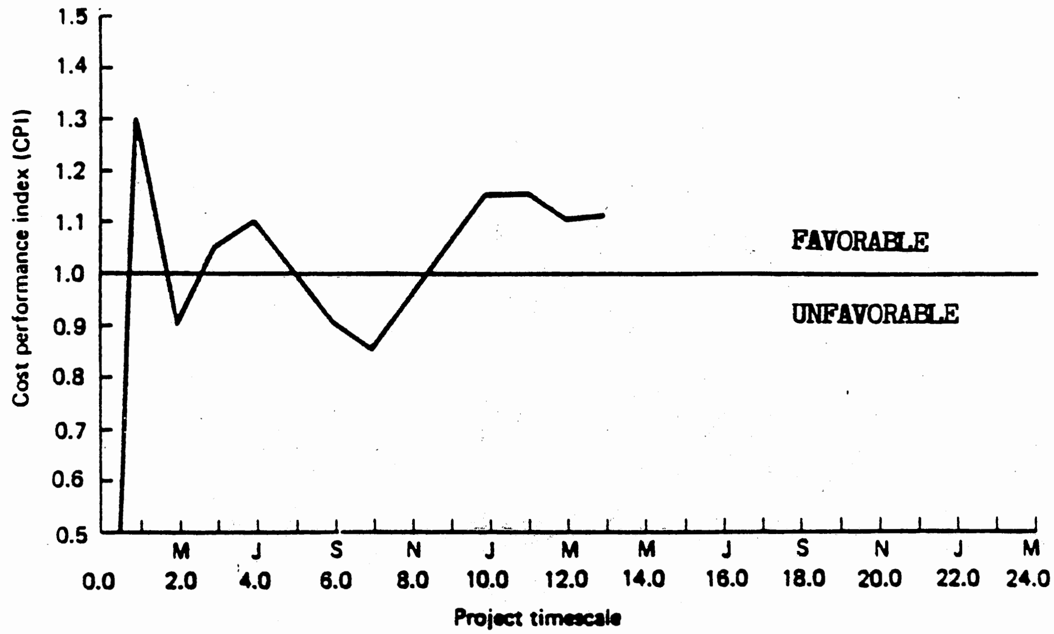

Figure 2.1 - Cost Performance Index Trend Over Time
[Moder, Philips, and Davis, 1983]

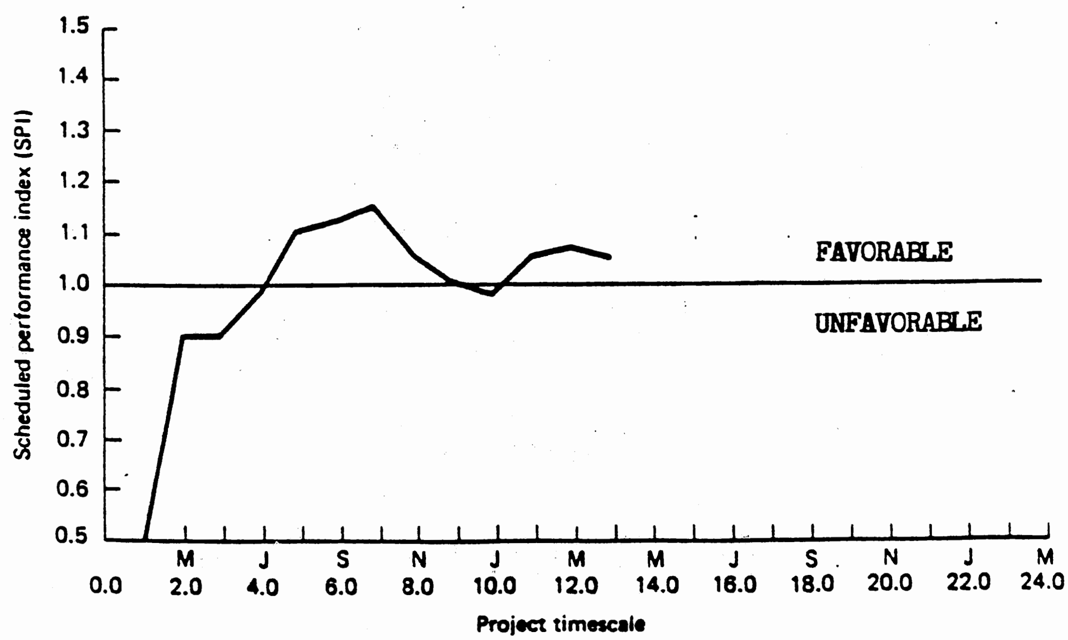

Figure 2.2 - Schedule Performance Index Trend Over Time
[Moder, Philips, and Davis, 1983]

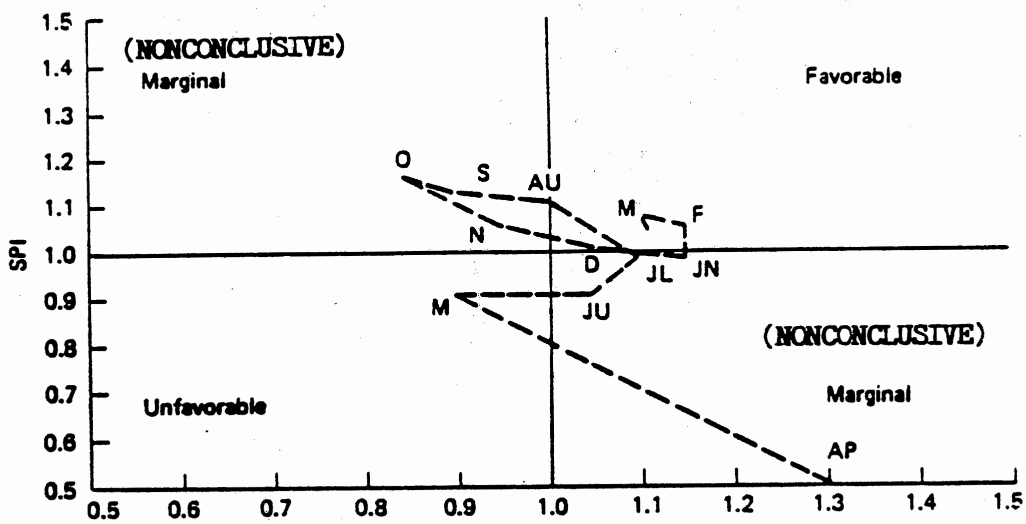

Figure 2.3 - Combined Cost/Schedule Performance Index Trend [Moder, Philips, and Davis, 1983]

system. However, network based cost control cannot be easily implemented unless applied to only selected projects or certain phases of a project [38], due to the problems discussed in Chapter I.

Cost Estimating Ratios

The first step in preparing a detailed estimate is the identification of the materials required for each cost account (control cost item). Once the types of materials are identified, quantities required are calculated from drawings and data sheets (specifications) in the proper unit of measurement. After quantities are determined for each account a costing method is then selected. Unit pricing and resource enumeration are the most frequently used [20,25,32].

In the unit pricing method, cost can be computed by multiplying the dollar per unit cost {($/Q) ratio}, obtained from company's past records with or without adjustment, by the quantities. Unit prices (cost ratios) are also available in many cost estimating manuals and standards such as Dodge Construction Manual, Means Cost Data, and Richardson Estimating Standards. These cost sources normally are representative of the national average value for such ratios with adjustment factors for particular locations. Cost ratios provided in these standards and manuals assume a certain resource (labor and equipment) composition and an estimated production rate. With the knowledge of the cost of resources per unit time {($/hr) ratio} and the output of such resources {(Q/hr) ratio} the cost ratio ($/Q) can be calculated by:

Cost Ratio ($/Q) = ($/hr) / (Q/hr) EQ. 2.6

Also, the cost ratios obtained from a company's records should be treated with caution since they are always presented as dollars per unit cost without the details of their associated resource composition and production rate data, which can affect their values significantly.

Since the numerator (i.e. $/hr) of the unit cost ratio varies rapidly over time, some contractors maintain the value of the ratio of man-hour or resource-hour per hour of production in their historical cost files. The man-hour or resource-hour per unit (RH/Q) ratio can be calculated as:

RH/Q = (Resource-hour per hour) / (Units per hour) EQ. 2.7

The value of the cost ratio ($/Q) in this case can be calculated using:

$/Q = (RH/Q) * ($/RH) EQ. 2.8

Collecting data on resource-hours per unit will not be affected by inflation over the years as will the data collected on cost per unit. A resource-hour data base is therefore more stable with time. It should also be noted that materials costs must be added to the value of the cost ratio calculated by Equation 2.8 in order to obtain an overall cost ratio for any cost item.

Although the unit price costing method suffices for typical cost items, unit price data on unusual and unique items may not exist. In such cases cost ratios must be developed by breaking the special work items into subcomponents and assigning specific resources to each subcomponent. Also, the productivity to be achieved by each resource must be estimated. This method is known as the resource enumeration method and has the advantage of allowing the estimator to specify the resource or crew combination, charge rate, and production level on each item. Applying the most recent charge rate of the resources incorporates inflationary and deflationary trends in calculating cost ratios. In this method a cost ratio is calculated as follows:

Cost ratio (\$/Q) = Resource cost per unit time(\$/hr)/ Production rate (Q/hr) EQ. 2.9

This method yields a more accurate price value for cost ratios than the unit price method. However, it is more time consuming, and therefore only recommended for estimating large and significant items, complex items, and items for which no cost data are available.

In conclusion, ratios in construction have been used to appraise construction companies, reporting project status to top management, and preparing construction cost estimates. Ratio techniques have not yet been used as a project control tool in the project tracking phase or as a performance appraisal procedure for construction projects. In addition, ratios analysis has not been used as a comprehensive problem detection technique to identify areas of a project having potential problems. This study address this issue by extending the utilization of ratios analysis techniques to cover these three useful applications.

CHAPTER III

ASSESSMENT OF THE APPLICABILITY OF FINANCIAL RATIOS ANALYSIS IN CONSTRUCTION PROJECTS

General

The purpose of this chapter is to assess the applicability of the business financial ratios analysis technique in construction projects. A comparison is made between a company's operating mode and a project's operating mode to identify similarities and differences in the activities and operations conditions. Based on this comparison a decision is made regarding what modifications must be made to the existing technique for it to be adopted for evaluating construction projects. This chapter also establishes the criteria for selecting the project ratios necessary and sufficient for describing the work conditions and perfor- mance of cost items that make up the control budget for a construction project.

Company's Operating Mode

Since the financial ratios analysis technique was originally devised for appraising manufacturing companies, attention was directed towards understanding the activities of such companies and the operating conditions under which they perform. A schematic presentation of such activities is shown in Figure 3.1. In its simplest form a manufacturing company can involve two major parties, owners and creditors. Both parties contribute cash to the business with which inventory is purchased. Inventory is then turned into goods, and the goods are then sold. The sales generate an amount of cash which hopefully is greater than the amount that existed at the beginning of the operating cycle. The generated cash goes back to both parties in the form of return and dividends to the owners and principle and interest to the creditors. The process is then repeated in a continuous mode without stoppage as long as the company is in business.

Some of the characteristics of this operating cycle worth noting are:

1. The cycle starts with the contribution of cash and ends with the distribution of cash. In other words, it starts and ends with the same commodity (if money can be called a commodity).
2. Both parties contribute the same thing (cash) at the beginning of the cycle and receive the same thing (cash) at the end of the cycle.
3. Both parties are interested in increasing the cash generated at the end of the cycle. Obviously, owners are keen on increasing the generated cash because this increases their worth at the end of each cycle. Although creditors will not receive more than the principle and the interest agreed upon before the start, their appreciation of the increase in generated cash at the end of the

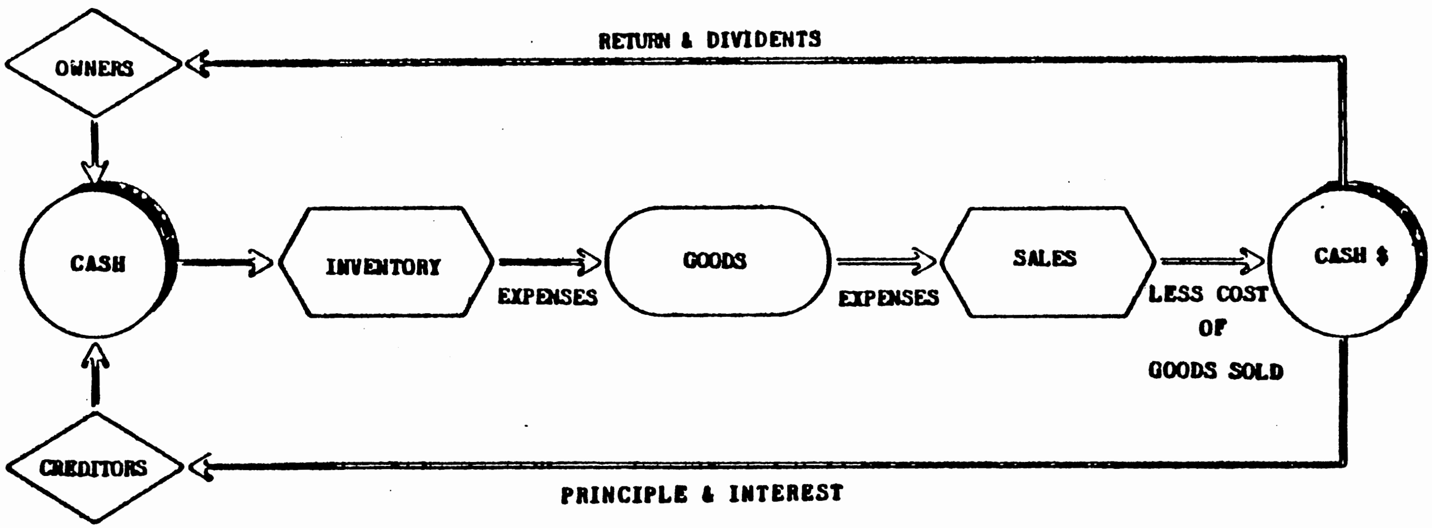

Figure 3.1 - Schematic Presentation of Operation Mode
for a Manufacturing Company

cycle is based on an understanding of the relationship between risk and interest rate, the higher the expected risk in the investment the higher the interest rate. Increasing the generated cash at the end of an operating cycle decreases the risk involved and hence, for the same interest rate, is equivalent to making more money. This may explain why the two parties have no conflict of interest during the business process, in contrast to the situation in the construction industry as will be explained in the next section.

In light of the simulation of the business cycle shown in Figure 3.1 and explained in the analysis above, a clearer understanding of the meaning of the business ratios and the rationale of their four major groups of performance measures discussed in Chapter 2, may be possible, as shown by Figure 3.2. This Figure is a pictorial presentation of the grouping of these ratios showing the approximate phases at which they are applied to the operating cycle. As illustrated, different ratios are applied at different phases of the cycle in order to measure different aspects of the business and to assess the performance of each phase.

The ratios of liquidity measures are designed to assure analysts of the availability of enough liquidity (cash and short-term securities) to start and continue the operating cycle. It also assures junior creditors (short-term investors) of the ability of the business to pay back their investments at any point in time during the operating cycle, if they so desire or they are forced to. The ratios included in efficiency measures are chosen to determine the turnover of inventory to sales, and to measure the proportion of cash tied into each production stage (inventory, goods, and sales).

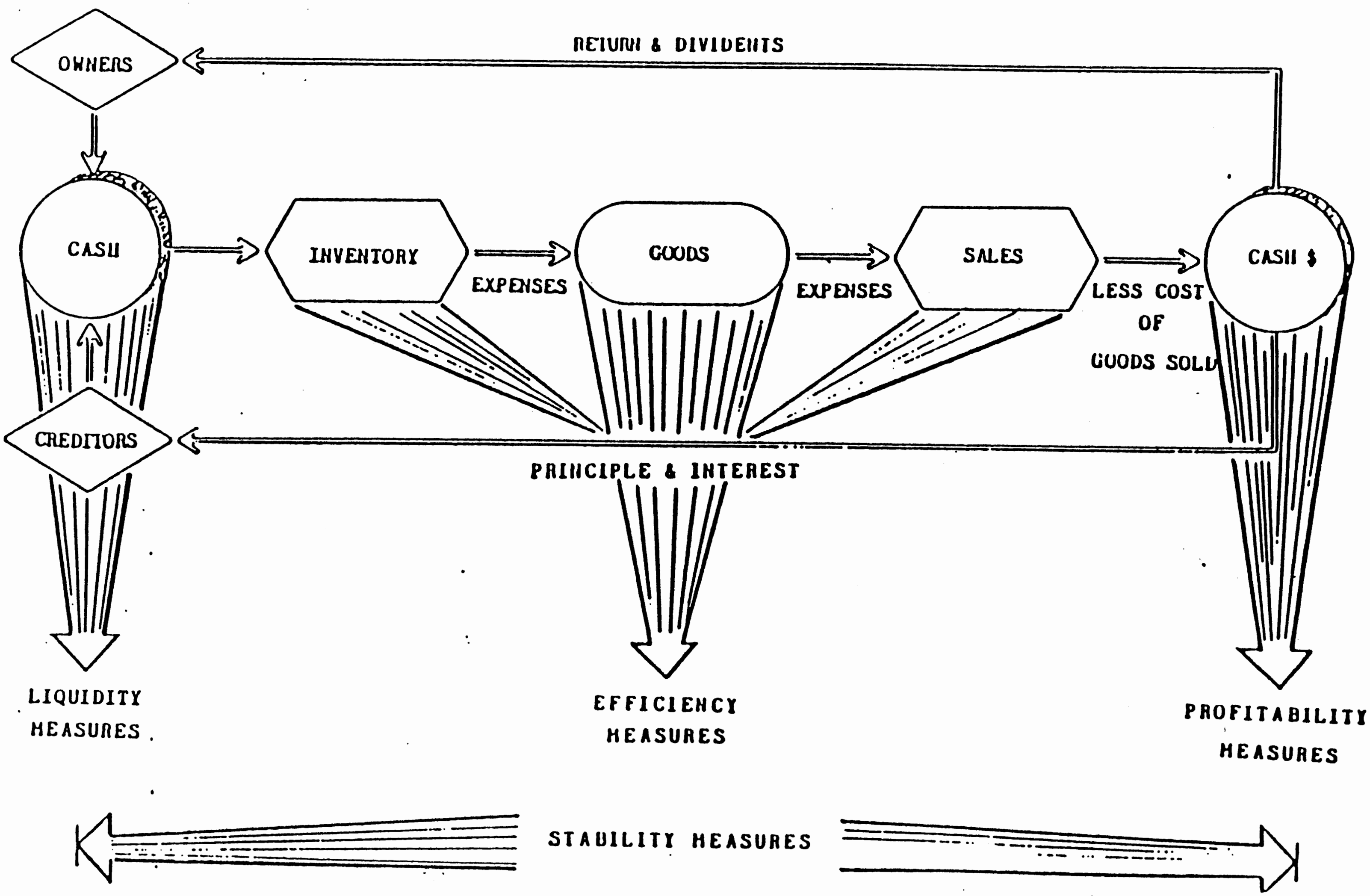

Figure 3.2 - Compatibility of Financial Ratios and Operation Cycle for a Manufacturing Company

The ratios of the profitability measures are directed towards determining the proportion of the extra cash generated by the business operations compared to that existed at the start of the process. The ratios included in stability measures are oriented towards expressing the leverage status by determining the relationship between what is owed and what is owned by the business firm. They assure senior creditors (long-term investors) of the business' ability to pay back its investments in case of bankruptcy or a decision to get out of the market.

Project's Operating Mode

To facilitate the comparison between the operating condition of a manufacturing company and a construction project, the schematic diagram shown in Figure 3.3 was developed for a construction project similar to that shown in Figure 3.1 for a manufacturing company. In its simplest form, a construction project can involve two major parties, an owner and a contractor. In this case, only the owner contributes cash to the project while all expertise is contributed by the contractor. For reasons of simplification the interim finance, which is a contractor's responsibility, is omitted since it does not permanently remain in the project.

Using the contractor's expertise all materials, labor, and construction operations, including construction equipment and overhead, are bought with the cash available for the project. Two end products come out of the construction operating cycle. These are the physical plant that goes to the owner only, and the balance of the cash, left after

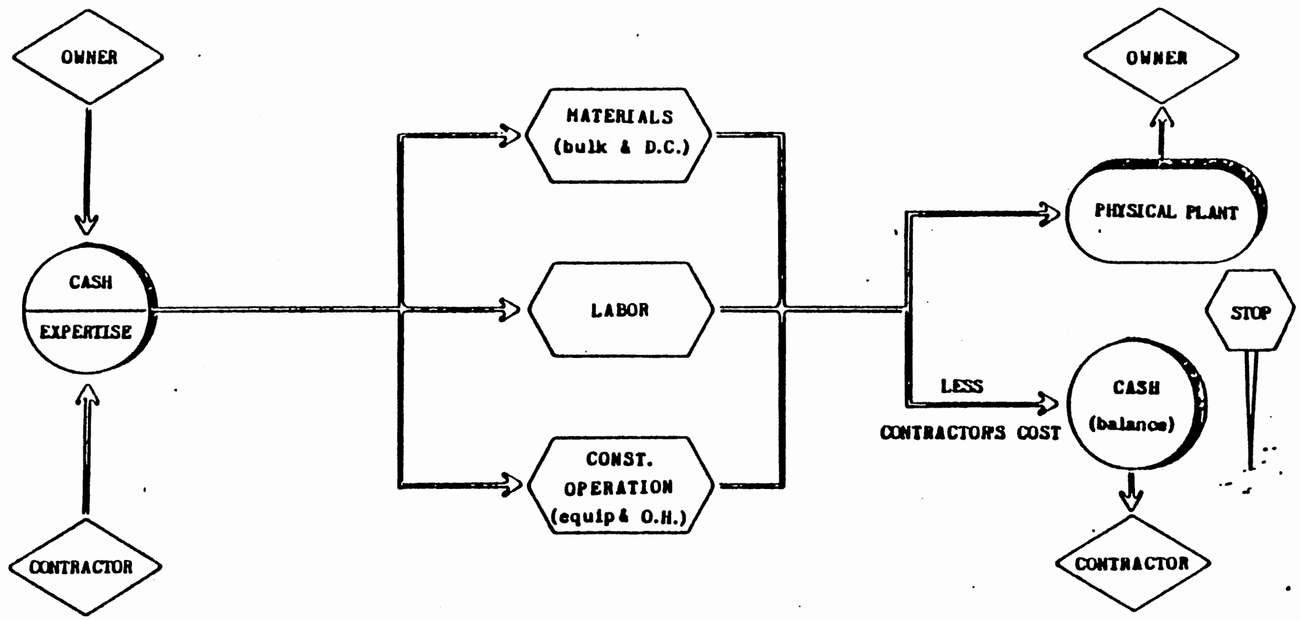

Figure 3.3 - Schematic Presentation of Operation Mode for a Construction Project

the expenditures incurred during construction, that goes to the contractor only in the form of profit. The process then comes to a stop for these two parties on this project.

Comparisons and Differances

Some differences are obvious from the analysis of the activities and the operating conditions of a manufacturing company in contrast with a construction project. These are shown in Figure 3.4 and can be summarized as follows:

1. Differences in the starting contribution and end results - In the case of a manufacturing company the activities cycle starts and ends with the same thing, cash. On the other hand, the activities cycle for a construction project starts with two different contributions and ends with two distinct end products. The two contributions are cash obtained from the owner only, and expertise provided by the contractor only. The end products are a physical plant (the tangible project) that goes to the owner only; and a profit (balance of cash) that goes to the contractor only.

2. Conflict of interest - There is an apparent conflict of interest between the two parties involved in a construction project, which does not appear to be the case in a manufacturing company's situation. This could be due to the fact that the share which one party gains at the end of the cycle may inversely affect the share of the other party.

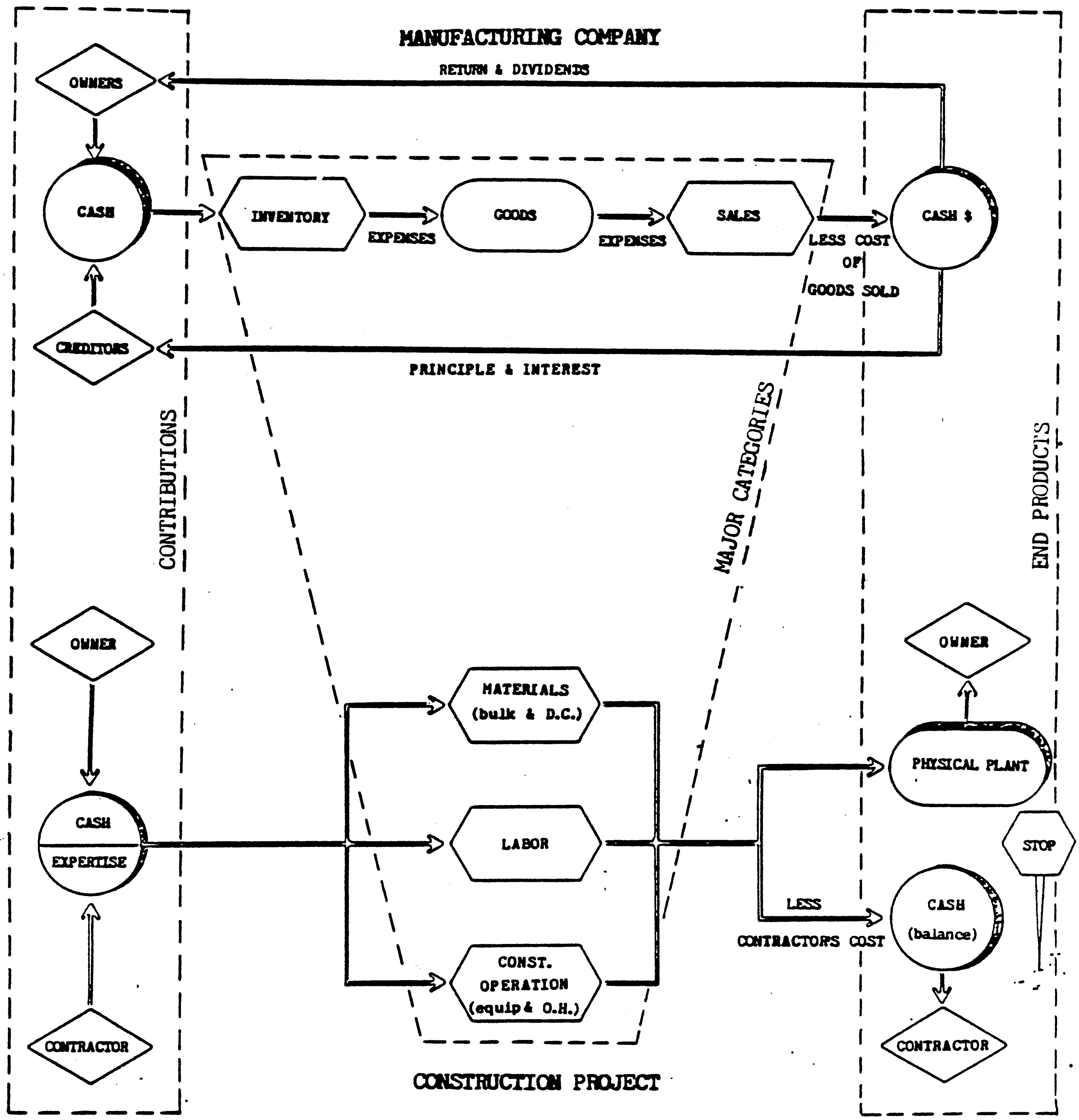

Figure 3.4 - Schematic Comparison of Operation Modes

3. Continuous versus one-time process - The activities cycle for a manufacturing company proceeds in a continuous mode. The activities cycle for a construction project proceeds in a definite start-stop mode, which is a one-time procedure that is never repeated exactly due to the uniqueness of each project, the uniqueness of its contract, and the uniqueness of its conditions (physical and otherwise).

4. Nature of pertinent financial items - Significant differences exist between the two operating cycles due to the different nature of the detailed elements of each cycle. Financial items pertinent to manufacturing companies that are used to develop the financial ratios do not exist on construction projects. For example, sales and the degree of leverage that are crucial for a manufacturing operating cycle do not exist and have no similarities on construction projects. All the key ratios using these two items would have no meaning in the case of a construction project. Also, there are no goods manufactured and sold on a construction project. Therefore, all the financial relationships involving cost of goods and goods sold would not exist on a construction project.

5. Generated income - The objective of the construction operating cycle is not to generate income during the building phase in the business sense. Therefore, all the ratios using income would have no meaning on a construction project.

6. <u>Assets to cash relationship</u> - In the manufacturing operation lenders' and investors' money is held in two distinct categories, liquid cash and assets. Known ratios have been established and must be kept between these two items to indicate healthy operation and acceptable risk. This is not applicable in a construction project. Even if cash is simulated in the project budget and assets are simulated by the physical plant, no constant ratio exists between the two items in a construction project since the value of such a ratio depends on the type of project, sequence of activities, and more importantly, it will diminish with time when the project is complete.

7. <u>Effect of depreciation</u> - On a construction project there is no depreciation considered during the building phase, while depreciation is a major expense item for a manufacturing company.

8. <u>Investors interest and relationships</u> - A similar relationship between senior and junior creditors does not exist on a construction project since money is not committed, on long-term basis, as in a manufacturing company's operating cycle. All ratios addressing this relationship do not exist on a construction project.

Development of Criteria for Construction Ratios

The preceding analysis of the operating modes of a manufacturing company versus a construction project and the discussion of the differences between the two may help explain why existing financial ratios are suitable only for appraising manufacturing firms while other ratios need to be developed for construction projects.

The fact that the two parties involved in a manufacturing company are contributing and receiving cash with no conflicting interest in the share each party is getting makes financial ratios in the form of "cash/cash" an excellent measure of the relationship between any two items affecting the success of the overall operating cycle. However, the fact that the two parties involved in a construction project are making different contritions and receiving different end products with an apparent conflicting interest in the share each party is getting, suggests that other ratios need to be developed. These ratios need to be expressed in terms of the different contributions and distinct end products in order to protect each party's interest and to measure the relationship between any two items which may affect their shares at the end of the operating cycle.

The fact that the operating cycle in a manufacturing company is continuous makes financial ratios using the monetary value of general category items, e.g., assets, sales, cost of goods, liabilities, etc., an excellent tool for analyzing the presumably constant relationship between any two of these general items at any time. In the manufacturing cycle there is no maximum monetary value for each operating cycle or its various stages; there is no definite start or end for each of the operation's stages that could be used in measuring the operation's performance. Unlike with manufacturing companies, in a construction project the stages of the operating cycle have a maximum monetary value (definitive budget), and a definite start and end. This suggests that ratios should be developed for more specific items at a lower level of detail and should also be directly related to the cost of such items.

Cost items typically found in well designed cost control budgets represent the proper level of detail at which control ratios should be developed. At this level an item is large enough to satisfy the criteria for typical cost items. However, it should also be small enough to avoid other problems imposed by subtle changes in the nature of the work and the resulting cost differences during the execution of one item. For example, the work involved and the cost of one cubic yard of concrete placed in the foundation of a high rise building is not equal to that of the same amount of concrete placed in the top floor of the same building. This is due to the introduction of more complexity in the nature of the work involved. Similarly, the work involved and the cost of laying one linear foot of 2 inch diameter pipeline compared to that of a 60 inch diameter pipeline laid on the same project differs considerably. This is also true even in a comparison between two pipelines of the same diameter but of different wall thickness or metallurgy. A good example of a cost item at the appropriate level of detail, therefore, shall be neither "All Concrete Work in Building A", nor "Concrete for Footing #B-15". Rather it will be "Concrete Work in Foundations", "Concrete Work for Floor 1-5", "Deep Excavation", "Large Size Piping -over 48 inch", etc..

A cost item of this size is expected to have a reasonably long enough duration to allow for recording enough data during the execution time of the item. This gives management a chance to record and control the performance of the item before all of its costs become history. This may also permit management to apply some of the available techniques on the recorded data to establish trends of major items and forecast their costs. In addition, applying control ratios at this level of detail limits the fluctuation of the project's overall forecasts due to the fluctuations of only a few cost items, which improves the credibility and reliability of this new analysis technique.

Ratios should be developed with the intention of measuring specific aspects that are significant to the overall project performance. They should also be directed towards the use of data normally collected on construction projects to avoid creating extra work and imposing unnecessary constraints during the collection of data. More importantly, ratios should be selected to satisfy the project manager's needs and should not be reported in an information overload mode, which is one of the current problems in the construction industry.

Key control ratios should be developed in order to identify areas with potential problems. Once a problem area is identified, other control ratios may be applied to determine the immediate causes of the problem. After examining the appropriate ratios and performing the necessary analyses, forecasts of the monetary magnitude of the different causes should be calculated. Based on their magnitude, a sound decision can be made regarding which of the causes of an identified problem deserve more management attention and what corrective action is required.

Development of Control Ratios for Construction Projects

In addition to the above criteria, the following questions were posed to aid the development process for establishing the necessary control ratios:

1. What types of data are typically available on a construction project ?
2. What meaningful control ratios can be developed from such project data ?
3. What is the significance of such ratios with regard to the needs of a project manager to control a project ?
4. What are the basic key identifiers of a potential problem area on a construction project ?

It is well known that quantities (Q), man-hours (Mhr), and the overall cost ($) of work items are the three basic data elements typically available on construction projects regardless of the degree of sophistication of the contractor or the control system involved. Manipulating the absolute amounts of these three data control elements can produce meaningful key ratios, namely, the overall unit cost ($/Q) ratio; the unit man-hour (Mhr/Q) ratio; and the average labor cost ($/Mhr) ratio. Each of these ratios is a measure of a certain significant performance aspect on a construction project.

The overall unit cost ratio is a measure of the overall cost per physical unit of the measurements of the subject item, e.g., $/CY,

$/lb, $/Ton, $/SF, etc.. It is a crucial measurement for assuring the delivery of the project within its budget. From the project manager's point of view, if the actual performance of the work on any one item is progressing at or below the budgeted overall cost per physical unit, no management action is needed on that item. Only when an item is progressing at a cost ratio above the budgeted value should further investigation be warranted. This ratio, therefore, can be considered the key ratio to separate items that need management attention from those that are progressing as expected. The project manager's reports may, therefore, contain only those items identified by this ratio as showing symptoms of financial problems. The problem of information overloading discussed in Chapter 1 can thus be avoided.

The unit man-hour ratio is a measure of labor productivity per physical unit of the measurements, e.g., Mhr/CY, Mhr/lb, Mhr/Ton, Mhr/SF, etc., of the cost item under investigation. It is an essential measurement for assuring the delivery of the project within its budget and scheduled time, assuming that a proper work sequence and the availability of resources exist. It can also provide support to and an essential test of the reliability of the scheduling information generated by the project's scheduling system. If a trend is established by this ratio indicating activities are being performed below their planned production rates, extra man-hours will certainly be needed to complete the work involved in these items. Additional resources, scheduled work shifts, consumption of existing float, or extension of the total project duration may become necessary depending on the magnitude of the extra man-hours and the planned time frame for their execution. Since the scope of this study does not cover the interface with scheduling systems, no further discussion of this issue will be pursued, which is a recommended area for future research.

The average labor cost ratio is a measure of the average cost per man-hour of the labor mix. It is a significant ratio that brings into consideration the most expensive single cost category on a construction project, that is, the labor cost. Although the labor cost is the most expensive single item on a construction project, it is considered the item most controllable by management compared to the other major cost categories. If the overall labor cost is proven to be a potential problem area on any major work item, further investigation utilizing other control ratios can be helpful in discovering the cause of such a potential overrun. Causes for an overrun of the labor cost could be a result of one of two reasons or a combination of both. It could be the result of using a more expensive crew mix than allowed in the budget, using higher crafts' rates than budgeted, or a combination of both.

Performance Indices and Project Forecasts

The control ratios discussed above can be calculated from the control budget as well as from the actual data collected during the execution of the various cost items. The relationships between the budget ratios and the actual ratios can serve as performance indices. These performance indices can be expressed in terms of the overall total cost, labor productivity, average labor cost, and materials procurement cost depending on the data used in generating these indices.

The relationship between the actual and budget ratios for an item can be calculated and expressed in the form of a ratio by dividing the value of one ratio by the other. If the quotient of dividing the budgeted value by the actual value of a control ratio is equal to or greater than unity, the performance is rated favorably. If the product of this expression is less than unity, the performance is rated unfavorrably. Since some fluctuation of the values of the control ratios is expected, use of the cumulative average, i.e., the average of all current and previous collected data on the item under consideration, is encouraged especially for items having a high degree of irregularity. This is a simple and adequate way of reducing the effect of such fluctuation on the measured performances observed in the successive reporting periods.

Measuring the progress and actual performance of a cost item is not an end in itself. It is a means of achieving a more difficult and challenging objective, which is forecasting the future success of a task during the early phases of its life cycle. Forecasting is merely an educated guess based on information drawn from present data as to what will happen at some future time. All forecasts are based on an assumption of the validity of the projection of past data and experience into an uncertain future. Although the process is never claimed to be highly accurate, forecasting is still necessary because organizations are faced with the need to make decisions in an atmosphere of uncertainty.

Forecasting procedures can be classified as either quantitative or qualitative. A purely qualitative technique requires nothing but the judgement of the forecaster. A purely quantitative technique needs no input of judgment but is based on mechanical procedures that produce quantitative results. Although this study emphasizes quantitative forecasting techniques, it realizes the significance of judgment and common sense which must also be used to ensure intelligent forecasting.

Two types of forecasting methods are recommended for this ratios analysis technique, trend forecasts and time series analysis. These two methods can be applied to forecast future values of the control ratios or final cost of an item indicating potential financial problems. Straight line and curve fitting plots, such as shown in Figures 3.5 and 3.6, provided for actual project data help establish the actual distribution of the value of any of the control ratios over time. Also, straight line regression forecasts utilizing calculated performance indices will be used to generate the overall total cost forecast for items showing symptoms of potential cost overrun. Early assessment of future behavior permits management to take corrective action when it is most effective.

Applying such forecasting methods is most beneficial for major items with relatively significant budgets and long durations to allow for enough data points to be collected on any one item. This is necessary for generating more reliable forecasts. Some selected major cost items may require more detailed analysis involving the quantities placed and the performance measured at each reporting period. This is required to determine whether the budget is sufficient for the completion of these items and whether significant variances are expected at some future time. More details on the forecast calculations and an example are provided in Chapters IV and V.

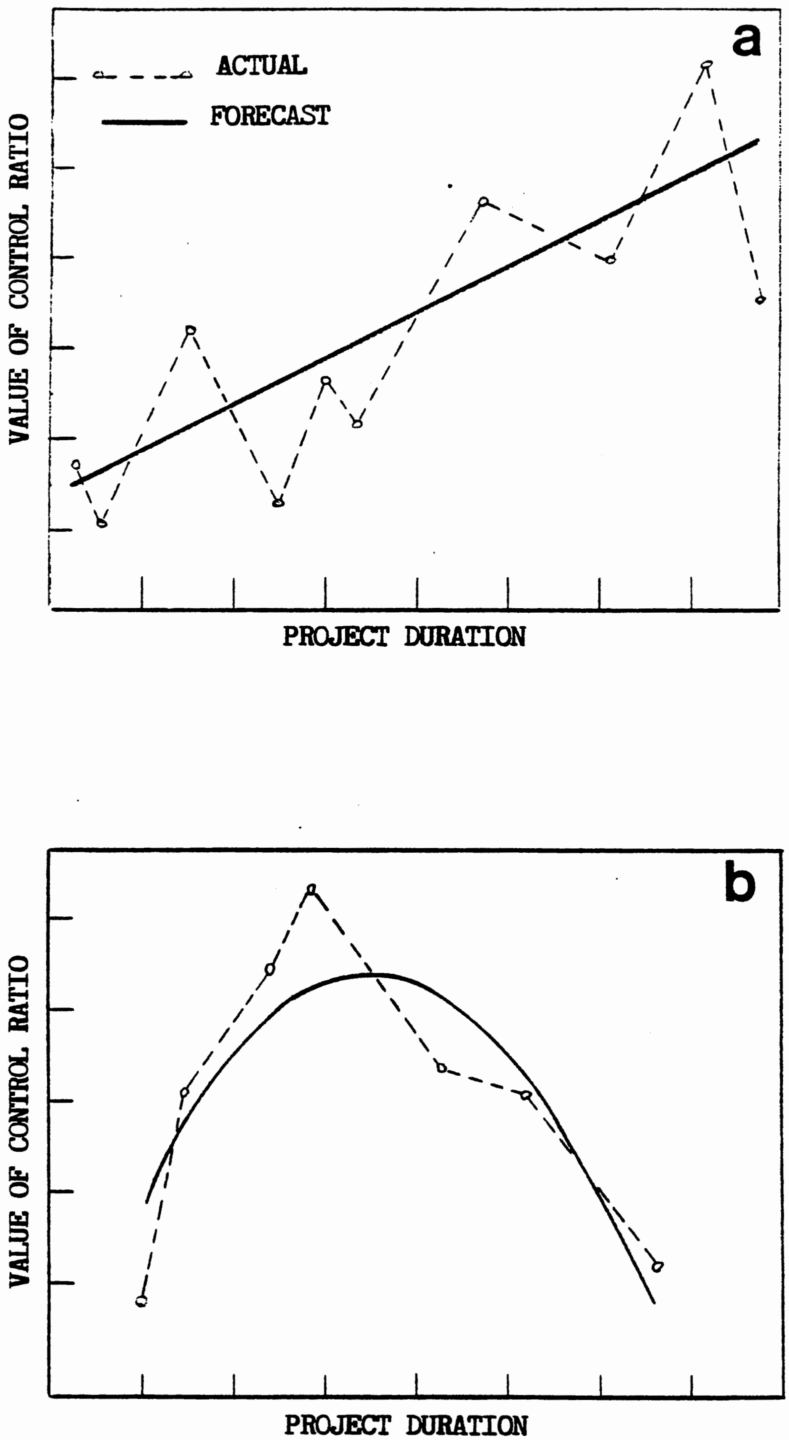

Figure 3.5 - Straight Line (a) and Curve Fitted (b) Trends for Actual Project Data

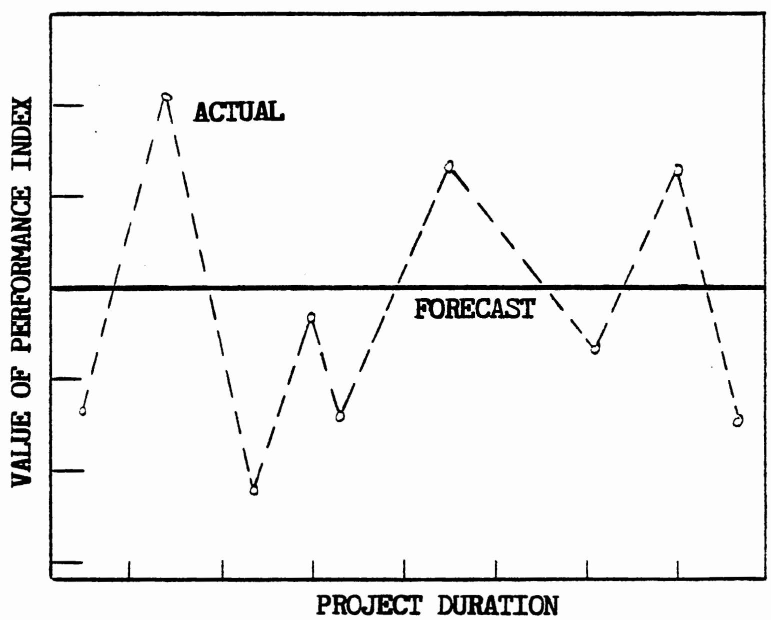

Figure 3.6 - Performance Chart for Monitoring Major Cost Items

CHAPTER IV

A RATIOS ANALYSIS TECHNIQUE FOR CONSTRUCTION PROJECTS

General

The concepts of the financial ratios analysis technique and the control ratios discussed in the previous chapters have been utilized to design a tracking technique that is suitable for construction projects. The purpose of this technique is to provide financial performance evaluation measures and a problem detection procedure for construction projects.

Performance Evaluation Measures

The application of financial ratios to the various stages of the operating cycle of a manufacturing company to appraise the business performance was used as the basis for employing similar performance measures for a construction project. As shown in Figure 4.1, four measures are employed to evaluate the performance of a construction project throughout its entire life cycle. These are called adequacy measures, conformance measures, completion measures, and detection measures. These four measures are analogous to those used in the

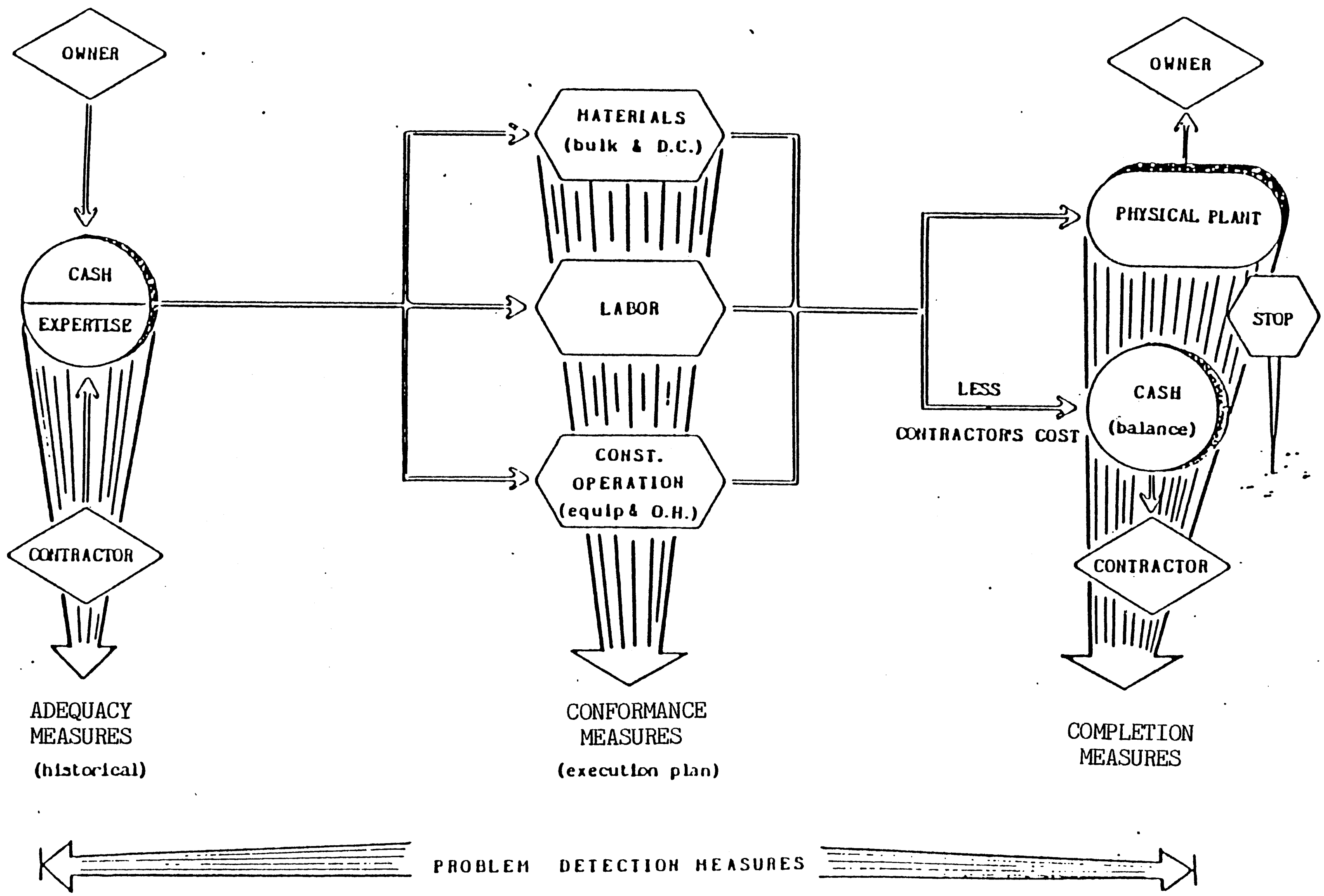

Figure 4.1 - Performance Evaluation Ratios for Construction Projects

business ratios analysis. Therefore, in discussing these performance measures, reference is made to Figure 3.2, presented in Chapter III, to facilitate the comparison between the existing and the proposed method.

Adequacy Measures - Instead of the liquidity measures used in the financial ratios technique in a manufacturing company, adequacy measures are used in construction projects. They are used to determine whether sufficient cash has been budgeted for each cost item. This will be assessed by a comparison of the values of the control ratios to historical records compiled from similar projects after proper adjustments for time, size, and location. At the start of the construction phase, this exercise can expose items with major deviations from normally expected values. Deviations can be a result of a poor estimate, estimate irregularities, or the uniqueness of some of the project elements. Deviations may also indicate a need for redistribution of the total budget among the cost items to provide a distribution that is more suitable for the project tracking rather than that serving bidding strategies.

Conformance Measures - With this method, the conformance measures replace the efficiency measures for manufacturing companies. They involve comparisons of budgeted values and actual values of the control ratios to ensure conformance of the actual conditions to the execution plan for each item.

The ratio of the budgeted to the actual value of a control ratio is a measure of the item's performance. Performance in this manner is quantitatively measured in terms of overall total cost $[(\$/Q)_b / (\$/Q)_a]$, labor productivity $[(Mhr/Q)_b / (Mhr/Q)_a]$, and labor cost

$[(\$/Mhr)_b/(\$/Mhr)_a]$, where:

$(\$/Q)_b$ and $(\$/Q)_a$ are the budget and actual cost per work unit; $(Mhr/Q)_b$ and $(Mhr/Q)_a$ are the budget and actual man-hour per work unit; $(\$/Mhr)_b$ and $(\$/Mhr)_a$ are the budget and actual average labor cost per man-hour.

Completion Measures - Unlike conventional business ventures, the objective of the activities cycle in a construction project is not to generate more cash than was available at the beginning of the cycle. Instead, it is to ensure the successful delivery of the physical plant within the project's budget, leaving a reasonable profit for the contractor. In the developed technique completion measures replace the business profitability measures. The completion measures include development of actual project performance indices. Forecasts at completion are generated based upon actual performance indices. Cost variances at completion can then be calculated using these forecasts.

Detection Measures - The fourth group of performance indicators are the detection measures. These are applied throughout the life of a construction project in place of the stability measures used for manufacturing companies. In these measures the key control ratios are examined in a preset order (sequence), as shown in Figure 4.2. The mechanism of this analysis is set to be triggered only when an overrun situation is detected. An overrun situation can be identified by the key ratio (\$/Q) when comparing its actual value to its budgeted value. If the actual value is greater than its budgeted value, a cost variance is expected and other control ratios need to be examined in order to identify the immediate cause of such a variance.

A cost overrun on any item can be the result of one of three

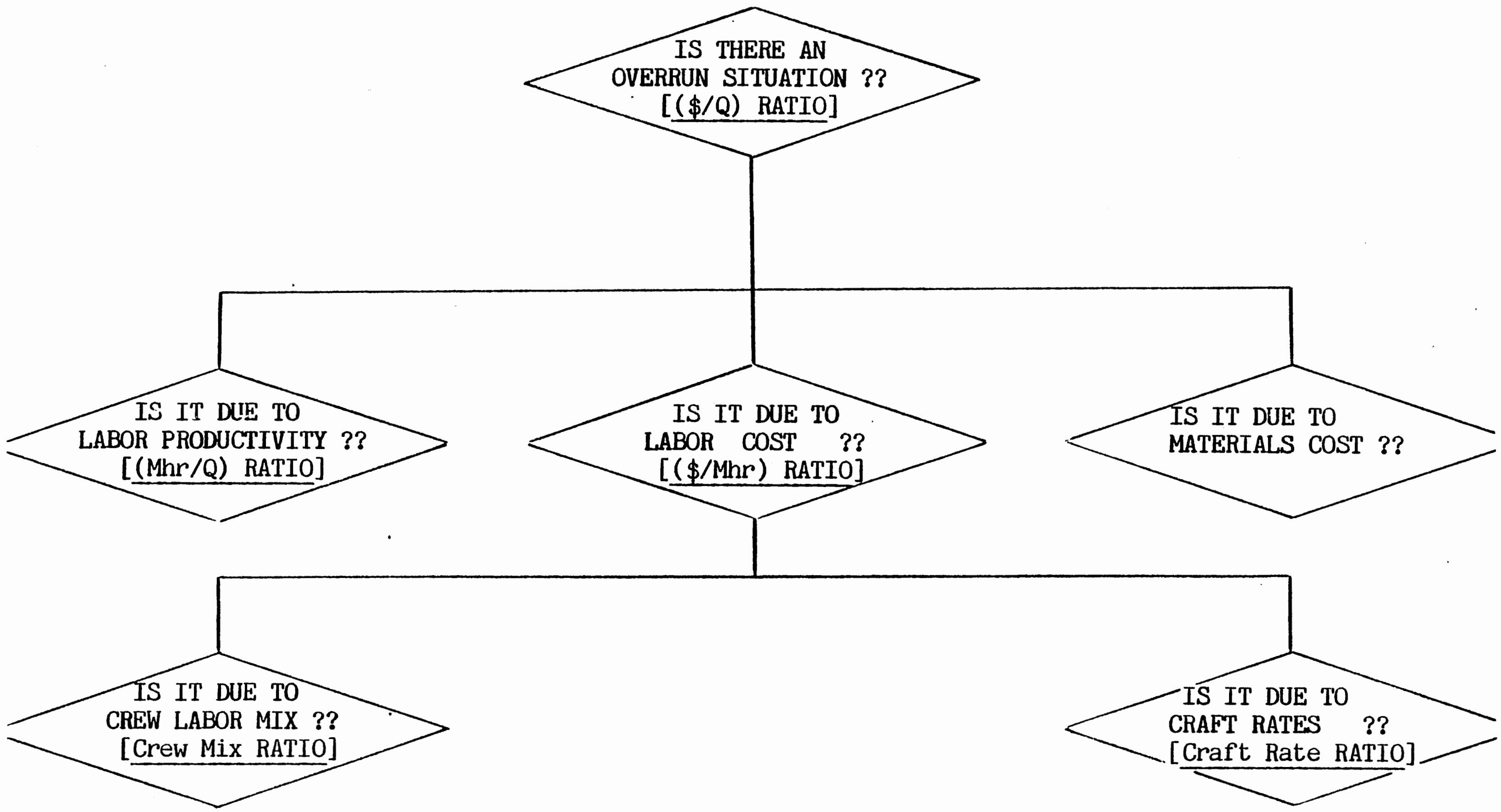

Figure 4.2 - Analysis Process for Detecting Causes of Cost Overrun

causes or a combination of them. These causes are: low productivity when labor utilization is not attained at the planned efficiency; higher labor costs than allowed in the budget; and higher materials costs than anticipated in the budget. Identification of the cause of the overrun can be achieved by examining appropriate control ratios. Productivity problems are tested by the (Mhr/Q) ratio. If the product of dividing the actual value by its budgeted value is numerically greater than one, a productivity problem is detected and the magnitude of the deviation is a measure of the severity of the problem. Similarly, overruns caused by labor costs can be detected using the ($/Mhr) ratio in the same manner. A materials cost problem can also be detected in the same way, or detection may be easier by eliminating the possibility of the other two causes or by determining their magnitudes and subtracting them from the overall total cost overrun.

If the labor cost is identified as a cause for an overrun, the crew mix ratio and the crafts rate ratio need to be examined to determine the type of corrective action required. The crew mix ratio and the crafts rate ratio are expressed as $[\Sigma(N_a * R_b)/\Sigma(N_b * R_b)]$ and $[\Sigma(N_b * R_a)/\Sigma(N_b * R_b)]$, where N_a and N_b are the budgeted and actual number of men in a crew, while R_a and R_b are the budgeted and actual craft's rates.

Problem Detection Procedure

Figure 4.3 presents a schematic flow diagram of the devised procedure for detecting potential problem areas and their possible

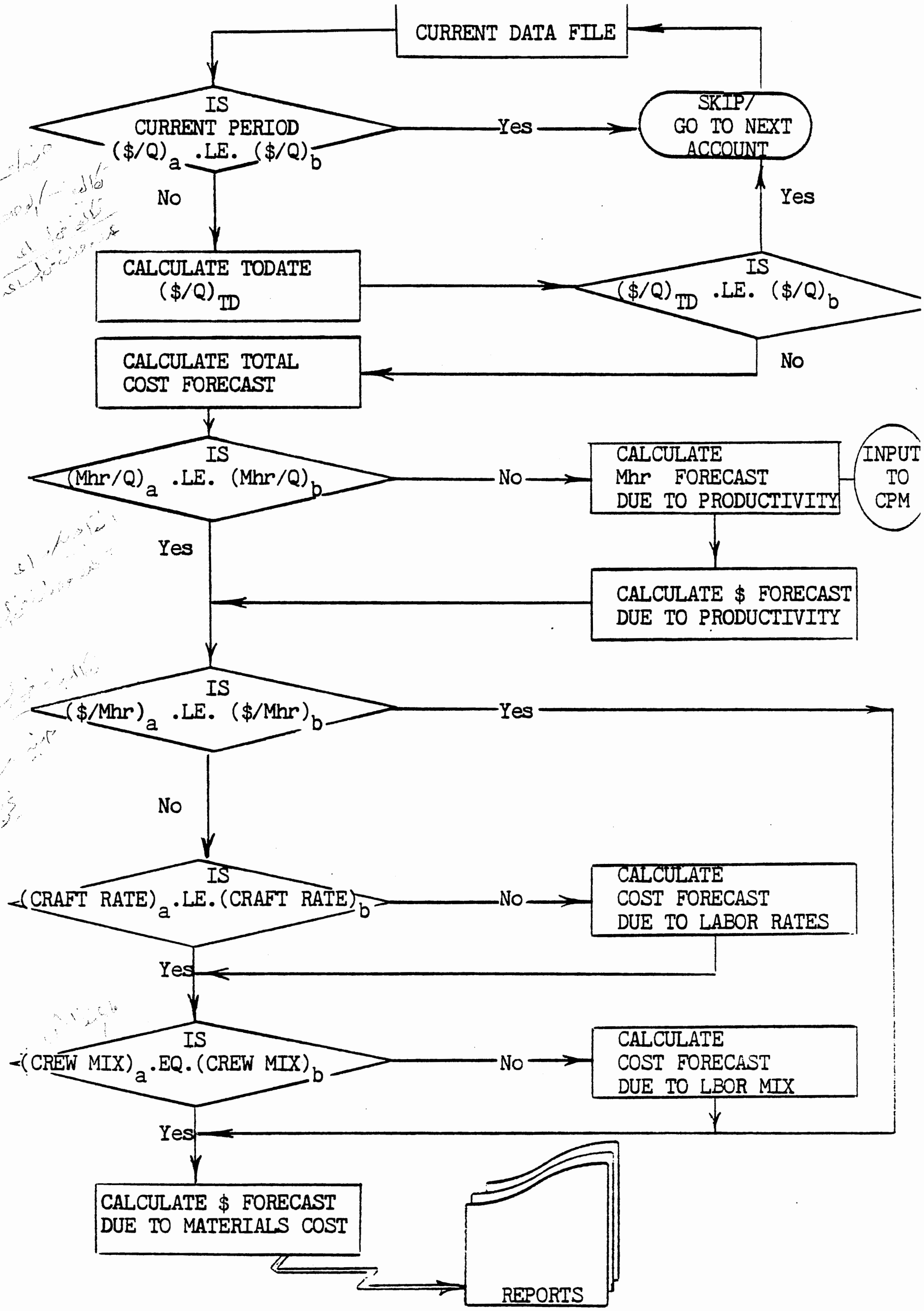

Figure 4.3 - Flow Diagram for the Developed Problem Detecting Technique

immediate causes. The use of typical project data and a minimum of data manipulation were emphasized in the design criteria for this procedure. The steps of the procedure can be summarized as follows:

1. As shown in Figure 4.3, the procedure starts by examining the actual ($/Q) ratio of the current updating period and comparing it to its budgeted value. If the actual value of this ratio is less than or equal to its budgeted value, no further investigation is required on this cost item since it is progressing as or better than expected. If the comparison shows that $(\$/Q)_a$ is greater than $(\$/Q)_b$, calculation of the to date cumulative value of this ratio is required. This is necessary to check whether the overall performance of the item under consideration is satisfactory. Occasional unsatisfactory performance of a cost item may be expected and can be tolerated if its overall performance is still within its budgeted value. If the $(\$/Q)_a$ ratio calculated using cumulative data is also greater than $(\$/Q)_b$ ratio, a cost item with a potential financial problem has been detected. For an item having potential financial problems, unfavorable differences between the budgeted value of the ($/Q) ratio and its actual value will certainly result in a cost variance and a need for additional budget to complete the work involved for that cost item. This is, of course, assuming that actual performance will continue in the future. The method of calculating variances and forecasts in all steps of this procedure is presented in the calculations section of this chapter to facilitate understanding of the sequence

of the steps in this procedure. Once an item with a potential financial problem is detected and its total cost forecast is calculated, the procedure identifies the possible immediate cause of such a problem. This is achieved in the following steps.

2. The second step is to calculate the actual value of the (Mhr/Q) ratio for the current period from the time cards and the quantities data. If the actual value is less than or equal to that budgeted, the detected overrun is not due to low labor productivity. If the actual value is greater than that budgeted, the labor productivity is a contributing factor to the cost overrun. A calculation of the extra man-hours required due to low productivity is carried out in this step. The amount of extra man-hours required is an important input to the scheduling control of the project since these extra man-hours may affect activities' durations, resource leveling, or both. The cost of these extra man-hours will be calculated to determine the magnitude of the monetary impact of low productivity on the overall cost variance.

3. Examining labor costs as the second possible cause of an overall cost overrun is performed in this step. This is done by calculating the average labor cost ratio $[\Sigma N_a * R_a / \Sigma N_b * R_b]$. This ratio expresses the relationship between the actual and budgeted average labor cost for a cost item. If this ratio is numerically greater than one, labor cost is a cause for the detected potential overrun of the troubled cost item. The expected forecast of the labor cost overrun can then be calculated

using this ratio, as will be illustrated in the calculations section and in Chapter V.

4. Since both crew mix and craft rate can feasibly be responsible for a labor cost overrun, two checks are necessary to identify the correct course for management action. These checks are made by examining the crew mix ratio and the crafts rate ratio, $[\Sigma(N_a*R_b)/\Sigma(N_b*R_b)]$ and $[\Sigma(N_b*R_a)/\Sigma(N_b*R_b)]$, where N_a and N_b are the budgeted and actual number of men in a crew, while R_a and R_b are the budgeted and actual craft's rates. If the value of the mix ratio is greater than one, the crew mix is a cause of the detected labor cost overrun. Similarly if the value of the crafts rate ratio is greater than one, the hiring rate of the crafts is a cause for the detected labor costs overrun. If both causes are identified as contributing to the overrun, the share contributed by each equals the quotient of dividing the part of the ratio in excess of one by the summation of the ratios in excess of one. For example, if a crew mix ratio equals 1.3 and a crafts rate ratio equals 1.1, both the crew mix and the hiring rates of the crafts are causes for a labor cost overrun. In this example 75 percent, which is (1.3 - 1.0) / ((1.3 - 1.0) + (1.1 - 1.0)), of such cost overrun is attributed to the crew mix. Similarly 25 percent of the cost overrun is attributed to the hiring rates of the crafts forming the crew.

5. After identifying which of the above causes are contributing to the forecasted overall cost overrun calculated in step 1, and after calculating their monetary magnitudes, determining if the

materials costs is also a contributory cause becomes more feasible. This will be equal to the difference between the total forecasted overrun and the summation of the monetary magnitudes of the other contributing causes.

Organization of Project Cost Data

In using the ratios analysis technique, data is organized in five categories. These are budget data, transaction data, modification data, budgeted labor data, and labor history data, as shown in Figure 4.4. Whether the application of this technique is implemented manually, by using a simple electronic spread sheet, or by using more sophisticated computer software, these categories can be looked at as five different data files. Since organization of data is necessary for successful implementation a description of each file is given below.

1. Budget File - As shown in Figure 4.5A, data in this file is organized by cost account numbers in two sections. The original control budget's data is entered in the budget section and the to date actual cumulative data is entered in the actuals section. This file provides a snap shot of the current control budget and the current actual data in terms of total cost, man-hours, and quantities per cost account.
2. Transaction File - As shown in Figure 4.5B, this file contains data collected at each update period for each cost account number. The collected data include craft type, number of men per

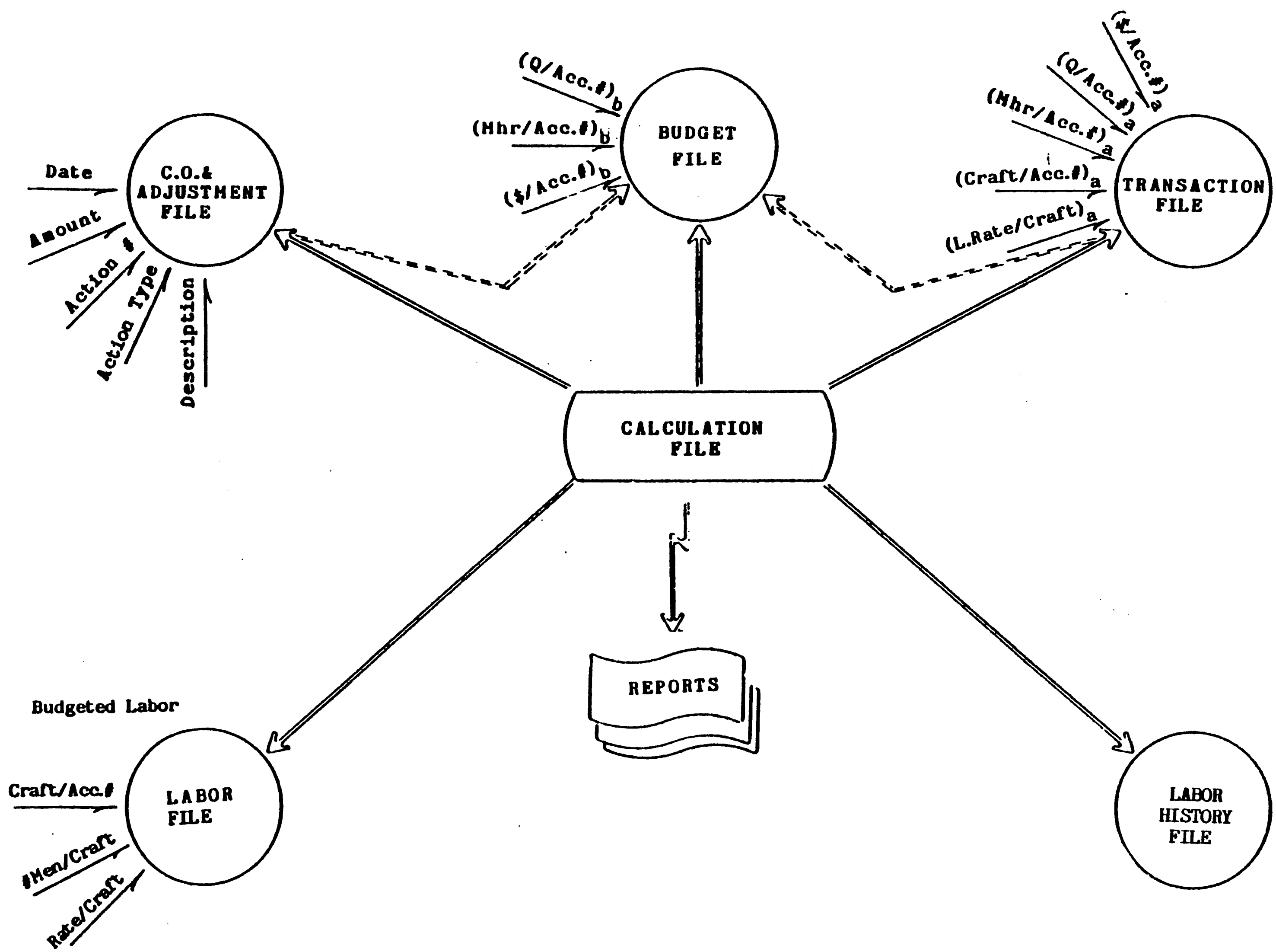

Figure 4.4 - Organization of Project Cost Data

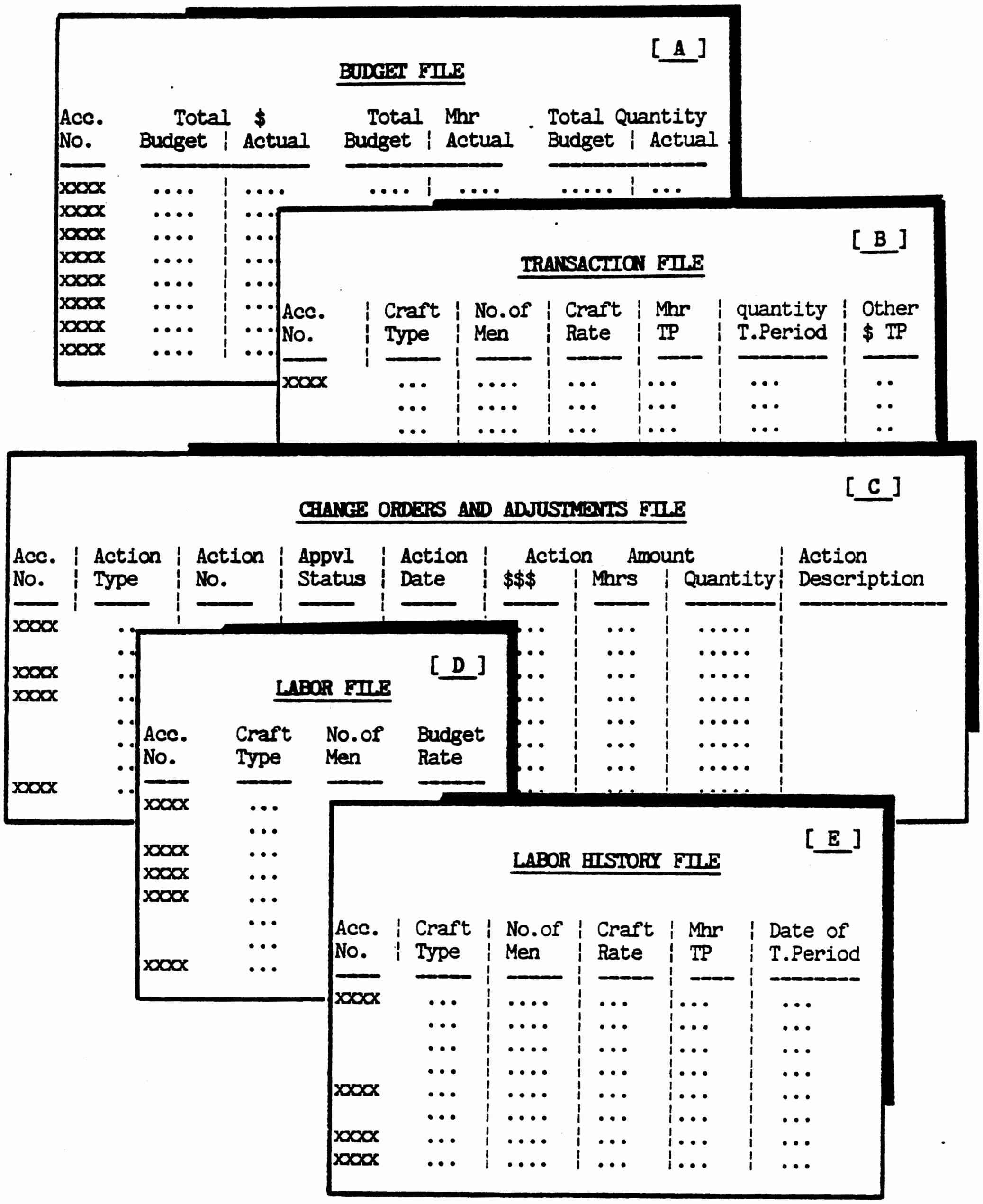

Figure 4.5 - Sample of Cost Files

craft, actual craft rate, man-hours worked this period, quantities placed this period, and any other charges incurred during the current period. Data in this file is used to update the actual cumulative figures in the budget file as well as calculating the control ratios pertinent to the current update period.

3. Modification File - This file provides a complete record of all approved and unapproved budget modifications in terms of total cost, man-hours, and quantities which may be incurred during the project duration. As shown in Figure 4.5C, a modification can fall into one of two action types. It can be either a change order approved by the owner, or an adjustment requested by the contractor. Although only change orders are used to update the budget file, adjustments are also recorded for several reasons. An accurate and detailed record of adjustments provides a useful list of modifications awaiting approval. It can also support factual justifications for any deviation from the execution plan, and furnishes a valuable project history that can benefit the contractor in future projects and in possible contract disputes.

4. Labor File - This file contains the budgeted craft types, numbers, and rates for each crew per cost account number, as shown in Figure 4.5D. It is used in the procedure to generate labor mix and craft rate ratios.

5. Labor History File - This file contains the labor history on each cost item in terms of craft type, number of men used, and pay rate of each craft for each update period as shown in Figure 4.5E. Data included in the Labor History File is typically available

in payroll reports. It is suggested, therefore, that this file should be prepared in collaboration with the payroll department to avoid double handling of the data.

Calculation of Required Information

The calculations included in this procedure generate three types of information that are useful for project managers. These are objective forecasts and variances, monetary magnitude contributed by each immediate cause of detected overruns, and performance indices.

As shown in the Figure 4.6, two forecasts are generated in terms of overall total cost and man-hours for each cost item. These two forecasts are the optimistic and pessimistic forecasts. A cost forecast can be calculated by either of the following equations:

$$(F1) : C_I = (Q)_b * (\$/Q)_a \qquad \text{EQ. 4.1}$$

$$(F1) : C_{II} = (Q)_a * (\$/Q)_a + (Q_b - Q_a) * (\$/Q)_{TP} \qquad \text{EQ. 4.2}$$

where:

C_I and C_{II} are the two different values of the total cost forecasts determined from Equations 4.1 and 4.2; $(Q)_a$ is the cumulative actual placed quantities from the budget file; $(Q)_b$ is the budgeted quantities from the budget file; $(\$/Q)_a$ is the actual cumulative average cost per unit from the budget file; and $(\$/Q)_{TP}$ is the actual cost per unit for current periods from the transaction file. The optimistic cost forecast is the smaller of the two values calculated by the above equations, while the pessimistic forecast is the larger of the two values.

INFORMATION ANALYSIS REPORT

	OPTIMISTIC Total Forecast		PESSIMISTIC Total Forecast		VARIANCE Expected		COST ANALYSIS Variance DueTo		LABOR DETAIL Variance Due To			PERFORMANCE INDICES Measured in Terms of		
Acc. No.	$$$	Mhr	$$$	Mhr	$$$	MHR	Labor	Mat'l	Prod	Rate	Mix	Cost	Prod	Labor
xxxx	(F1)	(F2)	(F1)	(F2)	(F3)	(F4)	(F5)	(F6)	(F7)	(F8)	(F9)	(F10)	(F11)	(F12)
xxxx	...	....	...	...	..	..	...	...	....	..	..	..	..	..
xxxx	...	....	...	...	..	..	...	...	....	..	..	..	..	..
xxxx	...	....	...	...	..	..	...	...	....	..	..	..	..	..
xxxx	...	....	...	...	..	..	...	...	....	..	..	..	..	..
xxxx	...	....	...	...	..	..	...	...	....	..	..	..	..	..
xxxx	...	....	...	...	..	..	...	...	....	..	..	..	..	..
xxxx	...	....	...	...	..	..	...	...	....	..	..	..	..	..
xxxx	...	....	...	...	..	..	...	...	....	..	..	..	..	..

Figure 4.6 - Project Manager's Information Analysis Report

Similarly, a man-hour forecast can be calculated by either of the following equations:

(F2) : $MHR_I = (Q)_b * (Mhr/Q)_a$ EQ. 4.3

(F2) : $MHR_{II} = (Q)_a * (Mhr/Q)_a + (Q_b - Q_a) * (Mhr/Q)_{TP}$ EQ. 4.4

where:

MHR_I and MHR_{II} designate the two different values of the man-hour forecasts determined from Equations 4.3 and 4.4; $(Mhr/Q)_a$ is the actual cumulative average man-hour per unit from the budget file; $(Mhr/Q)_{TP}$ is the current period's actual man-hours per unit from the transaction file; and all other terms are as defined previously. The optimistic man-hour forecast is the smaller of the two values calculated by these two equations while the pessimistic forecast is the larger of the two values.

The reason for generating optimistic and pessimistic forecasts is to avoid furnishing one "hard" figure that is rarely accurate. The reliance on a single number for a variable that is contiually changing tends to reduce the confidence level of top management that receives the information throughout the project's duration. Offering maximum and minimum forecasts provides management with a range of the forecast of the final project cost and man-hours based on actual current performance.

Both cost and man-hour variances are calculated using the mean value of the optimistic and pessimistic forecasts as given by Equations 4.5 and 4.6.

(F3) : $V_I = (\$)_b - (C_I + C_{II}) / 2$ EQ. 4.5

(F4) : $V_{II} = (MHR)_b - (MHR_I + MHR_{II}) / 2$ EQ. 4.6

where:

$(\$)_b$ and $(MHR)_b$ are the overall total budget cost and man-hour of the subject item from the budget file; V_I is the cost variance; V_{II} is the man-hour variance; and other terms are as defined above.

The second type of information involves determining the monetary magnitude of each possible cause for the detected cost variances. This information includes variances due to average labor costs and cost of materials.

A variance due to labor costs can be calculated in six different ways as given in Equations 4.7 through 4.13. The arithmetic mean of these values is considered an appropriate approximation for the expected variance.

$$L_I = [(MHR)_b * (\$/Mhr)_b] - [(MHR)_b * (\$/Mhr)_a] \qquad \text{EQ. 4.7}$$

$$L_{II} = [(MHR)_b * (\$/Mhr)_b] - [(MHR)_a * (\$/Mhr)_a] - [((MHR)_b - (MHR)_a) * (\$/Mhr)_{TP}] \qquad \text{EQ. 4.8}$$

$$L_{III} = [(MHR)_b * (\$/Mhr)_b] - [MHR_I * (\$/Mhr)_a] \qquad \text{EQ. 4.9}$$

$$L_{IV} = [(MHR)_b * (\$/Mhr)_b] - [(MHR)_a * (\$/Mhr)_a] - [(MHR_I - (MHR)_a) * (\$/Mhr)_{TP}] \qquad \text{EQ. 4.10}$$

$$L_V = [(MHR)_b * (\$/Mhr)_b] - [MHR_{II} * (\$/Mhr)_a] \qquad \text{EQ. 4.11}$$

$$L_{VI} = [(MHR)_b * (\$/Mhr)_b] - [(MHR)_a * (\$/Mhr)_a] - [(MHR_{II} - (MHR)_a) * (\$/Mhr)_{TP}] \qquad \text{EQ. 4.12}$$

$$(F5) : L = (L_I + L_{II} + L_{III} + L_{IV} + L_V + L_{VI}) / 6 \qquad \text{EQ. 4.13}$$

where:

L is the expected cost variance due to labor costs; L_I through L_{VI} are the cost variances due to the labor costs determined from Equations 4.7 through 4.13; and other terms are as defined previously.

A variance due to materials costs can be determined from Equation

4.14.

$$(F6) : M = V_I - L \qquad \text{EQ. 4.14}$$

where:

L is the cost variance due to labor costs determined from Equation 4.13; M is the cost variance due to materials costs; V_I is the overall cost variance determined from Equation 4.5.

A variance due to labor costs can be broken down further into its three main components, labor productivity and crafts' rate and mix. A variance due to low productivity can be calculated in three different ways as given in Equations 4.15 through 4.17. The arithmetic mean of these values is used as an approximation for the expected variance.

$$P_I = [(MHR)_b - MHR_I] * (\$/Mhr)_a \qquad \text{EQ. 4.15}$$

$$P_{II} = [(MHR)_b - (MHR)_{II}] * (\$/Mhr)_a \qquad \text{EQ. 4.16}$$

$$P_{III} = [(MHR)_b * (\$/Mhr)_b] - [(MHR)_a * (\$/Mhr)_a] - (Q_b - Q_a) * (Mhr/Q)_{TP} * (\$/Mhr)_{TP} \qquad \text{EQ. 4.17}$$

$$(F7) : P = (P_I + P_{II} + P_{III}) / 3 \qquad \text{EQ. 4.18}$$

where:

P_I is the cost variance due to low productivity determined from Equation 4.15; P_{II} is the cost variance due to low productivity determined from Equation 4.16; P_{III} is the cost variance due to low productivity determined from Equation 4.17; $(MHR)_a$ and $(MHR)_b$ are the cumulative actual and budgeted man-hours from the budget file; MHR_I is the man-hour forecast determined from Equation 4.3; $(\$/Mhr)_a$ is the actual overall crew rate from the labor history file; $(\$/Mhr)_b$ is the budgeted overall crew rate from the budget labor file; $(Mhr/Q)_{TP}$ is the current period's actual man-hour per unit from the transaction file; and $(\$/Mhr)_{TP}$ is the current period's actual average cost per man-hour, from the transaction file; and P is the expected cost variance due to low productivity.

There are three different ways for calculating variances due to craft rate which are given in Equations 4.19 through 4.21. The arithmetic mean of these values is considered an appropriate approximation for the expected variance.

$$R_{I} = (MHR)_{b} * [\ (\$/Mhr)_{b} - (\$/Mhr)_{a}] \qquad \text{EQ. 4.19}$$

$$R_{II} = MHR_{I} * [\ (\$/Mhr)_{b} - (\$/Mhr)_{a}] \qquad \text{EQ. 4.20}$$

$$R_{III} = MHR_{II} * [\ (\$/Mhr)_{b} - (\$/Mhr)_{a}] \qquad \text{EQ. 4.21}$$

$$\text{(F8)} \quad : \ R = [R_{I} + R_{II} + R_{III}] \ / \ 3 \qquad \text{EQ. 4.22}$$

where:

R is the expected cost variance due to craft rate; R_{I} through R_{III} are the cost variances determined from Equations 4.19 through 4.21; and all other terms are as defined previously.

A variance due to crew mix can be determined from Equation 4.23.

$$\text{(F9)} \quad : \ C = L - P - R \qquad \text{EQ. 4.23}$$

where:

C is the expected cost variance due to crew mix; L is the expected cost variance due to labor costs determined from Equation 4.13; P is the expected cost variance due to labor productivity determined from Equation 4.18;and R is the expected cost variance due to craft rate determined from Equation 4.22.

The third type of information involves determining the performance indices in terms of overall total cost, labor productivity, and labor costs. These indices can be determined from Equations 4.24 through 4.26

$$\text{(F10)} \ : \ PI_{tc} = (\$/Q)_{b} \ / \ (\$/Q)_{a} \qquad \text{EQ. 4.24}$$

$$(F11) : PI_{lp} = (Mhr/Q)_b \ / \ (Mhr/Q)_a \qquad \text{EQ. 4.25}$$

$$(F12) : PI_{lc} = (\$/Mhr)_b \ / \ (\$/Mhr)_a \qquad \text{EQ. 4.26}$$

where:

PI_{tc} is the overall total cost performance index; PI_{lp} is the labor productivity performance index; PI_{lc} is the labor cost performance index; and all other terms are as defined previously.

CHAPTER V

EXAMPLE PROJECT

General

The purpose of this chapter is to provide a numerical illustration of and a guide to the application of the ratios analysis technique (RAT) presented in this study. The technique was implemented on a project valued at $250,000 involving the refurbishment of an existing tile manufacturing plant. Since the project was substantially completed before the implementation of the proposed RAT, project data was reconstructed from existing project files and interviews with key project personnel.

Project Scope of Work

The selected project involved extensive foundation work including the demolition of the existing floor slab, installation of three hundred reinforced concrete drilled piers in the production area, installation of isolated footings in the non-production area, and placement of approximately six thousand cubic yards of concrete for a new reinforced concrete floor slab. The work also included the installation of underground electrical and mechanical systems as well as the installation of roof decking and some interior remodeling work.

Project Estimate and Control Budget

Implementation of the RAT was possible only on the portion of the project handled by the prime contractor's own work force because detailed records were not available on the subcontracted portion of the project. Table 5.1 presents the control budget of the portion of the project investigated in this research.

TABLE 5.1

ESTIMATE AND CONTROL BUDGET

Account No.	Item Description	Total Quantity	Unit	Materials Cost $	Labor Cost $	Total Cost $
Site Preparation and Exterior Work						
0322	Place Concrete Gutter	11	CY	460	110	570
Footings Foundations						
0212	Excavation	132	CY	1056	396	1452
0307	Place Concrete Footing	177	CY	7478	1416	8894
0550	Set Embeds	26	EA	0	78	78
Column Pedestals						
0348	Form Pedestals	133	SF	33	399	432
0306	Place Column Pedestal	2	CY	85	50	135
0512	Set Anchor Bolts	20	EA	50	160	210
0351	Grout Base Plates	20	EA	200	200	400

TABLE 5.1

ESTIMATE AND CONTROL BUDGET
(continued)

Account No.	Item Description	Total Quantity	Unit	Materials Cost $	Labor Cost $	Total Cost $
Grade Beams						
0223	Excavation Grade Beam	16	CY	128	48	176
0340	Form Grade Beams	513	SF	205	718	923
0309	Place Grade Beams	10	CY	425	100	525
Concrete Floors						
0219/49	Place Rock Pad 6-inch	340	Ton	3196	532	3728
0315/66	Place Concrete Floor	179	CY	10325	399	10724
0344	Column Blockouts	470	LF	115	670	785
0386	Construction Joints	1160	LF	406	290	696
Exterior Stairs						
0288	Excavation	16	CY	128	48	176
0327	Place/Finish Concrete	28	CY	1187	270	1457
0343	Form Staircases	1100	SF	461	1855	2316
Rough Carpentry						
0602	Treated Roof Blocking	3000	FBM	1500	3000	4500
0632	Plywood Decking	2240	SF	829	538	1367
0908	Studs And Track	1740	LF	1445	1080	2525
0965	Hat Channel	1260	LF	567	315	882
Drill Piers						
0306	Place/Finish Concrete	568	CY	22701	4917	27618
0226	Preparation/Sonotube	909	LF	2313	2727	5040

Data Collection and Existing Deficiencies

Since the RAT was implemented on a practically completed project for which cost records had not been kept in a manner similar to that required for the proposed technique, data collection was a major task. Data was obtained from payroll reports, accounts receivable reports, accounts payable reports, construction logs, time cards, purchase requisitions, material delivery tickets, invoices, personnel interviews, personal diaries of the construction staff, as well as field operation files to establish the necessary data files. The data collected from these various sources was completely restructured to match the data organization format required by the RAT.

This exercise furnished proof that the technique required only data commonly available on construction projects, and did not burden project personnel with additional paper work and record keeping. It also confirmed earlier findings [42] that contractors often have the data necessary for the implementation of a successful project control system on record. Contractors, however, do not always recognize the usefulness of a more efficient process of organization and utilization of the available data.

In this case study, the lack of efficient organization of the available data was apparent in that the different pieces of interrelated data were scattered among a number of reports and documents used by different departments within the contractor's company. This may have limited the accessibility of the data resulting in only partial awareness and use of the information available.

An example of the lack of efficient utilization of the available data could be seen in overlooking the utilization of the actual man hour records available on time cards and payroll reports in measuring and controlling labor productivity. It is worth noting that neither the control budget, shown in Table 5.1, nor any other project control report referenced man-hour requirements for each cost item. Tracking the unit man-hour, (Mhr/Q) ratio, is essential for measuring labor productivity. The unit man-hour can be a reliable measurement for ensuring the delivery of the project within its budget and scheduled time, providing the availability of resources and a proper work sequence exist. By tracking the unit man-hour a check can be made on whether a trend has been established that indicates activities are being performed at their planned production rates. Extra man-hours will certainly be needed to complete work involved in items performing at a lower production rate than allowed in the budget. Additional resources, scheduled work shifts, consumption of existing float, or extension of the total project duration may become necessary to accommodate extra man-hours within the planned execution time of the project. Any of these alternatives, of course, result in additional costs to the project.

As seen in Table 5.1, labor was addressed in the estimate only in terms of total labor cost per cost item rather than in terms of required unit man-hours and labor rates. A control data-base based on unit man-hour would be more stable than one based on labor cost per unit. The labor cost per unit is subject to cyclic changes in craft rates, inflation and deflation, and the type of labor agreement (union/ non-union labor, open shop, closed shop, etc.) for a particular project. Most of these factors are outside the contractor's control, and can distort the actual project performance. The unit man-hour is a function of the contractor's planning, organization, supervision, training, materials handling, and selection of proper crew labor mix. All of these factors are, to a great extent, under the contractor's control.

Establishment of Data Files

Three of the five data files required for implementing the RAT were established for the example project. These three files were the Budget File, the Transaction File, and the Labor History File. A budget Labor File could not be created since no data was included in the estimate and control budget regarding crew mixes and craft rates. A Modification File was not needed because no changes were recorded and no extra compensation was requested by the contractor.

In establishing the Budget File shown in Table 5.2, the budgeted man-hours were calculated indirectly by dividing the estimated labor cost for each cost item by an average labor rate obtained from similar projects completed in the last five years. The other data contained in the Budget File was taken directly from the project's estimate.

The absence of periodical records on quantities-in-place was a problem faced in establishing the Transaction File. The contractor's reported percent complete was based on either expenditures or the subjective judgment of senior field personnel and not on quantities in-place. Quantities in-place required to establish the Transaction File and to calculate several key control ratios were not recorded

TABLE 5.2

BUDGET FILE

ACC	TCOST	LCOST	MHR	QUAT	T/Q	MHR/Q	L/MHR	UNIT
1	570	110	10	11	51.82	0.91	11.00	CY
2	1452	396	35	132	11.00	0.27	11.31	CY
3	8894	1416	115	177	50.25	0.65	12.31	CY
4	78	78	6	26	3.00	0.23	13.00	EA
5	433	399	30	133	3.26	0.23	13.30	SF
6	135	50	4	2	67.50	2.00	12.50	CY
7	210	160	13	20	10.50	0.65	12.31	EA
8	400	200	28	20	20.00	1.40	7.14	EA
9	176	48	5	16	11.00	0.31	9.60	CY
10	923	718	60	513	1.80	0.12	11.97	SF
11	525	100	8	10	52.50	0.80	12.50	CY
12	3728	532	52	340	10.96	0.15	10.23	TON
13	10724	399	70	179	59.91	0.39	5.70	CY
14	785	670	34	470	1.67	0.07	19.71	LF
15	696	290	20	1160	0.60	0.02	14.50	LF
16	4400	2890	280	5828	0.75	0.05	10.32	LF
17	176	48	4	16	11.00	0.25	12.00	CY
18	1457	270	22	28	52.04	0.79	12.27	CY
19	2316	1855	134	1100	2.11	0.12	13.84	SF
20	4500	3000	290	3000	1.50	0.10	10.34	BF
21	1367	538	48	2240	0.61	0.02	11.21	SF
22	2585	1080	96	1740	1.49	0.06	11.25	LF
23	882	315	28	1260	0.70	0.02	11.25	LF
24	27618	4917	400	568	48.62	0.70	12.29	CY
25	5040	2727	281	303	16.63	0.93	9.70	EA
SUM:	80070	23206	2073					

periodically as part of the project control system. This problem was overcome by obtaining the periodical quantities from materials delivery tickets, invoices, purchase orders, construction logs, and field personnel diaries. All the collected data was organized chronologically on a weekly basis in the Transaction File, as shown in Table 5.3, to enable the calculation of current control ratios. This table simulates an actual weekly Transaction File which contains only cost items that were active in any current week. This shows the number of cost items expected to be handled in any week for a project similar to the one investigated. As seen in the table, it was necessary to collect data on a maximum of 8 items for any week. Data in the Transaction File was accumulated per account, as shown in Table 5.4, to facilitate the calculation of to-date control ratios.

Data required for the Labor History File was readily available in sufficient detail from the time cards and payroll reports. This data was not reorganized to match the format of the Labor History File presented in Chapter 4, although using the proposed file format would have been much more efficient in retrieving the data. It was the author's judgment that the effort and time needed to reorganize the existing data would offset the desired benefits.

A summary bar-chart, Figure 5.1, representing the actual as-built schedule was developed using the actual dates recorded on time cards and materials delivery tickets for each cost item. This was done because the project's original schedule was never updated. The development of such a schedule was necessary to simulate the actual sequence of events and flow of expenditures during the construction phase. In this manner the capabilities of the RAT to detect cost items having

TABLE 5.3

TRANSACTION FILE

WK#	ACC	MHR	L$	T$	Q	T/Q	MHR/Q	L/MHR
1	25	35	548	548	1	548.00	35.00	15.66
2	25	10	118	225	14	16.07	0.71	11.80
3	5	52	597	632	133	4.75	0.39	11.48
3	25	26	167	365	26	14.04	1.00	6.42
4	6	4	49	187	2	93.50	2.00	12.25
4	7	51	561	569	20	28.45	2.55	11.00
4	24	72	783	783	1	783.00	72.00	10.88
4	25	10	105	181	10	18.10	1.00	10.50
5	24	13	142	382	6	63.67	2.17	10.92
5	25	75	618	885	35	25.29	2.14	8.24
6	12	9	96	1225	130	9.42	0.07	10.67
6	24	44	408	3168	69	45.91	0.64	9.27
6	25	1	0	206	27	7.63	0.04	0.00
7	12	55	635	2564	222	11.55	0.25	11.55
7	24	35	304	3836	86	44.60	0.41	8.69
7	25	63	552	1002	59	16.98	1.07	8.76
8	2	112	1045	1500	132	11.36	0.85	9.33
8	12	40	438	2250	82	27.44	0.49	10.95
8	14	36	405	430	470	0.91	0.08	11.25
8	24	45	396	3836	86	44.60	0.52	8.80
8	25	69	582	697	15	46.47	4.60	8.43
9	3	4	43	673	15	44.87	0.27	10.75
9	4	5	57	58	26	2.23	0.19	11.40
9	9	15	134	134	16	8.38	0.94	8.93
9	12	7	70	295	26	11.35	0.27	10.00
9	13	87	796	8871	190	46.69	0.46	9.15
9	15	91	1112	1112	1518	0.73	0.06	12.22
9	24	31	260	2860	65	44.00	0.48	8.39
9	25	55	455	570	15	38.00	3.67	8.27
10	3	8	92	470	9	52.22	0.89	11.50
10	10	67	718	909	513	1.77	0.13	10.72
10	16	425	4481	5889	5828	1.01	0.07	10.54
10	24	26	215	1815	40	45.38	0.65	8.27
10	25	33	273	525	33	15.91	1.00	8.27
11	3	6	60	354	7	50.57	0.86	10.00
11	11	89	859	1326	11	120.55	8.09	9.65
11	24	48	397	2557	54	47.35	0.89	8.27
11	25	1	0	107	14	7.64	0.07	0.00
12	1	5	51	834	20	41.70	0.25	10.20
12	3	15	160	958	19	50.42	0.79	10.67
12	24	40	435	2675	56	47.77	0.71	10.88
12	25	144	1236	1580	45	35.11	3.20	8.58
13	3	4	51	135	2	67.50	2.00	12.75
13	24	72	628	3908	82	47.66	0.88	8.72
13	25	41	332	408	10	40.80	4.10	8.10
14	20	22	247	278	60	4.63	0.37	11.23
14	24	21	180	1460	32	45.63	0.66	8.57
15	8	40	436	730	20	36.50	2.00	10.90
15	20	161	1863	2071	400	5.18	0.40	11.57
15	21	8	94	131	100	1.31	0.08	11.75
16	17	28	267	455	16	28.44	1.75	9.54
16	20	261	3124	3618	950	3.81	0.27	11.97
16	21	17	190	322	360	0.89	0.05	11.18
17	18	12	110	446	8	55.75	1.50	9.17
17	19	180	1978	2445	1100	2.22	0.16	10.99
17	20	275	3366	3976	1174	3.39	0.23	12.24
17	21	53	660	1009	948	1.06	0.06	12.45
18	18	9	91	559	11	50.82	0.82	10.11
18	20	279	3273	3741	900	4.16	0.31	11.73
18	21	67	802	1238	1186	1.04	0.06	11.97
19	18	5	49	134	2	67.00	2.50	9.80

TABLE 5.4

CUMULATIVE DATA

WK#	ACC	MHR	L$	T$	Q	T/Q	MHR/Q	L/MHR
1	25	35	548	548	1	548.00	35.00	15.66
2	25	45	666	773	15	51.53	3.00	14.80
3	5	52	597	632	133	4.75	0.39	11.48
3	25	71	833	1138	41	27.76	1.73	11.73
4	6	4	49	187	2	93.50	2.00	12.25
4	7	51	561	569	20	28.45	2.55	11.00
4	24	72	783	783	1	783.00	72.00	10.88
4	25	81	938	1319	51	25.86	1.59	11.58
5	24	85	925	1165	7	166.43	12.14	10.88
5	25	156	1556	2204	86	25.63	1.81	9.97
6	12	9	96	1225	130	9.42	0.07	10.67
6	24	129	1333	4333	76	57.01	1.70	10.33
6	25	157	1556	2410	113	21.33	1.39	9.91
7	12	64	731	3789	352	10.76	0.18	11.42
7	24	164	1637	8169	162	50.43	1.01	9.98
7	25	220	2108	3412	172	19.84	1.28	9.58
8	2	112	1045	1500	132	11.36	0.85	9.33
8	12	104	1169	6039	434	13.91	0.24	11.24
8	14	36	405	430	470	0.91	0.08	11.25
8	24	209	2033	12005	248	48.41	0.84	9.73
8	25	289	2690	4109	187	21.97	1.55	9.31
9	3	4	43	673	15	44.87	0.27	10.75
9	4	5	57	58	26	2.23	0.19	11.40
9	9	15	134	134	16	8.38	0.94	8.93
9	12	111	1239	6334	460	13.77	0.24	11.16
9	13	87	796	8871	190	46.69	0.46	9.15
9	15	91	1112	1112	1518	0.73	0.06	12.22
9	24	240	2293	14865	313	47.49	0.77	9.55
9	25	344	3145	4679	202	23.16	1.70	9.14
10	3	12	135	1143	24	47.63	0.50	11.25
10	10	67	718	909	513	1.77	0.13	10.72
10	16	425	4481	5889	5828	1.01	0.07	10.54
10	24	266	2508	16680	353	47.25	0.75	9.43
10	25	377	3418	5204	235	22.14	1.60	9.07
11	3	18	195	1497	31	48.29	0.58	10.83
11	11	89	859	1326	11	120.55	8.09	9.65
11	24	314	2905	19237	407	47.27	0.77	9.25
11	25	378	3418	5311	249	21.33	1.52	9.04
12	1	5	51	834	20	41.70	0.25	10.20
12	3	33	355	2455	50	49.10	0.66	10.76
12	24	354	3340	21912	463	47.33	0.76	9.44
12	25	522	4654	6891	294	23.44	1.78	8.92
13	3	37	406	2590	52	49.81	0.71	10.97
13	24	426	3968	25820	545	47.38	0.78	9.31
13	25	563	4986	7299	304	24.01	1.85	8.86
14	20	22	247	278	60	4.63	0.37	11.23
14	24	447	4148	27280	577	47.28	0.77	9.28
15	8	40	436	730	20	36.50	2.00	10.90
15	20	183	2110	2349	460	5.11	0.40	11.53
15	21	8	94	131	100	1.31	0.08	11.75
16	17	28	267	455	16	28.44	1.75	9.54
16	20	444	5234	5967	1410	4.23	0.31	11.79
16	21	25	284	453	460	0.98	0.05	11.36
17	18	12	110	446	8	55.75	1.50	9.17
17	19	180	1978	2445	1100	2.22	0.16	10.99
17	20	719	8600	9943	2584	3.85	0.28	11.96
17	21	78	944	1462	1408	1.04	0.06	12.10
18	18	21	201	1005	19	52.89	1.11	9.57
18	20	998	11873	13684	3484	3.93	0.29	11.90
18	21	145	1746	2700	2594	1.04	0.06	12.04
19	18	26	250	1139	21	54.24	1.24	9.62

Acc. No.	PROJECT DURATION IN WEEKS																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1												===								
2								===												
3									===	===	===	===	===							
4									===											
5			===																	
6				===																
7				===																
8															===					
9									===											
10										===										
11											===									
12						===	===	===	===											
13									===											
14								===												
15									===											
16										===										
17																===				
18																	===	===	===	
19																	===			
20														===	===	===	===	===		
21															===	===	===	===		
22																				
23																				
24				===	===	===	===	===	===	===	===	===	===	===						
25	===	===	===	===	===	===	===	===	===	===	===	===	===							

Figure 5.1 - As-Built Project Barchart

potential financial problems, determine the causes of such problems, and forecast their monetary magnitudes using only the information available at that time were tested.

Applying the Algorithm

Control ratios and performance indices were calculated using the above data files. A sample of the results is presented in Table 5.5 and a full data set for all weeks is included in Appendix A. Table 5.5 presents the current and to date control ratios as well as the performance indices for each cost account on the last week of the project. Current ratios are shown only on account number 18 because it was the only active account during that week. Other accounts were completed at earlier periods, therefore, they show only cumulative control ratios.

Using the total cost performance indices, PI_{tc}, of the RAT made it easy to detect the cost items having potential financial problems and using the labor cost and the productivity performance indices, PI_{lc} and PI_{lp}, identified the causes of such problems. Analysis of the performance indices suggested that approximately half the cost items were performed unfavorably in terms of their total cost per unit. Further, they indicated that in most cases this was due to low productivity and not labor hiring rates. In fact, the labor cost performance index shows that the actual hiring rates were below their budgeted values resulting in superior ratings in terms of labor cost.

In order to determine the monetary magnitude of an identified problem and assess the impact on the total project cost, the developed

TABLE 5.5

WEEKLY CONTROL RATIOS

ACC	CURRENT RATIOS T/Q	CURRENT RATIOS L/MHR	CURRENT RATIOS MHR/Q	CUMULATIVE TO DATE T/Q	CUMULATIVE TO DATE L/MHR	CUMULATIVE TO DATE MHR/Q	PERFORMANCE INDICES T.COST	PERFORMANCE INDICES LCOST	PERFORMANCE INDICES PROD
1	0.00	0.00	0.00	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	0.00	0.00	0.00	49.81	10.97	0.71	1.01	1.12	0.91
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
8	0.00	0.00	0.00	36.50	10.80	2.00	0.55	0.66	0.70
9	0.00	0.00	0.00	8.38	8 93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.03	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
17	0.00	0.00	0.00	28.44	9.54	1.75	0.39	1.26	0.14
18	67.00	9.80	2.50	54.24	9.62	1.24	0.96	1.26	0.63
19	0.00	0.00	0.00	2.22	10.99	0.16	0.95	1.26	0.74
20	0.00	0.00	0.00	3.93	11.90	0.29	0.38	0.87	0.34
21	0.00	0.00	0.00	1.04	12.04	0.06	0.59	0.93	0.38
24	0.00	0.00	0.00	47.28	9.28	0.77	1.03	1.32	0.91
25	0.00	0.00	0.00	24.01	8.86	1.85	0.69	1.10	0.50

TABLE 5.6

INFORMATION ANALYSIS REPORT FOR WEEK NO.6

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1452	35	1452	35	0	0	0	0	0	0	0	1.00	1.00	1.00
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3204	24	3204	24	524	28	180	344	296	-14	-102	1.16	2.21	0.96
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	785	34	785	34	0	0	0	0	0	0	0	1.00	1.00	1.00
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26922	443	32383	964	-2035	-303	-1056	-979	-1865	1180	-370	0.85	0.41	1.19
25	3860	164	6462	421	-121	-12	519	-639	314	-60	264	0.78	0.67	0.98
SUM:	78280	2031	86343	2809	-2242	-347	-843	-1398	-1901	1238	-180			

RAT algorithm shown in Figure 4.4 was applied on the project data to generate the Information Analysis Report. Sample of the results are shown in Tables 5.6 and 5.7, and a full set of the reports generated on a weekly basis is provided in Appendix A. Table 5.6 presents information available at the sixth week of the project, and Table 5.7 presents information at the last week of the project. Although control ratios were generated on active accounts from the first week for tracking purposes, it is understood that reliable forecasts can be generated only after the project has advanced by 25-35 percent of its total duration. At this stage most of the common problems at the start of the construction phase should have been resolved and steady production rates reached.

The information available in the sixth week indicated that the final total project cost was expected to be between $78,280 and $86,343. It also indicated that a total unfavorable variance of $2,242 and 347 man-hours was likely to occur by project completion. A study of the magnitude of the causes of such variances revealed that labor costs were responsible for $843 and materials costs were responsible for $1,398 of the variance. Further analysis of the unfavorable labor cost variance showed that low productivity on the project resulted in an unfavorable variance of $1,901 and an improper labor mix contributed an unfavorable variance of $180. However, the impact of these two variances was partly offset by a savings of $1,238 on craft hiring rates leaving a net unfavorable labor cost variance of only $843.

Performance indices confirmed the above conclusions. The values of PI_{tc} were less than unity indicating that unfavorable cost

TABLE 5.7

INFORMATION ANALYSIS REPORT FOR WEEK NO.20

ACC	OPTIMISTIC FORECAST $$$ F1	OPTIMISTIC FORECAST MHR F2	PESSIMISTIC FORECAST $$$ F1	PESSIMISTIC FORECAST MHR F2	VARIANCE EXPECTED $$$ F3	VARIANCE EXPECTED MHR F4	COST ANALYSIS VAR. DUE TO LCOST F6	COST ANALYSIS VAR. DUE TO MAT¢L F7	LABOR COST VARIANCE DUE TO PROD F5	LABOR COST VARIANCE DUE TO RATE F8	LABOR COST VARIANCE DUE TO MIX F9	PERFORMANCE MEASURED IN TERMS OF COST F10	PERFORMANCE MEASURED IN TERMS OF PROD F11	PERFORMANCE MEASURED IN TERMS OF LCOST F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	2590	37	2590	37	6304	78	867	5437	907	84	-124	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	730	40	730	40	-330	-12	-214	-116	-166	-135	87	0.55	0.70	0.66
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	455	28	455	28	-279	-24	-181	-98	-226	49	-5	0.39	0.14	1.26
18	1139	26	1139	26	318	-4	26	292	-19	66	-20	0.96	0.63	1.28
19	2445	180	2445	180	-129	-46	-39	-90	-378	470	-131	0.95	0.74	1.26
20	13684	998	13684	998	-9184	-708	-7469	-1715	-8573	-1183	2286	0.38	0.34	0.87
21	2700	145	2700	145	-1333	-97	-1013	-320	-1181	-94	262	0.59	0.38	0.93
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27280	447	27280	447	338	-47	842	-504	-34	1300	-423	1.03	0.91	1.32
25	7299	563	7299	563	-2259	-282	-1843	-416	-2418	398	177	0.69	0.50	1.10
SUM:	90574	3738	90574	3738	-10504	-1665	-13368	2864	-17512	1541	2603			

variances were expected. The values of PI_{1p} and PI_{1c} showed that labor productivity was significantly below the estimated rates while the craft hiring rates were better (lower) than estimated.

for the project's last period, Table 5.7, the actual final total project cost was approximately four percent higher than the pessimistic forecast of the sixth week making the final project cost $90,574. Low productivity persisted as the major cause of unfavorable cost variances resulting in an extra cost of $17,512 by project completion. This extra cost was partly offset by the $2,864 savings realized in the materials cost. This extra cost was also reduced by the $1,541 savings realized by hiring crafts at a lower than budgeted rates, and the $2,603 savings realized by organizing crew mixes that were less expensive than budgeted. The summation of the savings and the extra cost due to low productivity resulted in a net overrun of $10,504 at the project's close out.

RAT Computer Application

Manual calculations to generate the information contained in the Information Analysis Report were found to be tedious and time consuming. To facilitate the generation of the needed information in a timely manner a computer program was developed. The computer output was validated by comparisons with the manual calculations of all control ratios and the information provided in the Information Analysis Report using several data sets for various weeks. A full set of the output reports is provided in Appendix B and the source code of the program is provided in Appendix C. Figure 5.2 shows the optimistic and

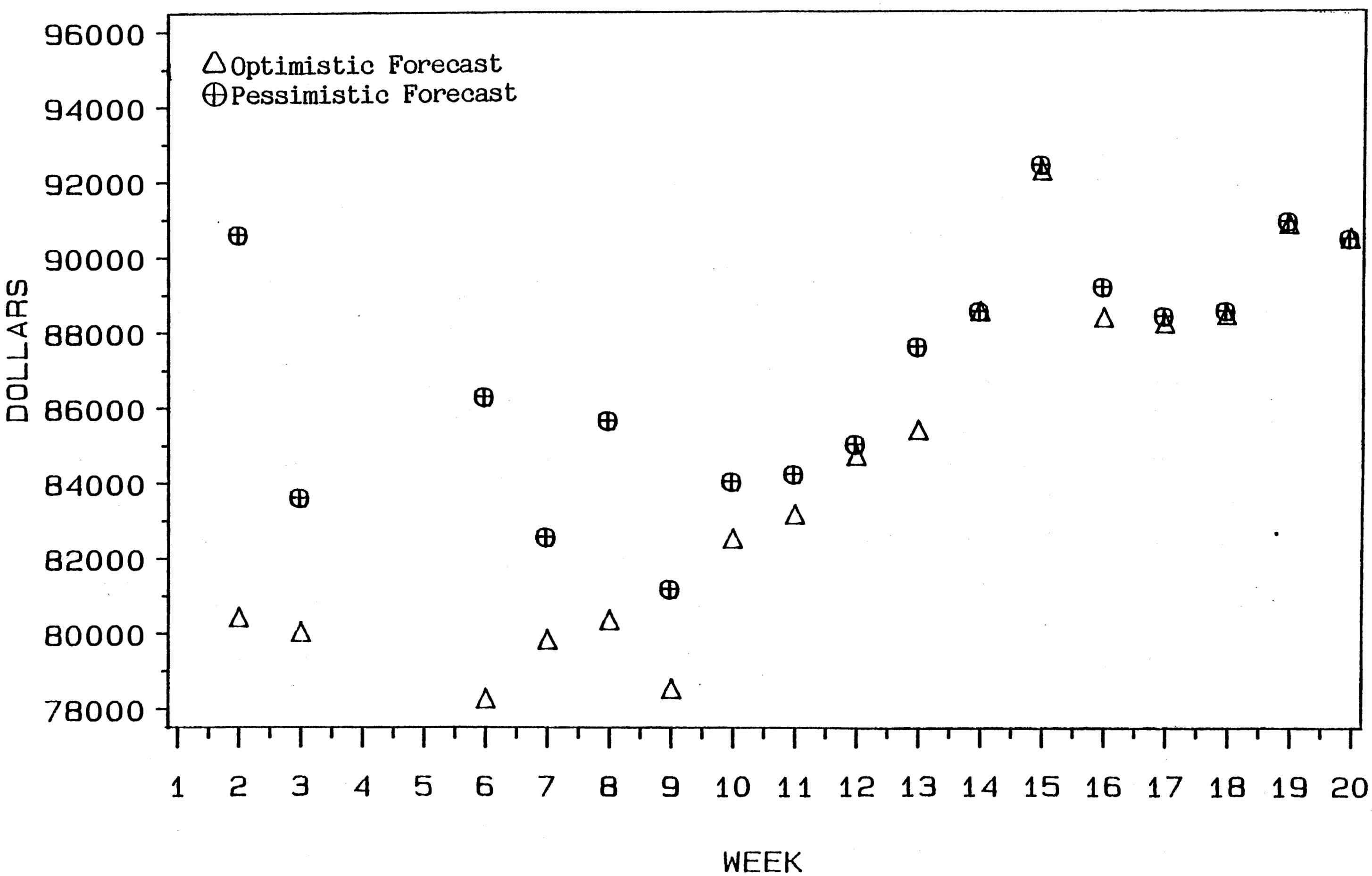

Figure 5.2 - Total Optimistic and Pessimistic Cost Forecasts

pessimistic forecasts generated by the RAT for each week. The figure suggests that both forecasts showed a fairly well defined trend from the seventh week to project completion.

Regression lines for the forecasts generated from weeks seven through eleven were drawn to test the accuracy of the RAT in forecasting the final project cost at an early stage of completion. As shown in Figure 5.3, an optimistic and pessimistic total project cost of $85,000 and $90,000 could be forecasted at the end of the eleventh week of the project. The values of these forecasts were within seven percent of the actual final project cost.

Figure 5.4 shows the regression line of the mean values of the optimistic and pessimistic forecasts for the data presented in Figure 5.3. This regression line seemed to be a good estimator for forecasting the actual final project cost. Using the mean values of the forecasts that were available in the end of the eleventh week resulted in a forecast of $88,000 which is within three percent of the actual final project cost. As more information became available, a forecast of the actual final figure could be determined with a high degree of confidence. The regression line drawn for the forecasts available at the end of the fifteenth week resulted in a forecast of $96,000, which was within six percent of the actual final project cost, as shown in Figure 5.5.

Similarly, man-hour forecasts were generated for the data sets of the weeks mentioned above. Figures 5.6 and 5.7 show that final man hours could have been forecast within eight percent accuracy as early as the eleventh week of the project.

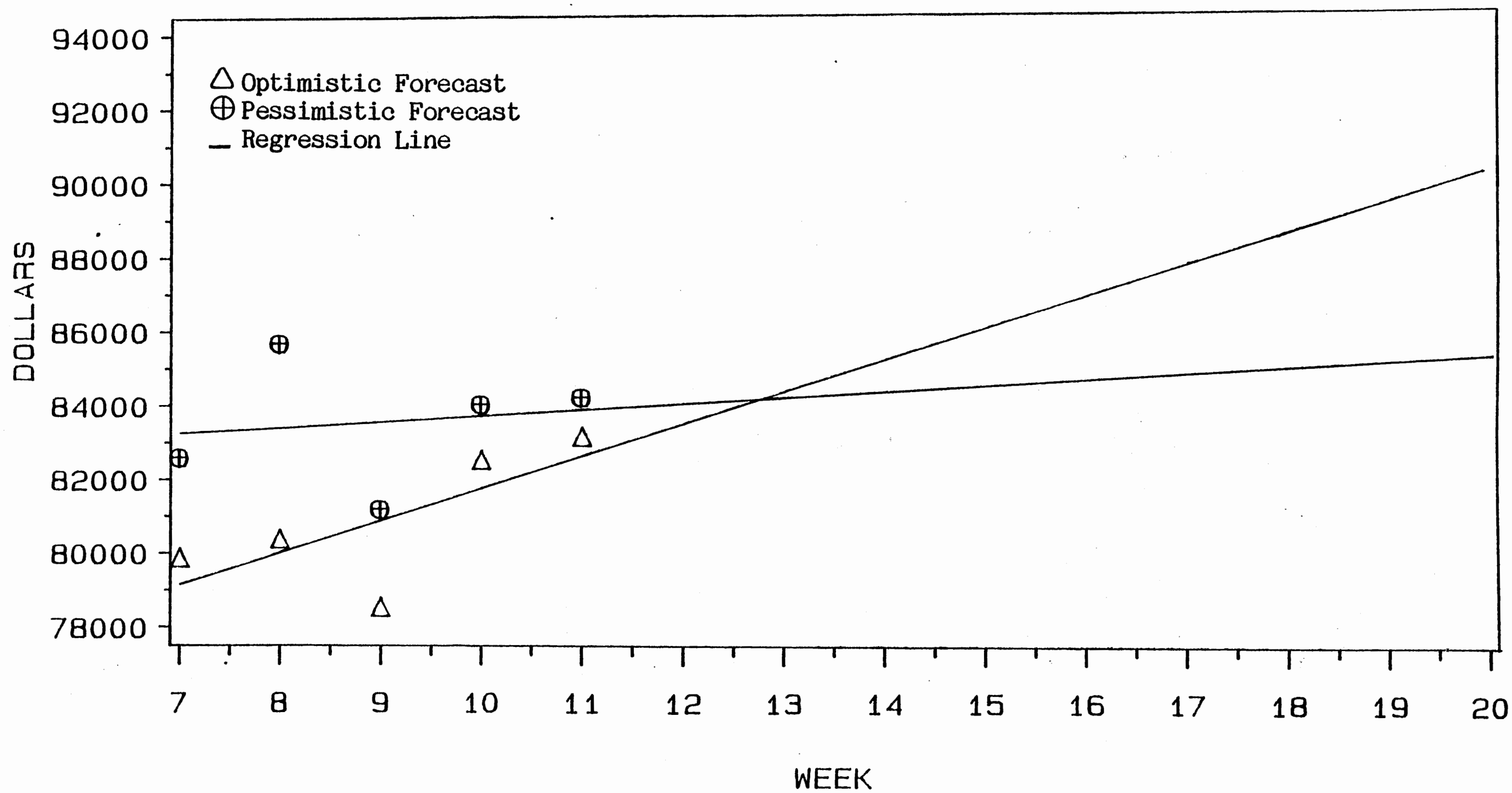

Figure 5.3 - Regression Lines of Optimistic and Pessimistic Cost Forecasts for Week Seven Through Eleven

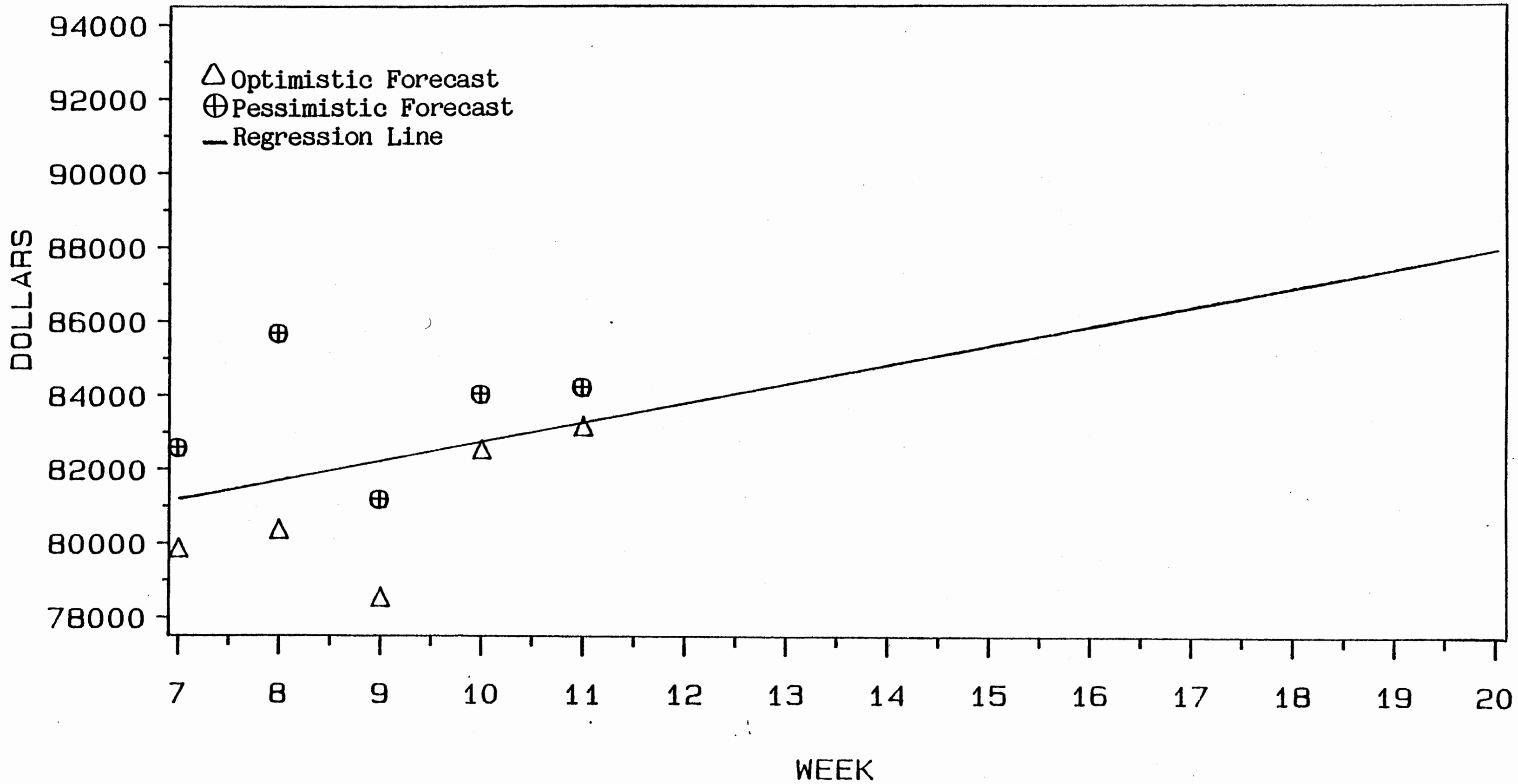

Figure 5.4 - Regression of Optimistic and Pessimistic Average Cost Forecasts for Week Seven Through Eleven

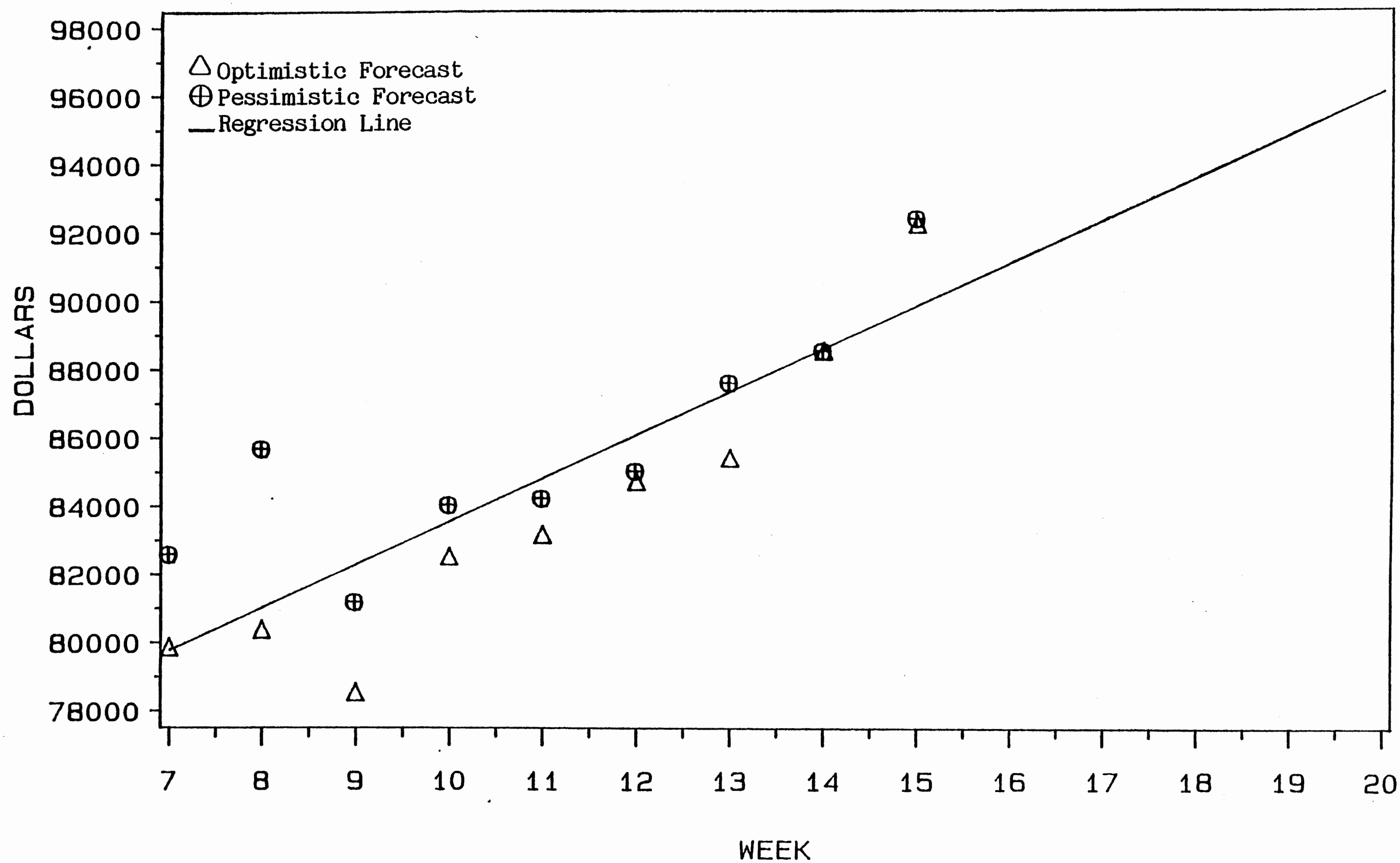

Figure 5.5 - Regression of Optimistic and Pessimistic Average Cost Forecasts for Week Seven Through Fifteen

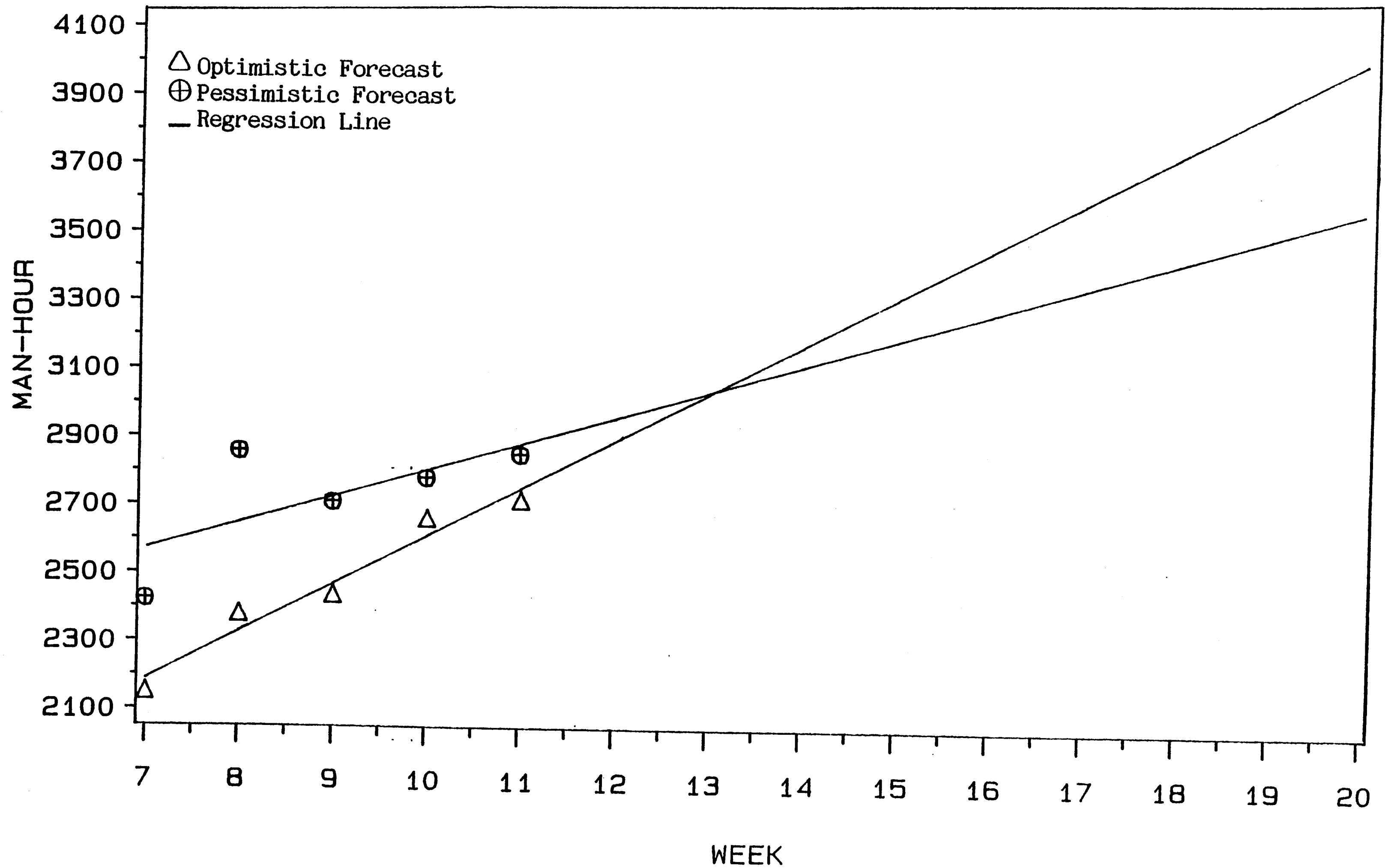

Figure 5.6 - Regression lines of Optimistic and Pessimistic Man-Hour Forecasts for Week Seven Through Eleven

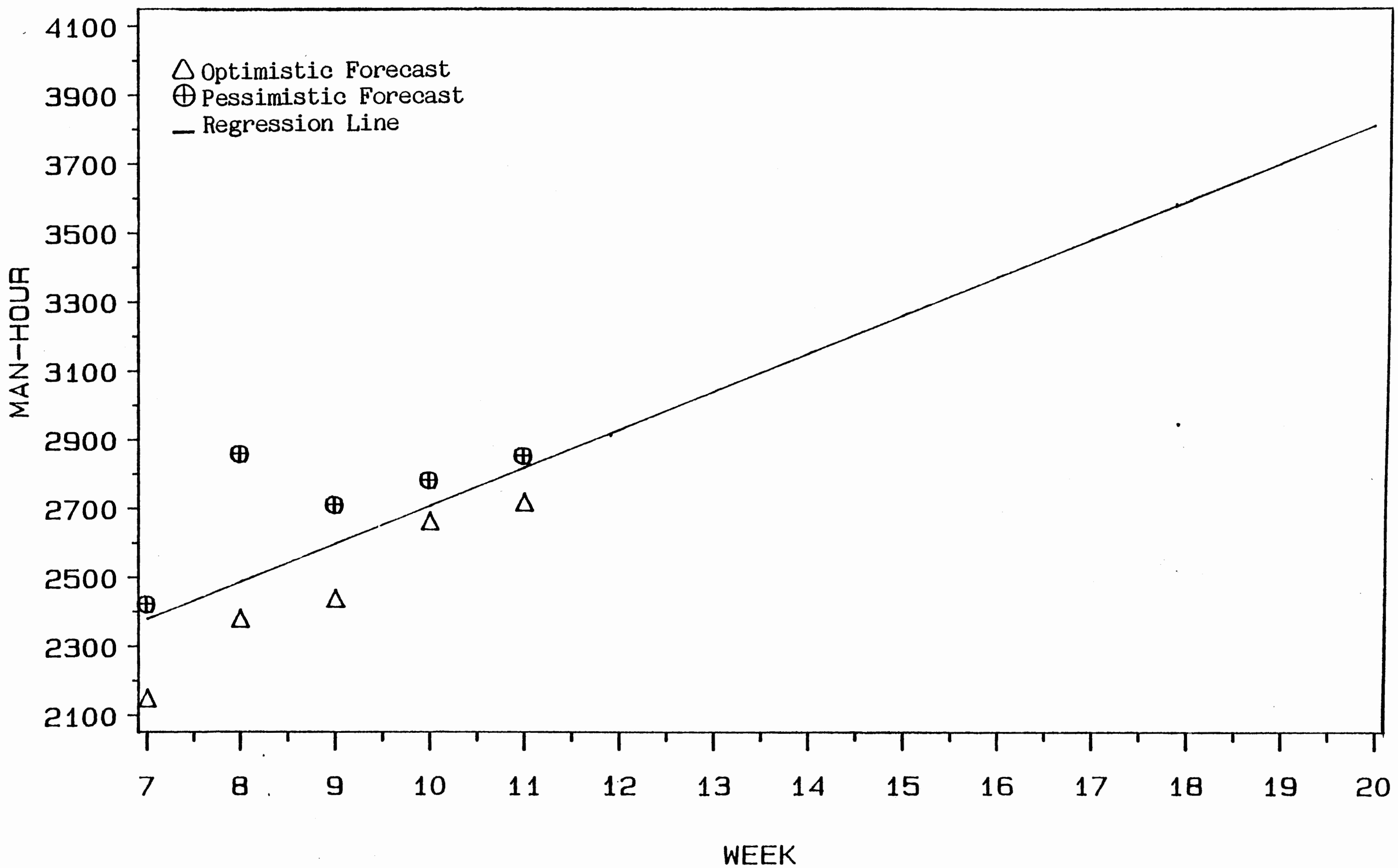

Figure 5.7 - Regression of Optimistic and Pessimistic Average Man-Hour Forecasts for Week Seven Through Eleven

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

This study was undertaken to analyze a different approach for the management of construction projects. This approach addressed project tracking at a micro level in contrast to the current macro management approach. This was accomplished by identifying key control ratios that describe work performance and by devising analytical procedures to detect potential problem areas and assess their monetary impact on the total project cost.

The selected control ratios require project data commonly available on construction projects such as quantities, man-hours, and total cost. Each control ratio measures a particular aspect of project performance. A problem detection procedure was employed using the control ratios to identify project cost items showing symptoms of financial problems. Once these items were identified, an analysis procedure was implemented to determine the immediate causes of these problems and their monetary magnitude. This procedure also involved calculating performance measurements and generating cost and man-hour forecasts based on actual work performance. The performance indices were expressed in terms of total cost, labor cost, and labor productivity. An actual project was used to illustrate the ratios analysis technique described in this study.

Conclusions

This study investigated the application of a modified management tool by extending the utilization of ratios analysis techniques to the tracking and control of construction projects. Based on this investigation the following conclusions were made:

1. The business ratios analysis technique is not directly applicable to construction projects due to measurable differences in the financial structure and operational cycles of a construction project in comparison with other commercial businesses. The main concept of this technique, evaluating performance at a micro rather than macro level, presented a different approach to the management of construction projects. This approach has the potential to resolve current management problems resulting from a lack of the proper integration of costs and scheduling and the absence of a systematic procedure, acceptable industry wide, to measure work progress.
2. The proposed RAT procedure described in this study can be a successful management tool during the tracking and control phases of construction projects.
3. RAT uses five key control ratios, cost per work unit ($/Q), man-hour per work unit (Mhr/Q), average cost per man-hour

($/Mhr), crew mix ratio ($\Sigma Rb*Na/ \Sigma Rb*Nb$), and craft rate ratio ($\Sigma Ra*Nb/ \Sigma Rb*Nb$), which were found to be sufficient for measuring work performance at the cost item level.

4. The five control ratios can be utilized successfully to identify cost items having potential financial problems. They can also be used to detect the immediate causes of problems when utilized in a problem detection procedure as described in this research.
5. Performance indices expressed in terms of total cost, labor cost, procurement cost, and labor productivity can be generated by comparing the budgeted and actual values of the five control ratios.
6. Sound objective forecasts can be generated based on actual performance indices and the utilization of the control ratios.

Recommendations for Future Research

The list of unresolved management problems provided in Chapter I indicates a continuing need for research efforts in the construction industry. The procedure presented in this study suggests the following additional areas for future research:

1. The creation of a detailed systematic approach for collecting and organizing project data emphasizing simplicity, avoiding double handling of data, and interfacing with other information systems, i.e., payroll, purchasing, and materials procurement, commonly available in construction companies.

2. The automation of the problem detection procedure through user oriented microcomputer software.
3. The development and utilization of a detailed interface between the calculated forecasts of extra man-hours based on actual productivity and the scheduling system.
4. The application of the RAT on a range of construction projects to better determine its accuracy and practicality.
5. The investigation of the correlation between the performance indices and combinations of control ratios and their data elements which may result in new complex ratios. These ratios may prove to have definite relationships with successful overall project performance.
6. The collection and organization of construction industry standard values for the five control ratios and their actual distribution with time for different types of work.

BIBLIOGRAPHY

1. Abrams, R. W., "How to Diagnose, and Help Cure a Case of Solvency", Practical Accountant, 1979, pp. 65-69.

2. American National Standards Institute, ANSI, "Cost Engineering Terminology", Index to Z94.1 - Z94.2, 1972.

3. Arditi, D., "Diffusion of Network Planning In Construction", ASCE, Journal of Construction Engineering and Management, Vol. 109, No. 1, March 1983, pp. 1-12.

4. Argenti, J., Systematic Corporate Planning, London: Thomas Nelson, 1979.

5. Barrie, D. S., and Paulson, B. C., Professional Construction Management, New York: McGraw-Hill Book Co., 1984.

6. Baumgeartner, W. E., "Tracking The Project Budget", ASCE, Journal of Management in Engineering, Vol. 2, No. 2, April 1986, pp. 125-138.

7. Beaver, W. H., "Financial Ratios as Predictors of Failure", Journal of Accounting Research, 1966, pp. 71-111.

8. Bell, L. C. and McCullouch, B. G., "Microcomputer Spreadsheet Application", ASCE, Journal of Construction Engineering and Management, Vol. 109, No. 2, June 1983, pp. 214-223.

9. Bernstein, L. A., Financial Statement Analysis: Theory, Application, and Interpretation, Homewood: Richard Irwin, 1978.

10. Bhandari, N., "Interaction of Information Flow with CM Systems", ASCE, Journal of the Construction Division, Vol. 104, No. CO3, September 1978, pp. 261-268.

11. Bittel, L. R. (ed.), Encyclopedia of Professional Management, New York: McGraw-Hill Book Co., 1978.

12. Bromberg, I., "Earned Value Back to Basics", AACE Transactions, No. A-6, 1984.

13. Burger, O. R., "Operational Strategy Integration", Manufacturing Systems, August 1986, pp. 23-29.

14. Caepari, J. E., and Varrone, M. J., "Application of a Manual Earned Value System for Small Engineering Projects", AACE Transactions, No. A-3, 1985.

15. Carr, R. I. and Maloney, W. F., "Basic Research Needs in Construction Engineering", ASCE, Journal of Construction Engineering and Management, Vol. 109, No. 2, June 1983, pp. 181-189.

16. Choromokos, J., and Mckee, K. E., "Construction Productivity Improvement", ASCE, Journal of the Construction Division, Vol. 107, No. CO1, March 1981, pp. 35-48.

17. Clough, R. H., Construction Management, New York: Wiley-Interscience, 1975.

18. Clough, R. H. and Sears, G. A., Construction Project Management, Toronto: John Wiley & Sons, 1979.

19. Cohen J. B., and Robbins, S. M., The Financial Manager, New York: Harper and Row, 1966.

20. Collier, K., Fundamentals of Construction Estimating and Cost Accounting, Englewood Cliffs: Prentice-Hall Inc., 1974.

21. Coombs, W. E., and Palmer, W. J., Construction Accounting and Financial Management, New York: McGraw-Hill Book Co., 1958.

22. Dabbas, A. A. and Haplin, D. W., "Integrated Project And Process Management", ASCE, Journal of Construction Engineering and Management, Vol. 108, No. CO3, September 1982, pp. 361-374.

23. Forrest, D. C. and Lorenzoni, A. B., Applied Cost Engineering, New York: Marcel Dekker, Inc., 1979.

24. Halpin, D. W. , Financial and Cost Concepts for Construction Management, New York: John Wiley & Sons, 1985.

25. Halpin, D. W. , and R. W. Woodhead, Construction Management, New York: John Wiley Inc., 1980.

26. Heath, L. C., Financial Reporting and Evaluation of Solvency, New York: American Institute of Certified Public Accountants, 1978.

27. Helfert, E. A., Techniques of Financial Analysis, Homewood: Richard Irwin, 1972.

28. Heyel, C. (ed.), The Encyclopedia of Management, New York: Reinhold, 1963.

29. Hinze, J. and Ashton, B., "Financial Management Practices in Utility Construction Firms", ASCE, Journal of the Construction Division, Vol. 107, No. CO3, September 1981, pp. 469-483.

30. Horrigan, J. O., "An Evaluation of Financial Ratio Analysis", Ph.D. Dissertation, University of Chicago, 1967.

31. Johnson, W. B., "The Cross Sectional Stability of Financial Ratio Patterns", Journal of Financial and Quantitative Analysis, Vol. 37, 1979, pp. 1035-1048.

32. Lang, H. J., and Decoursey, M., Profitability Accounting and Bidding Strategy for Engineering and Construction Management, New York: Wiley-Interscience, 1981.

33. Lev, B., Financial Statement Analysis: A New Approach, London: Prentice-Hall, Inc., 1974.

34. LeVitt R. R. , "New Methods in Construction Systems", ASCE, Journal of the Construction Division, Vol. 100, No. CO3, September 1974, pp. 211-222.

35. Liberatore, M. J. and Titus, G. J., "The Practice of Management Science in R&D Project Management", Management Science, Vol. 29, No. 3, August 1983, pp. 81-97.

36. Lohman, R. A., Breaking Even: Financial Management in Human Service Organizations, Temple University Press, 1980.

37. Meredith, J. R., and Mantel, S. J., Project Management - A Managerial Approach, New York: John Wiley & Sons, 1985.

38. Moder, J. J., Phillips, C. R., and Davis, E. W., Project Management With CPM, PERT and Precedence Diagraming, New York: Van Nostrand Reinhold Co., 1983.

39. Oglesby, C. H., "Construction Education: Past, Present and Future", ASCE, Journal of the Construction Division, Vol. 108, No. CO4, December 1982, pp. 605-616.

40. Pinches, G. E., Eubank, A. A., Mingo, K. A., and Caruthers, J. K., "The Hierachical Classification of Financial Ratios", Journal of Business Research, 1975, pp. 295-310.

41. Royer, K., "The Federal Government and the Critical Path", ASCE, Journal of Construction Engineering and Management, Vol. 112, No. 2, June 1986, pp. 220-226.

42. Russell, A. D., "General Contractor Project Control Practices and MIS", ASCE, Journal of the Construction Division, Vol. 108, No. CO3, September 1982, pp. 419-437.

43. Sanvido, V. E., "Designing Productivity Management and Control Systems for Construction Projects", Ph.D. Dissertation, Stanford University, 1984.

44. Schlick, H., "Project Integrated Management System (PRIM)", ASCE, Journal of Construction Engineering and Management, Vol. 107, No. CO2, June 1981, pp. 361-372.

45. Sears, G. A., "CPM/Cost: An Integrated Approach", ASCE, Journal of the Construction Division, Vol. 107, No. CO2, June 1981, pp. 227-238.

46. Stephens, L. M., "An Empirical Investigation of the Connections Between Financial Ratios and Operating Characteristics of Homogeneous Groups of Manufacturing Firms", Ph.D. Dissertation, University of Nebraska, 1983.

47. Stevens, W. M., "Cost Control: Integrated Cost/Schedule Performance", ASCE, Journal of Management in Engineering, Vol. 2, No. 2, July 1986, pp. 157-164.

48. Sukarieh G., "Construction Management Control With Microcomputers", ASCE, Journal of Construction Engineering and Management, Vol. 110, No. 1, March 1984, pp. 72-78.

49. Tamari, M., Financial Ratios: Analysis and Prediction, London: Paul Elek, 1978.

50. Teicholz P., "Requirements of Construction Company Cost System", ASCE, Journal of the Construction Division, Vol. 100, No. CO3, September 1974, pp. 255-265.

51. Tenah, K. A., "Construction Personnel Role and Information Needs", ASCE, Journal of Construction Engineering and Management, Vol. 112, No. 1, March 1986, pp. 33-48.

52. U.S. Department of Energy, "Cost and Scheduling Control Systems Criteria for Contract Performance Measurement - Work Breakdown Structure Guide", October 1981.

53. Warszawski, A., "Construction Management Program", ASCE, Journal of Construction Engineering and Management, Vol. 110, No. 3, September 1984, pp. 279-310.

54. Warszawski, A., and Rosenfeld, Y., "Financial Analysis Under Inflation in Construction", ASCE, Journal of the Construction Division, Vol. 108, No. CO2, June 1982, pp. 341-354.

55. Westwick, C. A., How To Use Management Ratios, New York: John Wiley & Sons, 1973.

APPENDIXES

APPENDIX A

WEEKLY CONTROL RATIOS REPORTS

WEEKLY CONTROL RATIOS :

FOR WEEK # : 1

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
25	548.00	15.66	35.00	548.00	15.66	35.00	0.03	0.62	0.03

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 2

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
25	16.07	11.80	0.71	51.53	14.80	3.00	0.32	0.66	0.31

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 3

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
5	4.75	11.48	0.39	4.75	11.48	0.39	0.69	1.16	0.58

25	14.04	6.42	1.00	27.76	11.73	1.73	0.60	0.83	0.54

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 4

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	93.50	12.25	2.00	93.50	12.25	2.00	0.72	1.02	1.00
7	28.45	11.00	2.55	28.45	11.00	2.55	0.37	1.12	0.25
24	783.00	10.88	72.00	783.00	10.88	72.00	0.06	1.13	0.01
25	18.10	10.50	1.00	25.86	11.58	1.59	0.64	0.84	0.58

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 5

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
24	63.67	10.92	2.17	166.43	10.88	12.14	0.29	1.13	0.06
25	25.29	8.24	2.14	25.63	9.97	1.81	0.65	0.97	0.51

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 6

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
12	9.42	10.67	0.07	9.42	10.67	0.07	1.16	0.96	2.21
24	45.91	9.27	0.64	57.01	10.33	1.70	0.85	1.19	0.41
25	7.63	0.00	0.04	21.33	9.91	1.39	0.78	0.98	0.67

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 7

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
12	11.55	11.55	0.25	10.76	11.42	0.18	1.02	0.90	0.84
24	44.60	8.69	0.41	50.43	9.98	1.01	0.96	1.23	0.70
25	16.98	8.76	1.07	19.84	9.58	1.28	0.84	1.01	0.73

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 8

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD

2	11.36	9.33	0.85	11.36	9.33	0.85	0.97	1.21	0.31
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
12	27.44	10.95	0.49	13.91	11.24	0.24	0.79	0.91	0.64
14	0.91	11.25	0.08	0.91	11.25	0.08	1.83	1.75	0.94
24	44.60	8.80	0.52	48.41	9.73	0.84	1.00	1.26	0.84
25	46.47	8.43	4.60	21.97	9.31	1.55	0.76	1.04	0.60

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 9

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	44.87	10.75	0.27	44.87	10.75	0.27	1.12	1.15	2.44
4	2.23	11.40	0.19	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
9	8.38	8.93	0.94	8.38	8.93	0.94	1.31	1.07	0.33
12	11.35	10.00	0.27	13.77	11.16	0.24	0.80	0.92	0.63
13	46.69	9.15	0.46	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.73	12.22	0.06	0.73	12.22	0.06	0.82	1.19	0.29
24	44.00	8.39	0.48	47.49	9.55	0.77	1.02	1.29	0.92
25	38.00	8.27	3.67	23.16	9.14	1.70	0.72	1.06	0.54

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 10

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD

2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	52.22	11.50	0.89	47.63	11.25	0.50	1.06	1.09	1.30
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	1.77	10.72	0.13	1.77	10.72	0.13	1.02	1.12	0.90
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	1.01	10.54	0.07	1.01	10.54	0.07	0.75	0.98	0.66
24	45.38	8.27	0.65	47.25	9.43	0.75	1.03	1.30	0.93
25	15.91	8.27	1.00	22.14	9.07	1.60	0.75	1.07	0.58

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 11

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	50.57	10.00	0.86	48.29	10.83	0.58	1.04	1.14	1.12
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	120.55	9.65	8.09	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
24	47.35	8.27	0.89	47.27	9.25	0.77	1.03	1.33	0.91
25	7.64	0.00	0.07	21.33	9.04	1.52	0.78	1.07	0.61

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 12

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
1	41.70	10.20	0.25	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	50.42	10.67	0.79	49.10	10.76	0.66	1.02	1.14	0.98
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
24	47.77	10.88	0.71	47.33	9.44	0.76	1.03	1.30	0.92
25	35.11	8.58	3.20	23.44	8.92	1.78	0.71	1.09	0.52

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 13

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
1	0.00	0.00	0.00	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	67.50	12.75	2.00	49.81	10.97	0.71	1.01	1.12	0.91
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
24	47.66	8.72	0.88	47.38	9.31	0.78	1.03	1.32	0.90
25	40.80	8.10	4.10	24.01	8.86	1.85	0.69	1.10	0.50

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 14

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
1	0.00	0.00	0.00	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	0.00	0.00	0.00	49.81	10.97	0.71	1.01	1.12	0.91
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
20	4.63	11.23	0.37	4.63	11.23	0.37	0.32	0.92	0.26
24	45.63	8.57	0.66	47.28	9.28	0.77	1.03	1.32	0.91
25	0.00	0.00	0.00	24.01	8.86	1.85	0.69	1.10	0.50

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 15

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
1	0.00	0.00	0.00	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	0.00	0.00	0.00	49.81	10.97	0.71	1.01	1.12	0.91
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58

6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
8	36.50	10.90	2.00	36.50	10.90	2.00	0.55	0.66	0.70
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
20	5.18	11.57	0.40	5.11	11.53	0.40	0.29	0.90	0.24
21	1.31	11.75	0.08	1.31	11.75	0.08	0.47	0.95	0.27
24	0.00	0.00	0.00	47.28	9.28	0.77	1.03	1.32	0.91
25	0.00	0.00	0.00	24.01	8.86	1.85	0.69	1.10	0.50

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 16

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
1	0.00	0.00	0.00	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	0.00	0.00	0.00	49.81	10.97	0.71	1.01	1.12	0.91
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
8	0.00	0.00	0.00	36.50	10.90	2.00	0.55	0.66	0.70
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
17	28.44	9.54	1.75	28.44	9.54	1.75	0.39	1.26	0.14
20	3.81	11.97	0.27	4.23	11.79	0.31	0.35	0.88	0.31
21	0.89	11.18	0.05	0.98	11.36	0.05	0.62	0.99	0.39
24	0.00	0.00	0.00	47.28	9.28	0.77	1.03	1.32	0.91
25	0.00	0.00	0.00	24.01	8.86	1.85	0.69	1.10	0.50

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 17

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
1	0.00	0.00	0.00	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	0.00	0.00	0.00	49.81	10.97	0.71	1.01	1.12	0.91
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
8	0.00	0.00	0.00	36.50	10.90	2.00	0.55	0.66	0.70
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
17	0.00	0.00	0.00	28.44	9.54	1.75	0.39	1.26	0.14
18	55.75	9.17	1.50	55.75	9.17	1.50	0.93	1.34	0.52
19	2.22	10.99	0.16	2.22	10.99	0.16	0.95	1.26	0.74
20	3.39	12.24	0.23	3.85	11.96	0.28	0.39	0.86	0.35
21	1.06	12.45	0.06	1.04	12.10	0.06	0.59	0.93	0.39
24	0.00	0.00	0.00	47.28	9.28	0.77	1.03	1.32	0.91
25	0.00	0.00	0.00	24.01	8.86	1.85	0.69	1.10	0.50

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 18

	CURRENT RATIOS			CUMULATIVE TO DATE			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
1	0.00	0.00	0.00	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	0.00	0.00	0.00	49.81	10.97	0.71	1.01	1.12	0.91
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25

8	0.00	0.00	0.00	36.50	10.90	2.00	0.55	0.66	0.70
9	0.00	0.00	0.00	8.38	8.93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
17	0.00	0.00	0.00	28.44	9.54	1.75	0.39	1.26	0.14
18	50.82	10.11	0.82	52.89	9.57	1.11	0.98	1.28	0.71
19	0.00	0.00	0.00	2.22	10.99	0.16	0.95	1.26	0.74
20	4.16	11.73	0.31	3.93	11.90	0.29	0.38	0.87	0.34
21	1.04	11.97	0.06	1.04	12.04	0.06	0.59	0.93	0.38
24	0.00	0.00	0.00	47.28	9.28	0.77	1.03	1.32	0.91
25	0.00	0.00	0.00	24.01	8.86	1.85	0.69	1.10	0.50

****

WEEKLY CONTROL RATIOS :

FOR WEEK # : 19

	CURRENT RATIOS			CUMULATIVE TO DAT			PERFORMANCE INDICES		
ACC	T/Q	L/MHR	MHR/Q	T/Q	L/MHR	MHR/Q	T.COST	LCOST	PROD
1	0.00	0.00	0.00	41.70	10.20	0.25	1.24	1.08	3.64
2	0.00	0.00	0.00	11.36	9.33	0.85	0.97	1.21	0.31
3	0.00	0.00	0.00	49.81	10.97	0.71	1.01	1.12	0.91
4	0.00	0.00	0.00	2.23	11.40	0.19	1.34	1.14	1.20
5	0.00	0.00	0.00	4.75	11.48	0.39	0.69	1.16	0.58
6	0.00	0.00	0.00	93.50	12.25	2.00	0.72	1.02	1.00
7	0.00	0.00	0.00	28.45	11.00	2.55	0.37	1.12	0.25
8	0.00	0.00	0.00	36.50	10.90	2.00	0.55	0.66	0.70
9	0.00	0.00	0.00	8.38	8 93	0.94	1.31	1.07	0.33
10	0.00	0.00	0.00	1.77	10.72	0.13	1.02	1.12	0.90
11	0.00	0.00	0.00	120.55	9.65	8.09	0.44	1.30	0.10
12	0.00	0.00	0.00	13.77	11.16	0.24	0.80	0.92	0.63
13	0.00	0.00	0.00	46.69	9.15	0.46	1.28	0.62	0.85
14	0.00	0.00	0.00	0.91	11.25	0.08	1.83	1.75	0.94
15	0.00	0.00	0.00	0.73	12.22	0.06	0.82	1.19	0.29
16	0.00	0.00	0.00	1.01	10.54	0.07	0.75	0.98	0.66
17	0.00	0.00	0.00	28.44	9.54	1.75	0.39	1.26	0.14
18	67.00	9.80	2.50	54.24	9.62	1.24	0.96	1.28	0.63
19	0.00	0.00	0.00	2.22	10.99	0.16	0.95	1.26	0.74
20	0.00	0.00	0.00	3.93	11.90	0.29	0.38	0.87	0.34
21	0.00	0.00	0.00	1.04	12.04	0.06	0.59	0.93	0.38
24	0.00	0.00	0.00	47.28	9.28	0.77	1.03	1.32	0.91
25	0.00	0.00	0.00	24.01	8.86	1.85	0.69	1.10	0.50

****

APPENDIX B

WEEKLY INFORMATION ANALYSIS REPORTS

INFORMATION ANALYSIS REPORT

FOR WEEK # : 1

ACC	OPTIMISTIC FORECAST $$$	OPTIMISTIC FORECAST MHR	PESSIMISTIC FORECAST $$$	PESSIMISTIC FORECAST MHR	VARIANCE EXPECTED $$$	VARIANCE EXPECTED MHR	COST ANALYSIS VAR. DUE TO LCOST	COST ANALYSIS VAR. DUE TO MAT¢L	LABOR COST VARIANCE DUE TO PROD	LABOR COST VARIANCE DUE TO RATE	LABOR COST VARIANCE DUE TO MIX	PERFORMANCE MEASURED IN TERMS OF COST	PERFORMANCE MEASURED IN TERMS OF PROD	PERFORMANCE MEASURED IN TERMS OF LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1452	35	1452	35	0	0	0	0	0	0	0	1.00	1.00	1.00
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	433	30	433	30	0	0	0	0	0	0	0	1.00	1.00	1.00
6	135	4	135	4	0	0	0	0	0	0	0	1.00	1.00	1.00
7	210	13	210	13	0	0	0	0	0	0	0	1.00	1.00	1.00
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3728	52	3728	52	0	0	0	0	0	0	0	1.00	1.00	1.00
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	785	34	785	34	0	0	0	0	0	0	0	1.00	1.00	1.00
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27618	400	27618	400	0	0	0	0	0	0	0	1.00	1.00	1.00
25	166044	10605	166044	10605	-161004	-10324	-109436	-51568	-162202	-42642	95408	0.03	0.03	0.62
SUM:	241074	12397	241074	12397	-161004	-10324	-109436	-51568	-162202	-42642	95408			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 2

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1452	35	1452	35	0	0	0	0	0	0	0	1.00	1.00	1.00
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	433	30	433	30	0	0	0	0	0	0	0	1.00	1.00	1.00
6	135	4	135	4	0	0	0	0	0	0	0	1.00	1.00	1.00
7	210	13	210	13	0	0	0	0	0	0	0	1.00	1.00	1.00
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3728	52	3728	52	0	0	0	0	0	0	0	1.00	1.00	1.00
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	785	34	785	34	0	0	0	0	0	0	0	1.00	1.00	1.00
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27618	400	27618	400	0	0	0	0	0	0	0	1.00	1.00	1.00
25	5402	251	15615	909	-5468	-299	-3728	-1740	-3071	-2447	1790	0.32	0.31	0.66
SUM:	80432	2043	90645	2701	-5468	-299	-3728	-1740	-3071	-2447	1790			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 3

ACC	OPTIMISTIC FORECAST $$$ F1	OPTIMISTIC FORECAST MHR F2	PESSIMISTIC FORECAST $$$ F1	PESSIMISTIC FORECAST MHR F2	VARIANCE EXPECTED $$$ F3	VARIANCE EXPECTED MHR F4	COST ANALYSIS VAR. DUE TO LCOST F6	COST ANALYSIS VAR. DUE TO MAT¢L F7	LABOR COST VARIANCE DUE TO PROD F5	LABOR COST VARIANCE DUE TO RATE F8	LABOR COST VARIANCE DUE TO MIX F9	PERFORMANCE MEASURED IN TERMS OF COST F10	PERFORMANCE MEASURED IN TERMS OF PROD F11	PERFORMANCE MEASURED IN TERMS OF LCOST F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1452	35	1452	35	0	0	0	0	0	0	0	1.00	1.00	1.00
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	632	52	632	52	-199	-22	-114	-85	-234	81	39	0.69	0.58	1.16
6	135	4	135	4	0	0	0	0	0	0	0	1.00	1.00	1.00
7	210	13	210	13	0	0	0	0	0	0	0	1.00	1.00	1.00
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3728	52	3728	52	0	0	0	0	0	0	0	1.00	1.00	1.00
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	785	34	785	34	0	0	0	0	0	0	0	1.00	1.00	1.00
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27618	400	27618	400	0	0	0	0	0	0	0	1.00	1.00	1.00
25	4816	333	8410	525	-1573	-148	-907	-666	-1086	-770	949	0.60	0.54	0.83
SUM:	80045	2147	83639	2339	-1772	-170	-1021	-751	-1320	-689	988			

NFORMATION ANALYSIS REPORT

FOR WEEK # : 4

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1452	35	1452	35	0	0	0	0	0	0	0	1.00	1.00	1.00
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-262	-97	-412	50	101	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3728	52	3728	52	0	0	0	0	0	0	0	1.00	1.00	1.00
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	785	34	785	34	0	0	0	0	0	0	0	1.00	1.00	1.00
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	444744	40896	444744	40896	-417126	-40496	-293029	-124097	-440205	38836	108340	0.06	0.01	1.13
25	5880	333	7836	481	-1818	-126	-1347	-471	-1259	-685	597	0.64	0.58	0.84
SUM:	498646	42681	500602	42829	-419554	-40682	-294793	-124761	-442110	38283	109035			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 5

ACC	OPTIMISTIC FORECAST $$$ F1	OPTIMISTIC FORECAST MHR F2	PESSIMISTIC FORECAST $$$ F1	PESSIMISTIC FORECAST MHR F2	VARIANCE EXPECTED $$$ F3	VARIANCE EXPECTED MHR F4	COST ANALYSIS VAR. DUE TO LCOST F6	COST ANALYSIS VAR. DUE TO MAT¢L F7	LABOR COST VARIANCE DUE TO PROD F5	LABOR COST VARIANCE DUE TO RATE F8	LABOR COST VARIANCE DUE TO MIX F9	PERFORMANCE MEASURED IN TERMS OF COST F10	PERFORMANCE MEASURED IN TERMS OF PROD F11	PERFORMANCE MEASURED IN TERMS OF LCOST F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1452	35	1452	35	0	0	0	0	0	0	0	1.00	1.00	1.00
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3728	52	3728	52	0	0	0	0	0	0	0	1.00	1.00	1.00
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	785	34	785	34	0	0	0	0	0	0	0	1.00	1.00	1.00
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	36882	1301	94531	6897	-38089	-3699	-26327	-11762	-29930	4041	-439	0.29	0.06	1.13
25	7691	550	7765	621	-2688	-304	-1815	-873	-2910	-131	1226	0.65	0.51	0.97
SUM:	92595	3303	150318	8970	-41387	-4063	-28628	-12759	-33486	4042	815			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 6

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1452	35	1452	35	0	0	0	0	0	0	0	1.00	1.00	1.00
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3204	24	3204	24	524	28	180	344	296	-14	-102	1.16	2.21	0.96
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	785	34	785	34	0	0	0	0	0	0	0	1.00	1.00	1.00
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26922	443	32383	964	-2035	-303	-1056	-979	-1865	1180	-370	0.85	0.41	1.19
25	3860	164	6462	421	-121	-12	519	-639	314	-60	264	0.78	0.67	0.98
SUM:	78280	2031	86343	2809	-2242	-347	-843	-1398	-1901	1238	-180			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 7

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1452	35	1452	35	0	0	0	0	0	0	0	1.00	1.00	1.00
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3650	61	3660	62	73	-9	-133	206	-127	-69	63	1.02	0.84	0.90
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	785	34	785	34	0	0	0	0	0	0	0	1.00	1.00	1.00
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26278	329	28642	575	158	-52	753	-595	268	1005	-520	0.96	0.70	1.23
25	5637	360	6011	388	-784	-93	-507	-276	-794	42	245	0.84	0.73	1.01
SUM:	79859	2150	82607	2425	-1163	-214	-373	-789	-1299	1110	-184			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 8

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1500	112	1500	112	-48	-77	-410	362	-695	171	114	0.97	0.31	1.21
3	8894	115	8894	115	0	0	0	0	0	0	0	1.00	1.00	1.00
4	78	6	78	6	0	0	0	0	0	0	0	1.00	1.00	1.00
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	176	5	176	5	0	0	0	0	0	0	0	1.00	1.00	1.00
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	3460	58	4731	81	-367	-18	-192	-176	-178	-64	51	0.79	0.64	0.91
13	10724	70	10724	70	0	0	0	0	0	0	0	1.00	1.00	1.00
14	430	36	430	36	355	-2	273	83	73	299	-100	1.83	0.94	1.75
15	696	20	696	20	0	0	0	0	0	0	0	1.00	1.00	1.00
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26278	376	27495	479	731	-28	944	-213	291	1073	-420	1.00	0.84	1.26
25	6658	468	9499	823	-3039	-364	-2047	-991	-3749	208	1494	0.76	0.60	1.04
SUM:	80383	2381	85712	2862	-2978	-549	-1918	-1059	-4904	1819	1167			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 9

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	7941	47	7941	47	953	68	666	287	789	109	-232	1.12	2.44	1.15
4	58	5	58	5	20	1	17	3	15	9	-6	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	134	15	134	15	42	-10	-56	98	-88	8	24	1.31	0.33	1.07
10	923	60	923	60	0	0	0	0	0	0	0	1.00	1.00	1.00
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	4682	79	4972	82	-1099	-28	-283	-816	-339	-66	122	0.80	0.63	0.92
13	8357	82	8357	82	2367	-12	-314	2681	-190	-269	144	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	850	70	850	70	-154	-50	-358	204	-590	121	111	0.82	0.29	1.19
16	4400	280	4400	280	0	0	0	0	0	0	0	1.00	1.00	1.00
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26085	362	26975	436	1088	1	1197	-109	544	1093	-439	1.02	0.92	1.29
25	7019	516	8517	714	-2728	-334	-1809	-918	-3197	283	1105	0.72	0.54	1.06
SUM:	78545	2439	81223	2714	186	-503	-1686	1873	-4324	1890	749			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 10

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	8430	89	9133	148	113	-3	85	28	-119	125	79	1.06	1.30	1.09
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	25	-11	-50	81	-6	1.02	0.90	1.12
11	525	8	525	8	0	0	0	0	0	0	0	1.00	1.00	1.00
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1081	-408	-1550	-84	552	0.75	0.66	0.98
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26436	406	26839	428	981	-17	1124	-143	312	1178	-366	1.03	0.93	1.30
25	6286	445	6710	486	-1458	-185	-925	-532	-1533	258	350	0.75	0.58	1.07
SUM:	82555	2664	84085	2786	-3249	-652	-3215	-33	-6044	1965	864			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 11

ACC	OPTIMISTIC FORECAST $$$ F1	OPTIMISTIC FORECAST MHR F2	PESSIMISTIC FORECAST $$$ F1	PESSIMISTIC FORECAST MHR F2	VARIANCE EXPECTED $$$ F3	VARIANCE EXPECTED MHR F4	COST ANALYSIS VAR. DUE TO LCOST F6	COST ANALYSIS VAR. DUE TO MAT¢L F7	LABOR COST VARIANCE DUE TO PROD F5	LABOR COST VARIANCE DUE TO RATE F8	LABOR COST VARIANCE DUE TO MIX F9	PERFORMANCE MEASURED IN TERMS OF COST F10	PERFORMANCE MEASURED IN TERMS OF PROD F11	PERFORMANCE MEASURED IN TERMS OF LCOST F12
1	570	10	570	10	0	0	0	0	0	0	0	1.00	1.00	1.00
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	8547	103	8880	143	180	-8	155	25	-68	178	45	1.04	1.12	1.14
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1205	81	1205	81	-680	-73	-446	-234	-696	161	89	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26847	438	26861	457	764	-48	980	-216	-18	1313	-315	1.03	0.91	1.33
25	5724	382	6463	460	-1053	-140	-674	-379	-1074	248	152	0.78	0.61	1.07
SUM:	83201	2720	84287	2857	-3674	-716	-3751	77	-6560	2304	505			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 12

ACC	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	459	3	459	3	111	7	57	54	77	4	-23	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	8691	117	8858	133	119	-10	111	9	-75	189	-4	1.02	0.98	1.14
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26881	429	26928	434	714	-32	896	-182	55	1203	-362	1.03	0.92	1.30
25	7102	538	7207	551	-2114	-263	-1355	-760	-2290	360	575	0.71	0.52	1.09
SUM:	84767	2882	85086	2916	-4856	-826	-4686	-170	-7711	2337	689			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 13

ACC	OPTIMISTIC FORECAST $$$ F1	OPTIMISTIC FORECAST MHR F2	PESSIMISTIC FORECAST $$$ F1	PESSIMISTIC FORECAST MHR F2	VARIANCE EXPECTED $$$ F3	VARIANCE EXPECTED MHR F4	COST ANALYSIS VAR. DUE TO LCOST F6	COST ANALYSIS VAR. DUE TO MAT¢L F7	LABOR COST VARIANCE DUE TO PROD F5	LABOR COST VARIANCE DUE TO RATE F8	LABOR COST VARIANCE DUE TO MIX F9	PERFORMANCE MEASURED IN TERMS OF COST F10	PERFORMANCE MEASURED IN TERMS OF PROD F11	PERFORMANCE MEASURED IN TERMS OF LCOST F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	8816	126	11028	287	-1028	-91	-639	-389	-1395	236	521	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	4500	290	4500	290	0	0	0	0	0	0	0	1.00	1.00	1.00
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26910	444	26916	446	705	-45	912	-207	-22	1281	-346	1.03	0 90	1.32
25	7258	559	7275	561	-2227	-279	-1445	-781	-2389	396	548	0.69	0.50	1.10
SUM:	85452	2929	87687	3094	-6500	-938	-5516	-983	-9230	2499	1217			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 14

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT'L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	2590	37	2590	37	6304	78	867	5437	907	84	-124	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	400	28	400	28	0	0	0	0	0	0	0	1.00	1.00	1.00
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	13900	1100	13900	1100	-9400	-810	-6319	-3081	-9179	-732	3593	0.32	0.26	0.92
21	1367	48	1367	48	0	0	0	0	0	0	0	1.00	1.00	1.00
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	26854	440	26869	441	756	-41	947	-191	22	1287	-362	1.03	0.91	1.32
25	7299	563	7299	563	-2259	-282	-1843	-416	-2418	398	177	0.69	0.50	1.10
SUM:	88611	3650	88626	3651	-8549	-1578	-10692	2143	-16092	1623	3778			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 15

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	2590	37	2590	37	6304	78	867	5437	907	84	-124	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	730	40	730	40	-330	-12	-192	-138	-166	-135	109	0.55	0.70	0.66
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	176	4	176	4	0	0	0	0	0	0	0	1.00	1.00	1.00
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	15320	1193	15500	1205	-10910	-909	-7349	-3561	-10637	-1062	4351	0.29	0.24	0.90
21	2934	179	2934	179	-1567	-131	-1054	-514	-1550	-73	570	0.47	0.27	0.95
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27280	447	27280	447	338	-47	842	-504	-34	1300	-423	1.03	0.91	1.32
25	7299	563	7299	563	-2259	-282	-1843	-416	-2418	398	177	0.69	0.50	1.10
SUM:	92354	3893	92534	3905	-12374	-1826	-13073	698	-19322	1098	5154			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 16

ACC	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	2590	37	2590	37	6304	78	867	5437	907	84	-124	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	730	40	730	40	-330	-12	-214	-116	-166	-135	87	0.55	0.70	0.66
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	455	28	455	28	-279	-24	-143	-136	-226	49	34	0.39	0.14	1.26
18	1457	22	1457	22	0	0	0	0	0	0	0	1.00	1.00	1.00
19	2316	134	2316	134	0	0	0	0	0	0	0	1.00	1.00	1.00
20	12022	881	12696	945	-7859	-623	-5336	-2523	-7382	-1018	3063	0.35	0.31	0.88
21	2045	109	2206	122	-759	-67	-511	-247	-739	-14	242	0.62	0.39	0.99
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27280	447	27280	447	338	-47	842	-504	-34	1300	-423	1.03	0.91	1.32
25	7299	563	7299	563	-2259	-282	-1843	-416	-2418	398	177	0.69	0.50	1.10
SUM:	88446	3535	89281	3612	-8794	-1500	-10682	1889	-15482	1250	3550			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 17

ACC	OPTIMISTIC FORECAST $$$ F1	OPTIMISTIC FORECAST MHR F2	PESSIMISTIC FORECAST $$$ F1	PESSIMISTIC FORECAST MHR F2	VARIANCE EXPECTED $$$ F3	VARIANCE EXPECTED MHR F4	COST ANALYSIS VAR. DUE TO LCOST F6	COST ANALYSIS VAR. DUE TO MAT¢L F7	LABOR COST VARIANCE DUE TO PROD F5	LABOR COST VARIANCE DUE TO RATE F8	LABOR COST VARIANCE DUE TO MIX F9	PERFORMANCE MEASURED IN TERMS OF COST F10	PERFORMANCE MEASURED IN TERMS OF PROD F11	PERFORMANCE MEASURED IN TERMS OF LCOST F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	2590	37	2590	37	6304	78	867	5437	907	84	-124	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	730	40	730	40	-330	-12	-214	-116	-166	-135	87	0.55	0.70	0.66
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	455	28	455	28	-279	-24	-181	-98	-226	49	-5	0.39	0.14	1.26
18	1561	42	1561	42	-104	-20	-54	-50	-161	110	-3	0.93	0.52	1.34
19	2445	180	2445	180	-129	-46	45	-174	-378	470	-47	0.95	0.74	1.26
20	11352	816	11544	835	-6948	-536	-4730	-2218	-6535	-1046	2851	0.39	0.35	0.86
21	2326	124	2348	125	-970	-76	-662	-308	-944	-88	370	0.59	0.39	0.93
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27280	447	27280	447	338	-47	842	-504	-34	1300	-423	1.03	0.91	1.32
25	7299	563	7299	563	-2259	-282	-1843	-416	-2418	398	177	0.69	0.50	1.10
SUM:	88290	3551	88504	3571	-8327	-1488	-10274	1947	-15379	1728	3377			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 18

ACC	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	2590	37	2590	37	6304	78	867	5437	907	84	-124	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	730	40	730	40	-330	-12	-214	-116	-166	-135	87	0.55	0.70	0.66
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	455	28	455	28	-279	-24	-181	-98	-226	49	-5	0.39	0.14	1.26
18	1462	28	1481	31	-15	-8	9	-24	-51	73	-14	0.98	0.71	1.28
19	2445	180	2445	180	-129	-46	-39	-90	-378	470	-131	0.95	0.74	1.26
20	11672	848	11783	859	-7228	-564	-4948	-2280	-6841	-1033	2927	0.38	0.34	0.87
21	2330	125	2332	125	-964	-77	-661	-303	-942	-83	364	0.59	0.38	0.93
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27280	447	27280	447	338	-47	842	-504	-34	1300	-423	1.03	0.91	1.32
25	7299	563	7299	563	-2259	-282	-1843	-416	-2418	398	177	0.69	0.50	1.10
SUM:	88515	3570	88647	3584	-8512	-1505	-10512	2000	-15573	1709	3352			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 19

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	2590	37	2590	37	6304	78	867	5437	907	84	-124	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	730	40	730	40	-330	-12	-214	-116	-166	-135	87	0.55	0.70	0.66
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	455	28	455	28	-279	-24	-181	-98	-226	49	-5	0.39	0.14	1.26
18	1519	35	1608	44	-106	-17	-52	-55	-160	89	20	0.96	0.63	1.28
19	2445	180	2445	180	-129	-46	-39	-90	-378	470	-131	0.95	0.74	1.26
20	13684	998	13684	998	-9184	-708	-7469	-1715	-8573	-1183	2286	0.38	0.34	0.87
21	2700	145	2700	145	-1333	-97	-1013	-320	-1181	-94	262	0.59	0.38	0.93
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27280	447	27280	447	338	-47	842	-504	-34	1300	-423	1.03	0.91	1.32
25	7299	563	7299	563	-2259	-282	-1843	-416	-2418	398	177	0.69	0.50	1.10
SUM:	90954	3747	91043	3756	-10928	-1678	-13446	2517	-17653	1564	2643			

INFORMATION ANALYSIS REPORT

FOR WEEK # : 20

	OPTIMISTIC FORECAST		PESSIMISTIC FORECAST		VARIANCE EXPECTED		COST ANALYSIS VAR. DUE TO		LABOR COST VARIANCE DUE TO			PERFORMANCE MEASURED IN TERMS OF		
ACC	$$$	MHR	$$$	MHR	$$$	MHR	LCOST	MAT¢L	PROD	RATE	MIX	COST	PROD	LCOST
	F1	F2	F1	F2	F3	F4	F6	F7	F5	F8	F9	F10	F11	F12
1	834	5	834	5	-264	5	51	-315	54	5	-9	1.24	3.64	1.08
2	1500	112	1500	112	-48	-77	-529	481	-695	171	-5	0.97	0.31	1.21
3	2590	37	2590	37	6304	78	867	5437	907	84	-124	1.01	0.91	1.12
4	58	5	58	5	20	1	19	1	15	9	-4	1.34	1.20	1.14
5	632	52	632	52	-199	-22	-156	-43	-234	81	-3	0.69	0.58	1.16
6	187	4	187	4	-52	0	1	-53	0	1	0	0.72	1.00	1.02
7	569	51	569	51	-359	-38	-331	-28	-412	50	31	0.37	0.25	1.12
8	730	40	730	40	-330	-12	-214	-116	-166	-135	87	0.55	0.70	0.66
9	134	15	134	15	42	-10	-71	113	-88	8	9	1.31	0.33	1.07
10	909	67	909	67	14	-7	13	1	-50	81	-18	1.02	0.90	1.12
11	1326	89	1326	89	-801	-81	-629	-172	-774	177	-31	0.44	0.10	1.30
12	6334	111	6334	111	-2606	-59	-597	-2009	-675	-85	163	0.80	0.63	0.92
13	8871	87	8871	87	1853	-17	-371	2224	-236	-281	146	1.28	0.85	0.62
14	430	36	430	36	355	-2	269	86	73	299	-103	1.83	0.94	1.75
15	1112	91	1112	91	-416	-71	-677	261	-852	154	21	0.82	0.29	1.19
16	5889	425	5889	425	-1489	-145	-1336	-153	-1550	-84	297	0.75	0.66	0.98
17	455	28	455	28	-279	-24	-181	-98	-226	49	-5	0.39	0.14	1.26
18	1139	26	1139	26	318	-4	26	292	-19	66	-20	0.96	0.63	1.28
19	2445	180	2445	180	-129	-46	-39	-90	-378	470	-131	0.95	0.74	1.26
20	13684	998	13684	998	-9184	-708	-7469	-1715	-8573	-1183	2286	0.38	0.34	0.87
21	2700	145	2700	145	-1333	-97	-1013	-320	-1181	-94	262	0.59	0.38	0.93
22	2585	96	2585	96	0	0	0	0	0	0	0	1.00	1.00	1.00
23	882	28	882	28	0	0	0	0	0	0	0	1.00	1.00	1.00
24	27280	447	27280	447	338	-47	842	-504	-34	1300	-423	1.03	0.91	1.32
25	7299	563	7299	563	-2259	-282	-1843	-416	-2418	398	177	0.69	0.50	1.10
SUM:	90574	3738	90574	3738	-10504	-1665	-13368	2864	-17512	1541	2603			

APPENDIX C

SOURCE CODE FOR RAT PROGRAM

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=U11769A.P.PAS

PROGRAM PROJECT(FILE1,FILE2,OUTPUT);

TYPE
  MAINREC = RECORD
          MHR : INTEGER;
            L : INTEGER;
            T : INTEGER;
            Q : INTEGER;
          TPERQ   :REAL;
          MHRPERQ :REAL;
          LPERMHR :REAL;
       END;
   MAIN1 = ARRAY ¢1..25,1..19! OF MAINREC ;
   MAIN2 = ARRAY ¢1..25! OF MAINREC ;
   U     = PACKED ARRAY ¢1..5! OF CHAR;
   IND   = ARRAY ¢1..25,1..19! OF REAL;
   UT    = ARRAY ¢1..25! OF U;

VAR
  TRANS , ACUM : MAIN1;
  BUDGET : MAIN2;
  UNIT   : UT ;
  ACC , WK ,QA,QB,TB,MHRA,MHRB,MHRT: INTEGER ;
  TQT,TQA,MHRQT,MHRQA,LMHRT,LMHRA : IND;
  FILE1 , FILE2 : TEXT;
  F1M,F2M,F1L,F2L,F3,F4,F5,F6,F7,F8,F9 : INTEGER;
  TF1M,TF1L,TF2M,TF2L,TF3,TF4,TF5,TF6,TF7,TF8,TF9  : INTEGER;
  C,C1,C2,M,M1,M2,V1,V2,  P,P1,P2,LT,L1,L2,L3,L4,L5,L6,
  R,R1,R2,R3,TPQA,TPQT, MPQA,MPQT,LPMA,LPMB,LPMT : REAL;
  F10,F11,F12 : REAL;

{ **************************************************** }

PROCEDURE INITIALIZE ;

BEGIN
  FOR ACC := 1 TO 25 DO
   FOR WK := 1 TO 19 DO
   WITH TRANS¢ACC,WK! DO
    BEGIN
      MHR := 0;
        L := 0;
        T := 0;
        Q := 0;
      TPERQ:=0;
      MHRPERQ:= 0;
      LPERMHR:= 0;
    END
END;

{ *********************************************** }

PROCEDURE FILLBUDGET ;
BEGIN
  RESET (FILE1);
  WRITELN;
  WRITELN('THE BUDGET FILE : ');
  WRITELN('----------------- ');
  WRITELN;
  WRITELN('ACC  TCOST   LCOST   MHR   QUAT  T/Q   MHR/Q  L/MHR  UNIT');
  WRITELN('----------------------------------------------------------');
  WRITELN;
```

```
  FOR ACC := 1 TO 25 DO
  BEGIN
    WITH BUDGET¢ACC! DO
      READ(FILE1,T,L,MHR,Q);
    READLN(FILE1,UNIT¢ACC!);
    WITH BUDGET¢ACC! DO
    BEGIN
      TPERQ := T/Q;
      MHRPERQ := MHR / Q;
      LPERMHR := L / MHR;
      WRITE(ACC:3,T:7,L:8,MHR:5,Q:6);
      WRITE(TPERQ:8:2,MHRPERQ:7:2,LPERMHR:7:2);
    END;
    WRITELN(UNIT¢ACC!:6);
  END;
END;

{ ********************************************************** }

PROCEDURE FILLTRANS ;
BEGIN
  RESET(FILE2);
  WRITELN;
  WRITELN('THE  TRANSACTION FILE:');
  WRITELN('----------------------');
  WRITELN;
  WRITELN(' WK# ACC  MHR    L$   T$    Q    T/Q    MHR/Q    L/MHR');
  WRITELN('-------------------------------------------------------');
  WHILE NOT EOF(FILE2) DO
  BEGIN
    READ(FILE2,WK,ACC);
    WITH TRANS¢ACC,WK! DO
    BEGIN
      READLN(FILE2,MHR,L,T,Q);
      TPERQ := T/Q;
      MHRPERQ := MHR / Q;
      LPERMHR := L / MHR;
      WRITE(WK:3,ACC:5,MHR:5,L:6,T:6,Q:5);
      WRITELN(TPERQ:8:2,MHRPERQ:7:2,LPERMHR:9:2);
    END;
  END
END;

{ ************************************************ }

PROCEDURE FILLACUM ;

BEGIN
  WRITELN;
  WRITELN;
  WRITELN('THE  ACUMULATIVE DATA :');
  WRITELN('-----------------------');
  WRITELN;
  WRITELN(' WK#  ACC  MHR   L$   T$   Q    T/Q    MHR/Q    L/MHR');
  WRITELN('-------------------------------------------------------');
  WRITELN;

  FOR ACC := 1 TO 25 DO
   BEGIN
    ACUM¢ACC,1!.MHR := TRANS¢ACC,1!.MHR;
    ACUM¢ACC,1!.L   := TRANS¢ACC,1!.L;
    ACUM¢ACC,1!.T   := TRANS¢ACC,1!.T;
    ACUM¢ACC,1!.Q   := TRANS¢ACC,1!.Q;

    WITH ACUM¢ACC,1! DO
      IF (Q <> 0) THEN
```

```
      BEGIN
        TPERQ := T / Q;
        MHRPERQ := MHR / Q;
        LPERMHR := L / MHR;
      END;

    FOR WK := 2 TO 19 DO
    BEGIN
     ACUM¢ACC,WK!.MHR := ACUM¢ACC,WK-1!.MHR + TRANS¢ACC,WK!.MHR;
     ACUM¢ACC,WK!.L := ACUM¢ACC,WK-1!.L + TRANS¢ACC,WK!.L;
     ACUM¢ACC,WK!.T := ACUM¢ACC,WK-1!.T + TRANS¢ACC,WK!.T;
     ACUM¢ACC,WK!.Q := ACUM¢ACC,WK-1!.Q + TRANS¢ACC,WK!.Q;
     WITH ACUM¢ACC,WK! DO
     IF (Q <> O) THEN
     BEGIN
       TPERQ := T / Q;
       MHRPERQ := MHR / Q;
       LPERMHR := L / MHR;
     END;
    END;
  END;

    FOR WK := 1 TO 19 DO
    BEGIN
      FOR ACC:= 1 TO 25 DO
      IF (TRANS¢ACC,WK!.Q <> O)  THEN
      WITH ACUM¢ACC,WK! DO
      BEGIN
         WRITE(WK:3,ACC:5,MHR:5,L:6,T:6,Q:5);
         WRITELN(TPERQ:8:2,MHRPERQ:7:2,LPERMHR:10:2);
      END;
      WRITELN;
    END
END;

{ ********************************************* }

PROCEDURE PRINTIND(A:IND) ;
VAR
  ROW,COL : INTEGER;

BEGIN
  WRITELN;
  WRITE('     ');
  FOR COL := 1 TO 19 DO
   WRITE(COL:5,' ');
  WRITELN;
  WRITE('   ');
  FOR COL := 1 TO 116 DO
    WRITE('*');
  WRITELN;
  FOR ROW := 1 TO 25 DO
  BEGIN
    WRITE(ROW:2,'* ');
    FOR COL := 1 TO 19 DO
    IF (A¢ROW,COL! <> O) THEN
       WRITE(A¢ROW,COL!:6:2)
    ELSE WRITE('    ** ');
    WRITELN;
  END;

  WRITELN;
  WRITELN('             *********************************** ');
  WRITELN;
END;
```

```
{ ******************************************** }

PROCEDURE INDICES ;

BEGIN
  WRITELN;
  WRITELN;
  WRITELN('              THE PERFORMANCE INDICES    ');
  WRITELN('              -----------------------    ');
  WRITELN;

  FOR ACC := 1 TO 25 DO
   FOR WK := 1 TO 19 DO
    BEGIN
      TQA¢ACC,WK! := 0;
      MHRQA¢ACC,WK! := 0;
      LMHRA¢ACC,WK! := 0;
    END;

   FOR ACC := 1 TO 25 DO
    FOR WK := 1 TO 19 DO
    BEGIN

     IF (ACUM¢ACC,WK!.TPERQ <> 0) THEN
      TQA¢ACC,WK! :=BUDGET¢ACC!.TPERQ / ACUM¢ACC,WK!.TPERQ;

     IF (ACUM¢ACC,WK!.LPERMHR <> 0) THEN
      LMHRA¢ACC,WK! := BUDGET¢ACC!.LPERMHR / ACUM¢ACC,WK!.LPERMHR;

     IF (ACUM¢ACC,WK!.MHRPERQ <> 0) THEN
      MHRQA¢ACC,WK! := BUDGET¢ACC!.MHRPERQ / ACUM¢ACC,WK!.MHRPERQ;

    END;
   WRITELN('THE TCOST/Q :');
   WRITELN('-------------');
   PRINTIND(TQA);
   WRITELN('THE MHR/Q :');
   WRITELN('-----------');
   PRINTIND(MHRQA);
   WRITELN('THE LCOST/MHR :');
   WRITELN('---------------');
   PRINTIND(LMHRA);
END;
{ ********************************************  }

PROCEDURE SUMTRANS ;

BEGIN
  WRITELN;
  WRITELN;
  WRITELN('SUMMARY OF TRANSACTION FILE :');
  WRITELN('-----------------------------');
  WRITELN;

  FOR ACC := 1 TO 25 DO
  IF (ACC IN ¢3,12,13,20,21,24,25!) THEN
  BEGIN
    WRITELN('FOR ACC# ',ACC:5);
    WRITELN('--------------');
    WRITELN;
    WRITELN('CONTROL BUDGET DATA');
    WRITELN(' MHR     LCOST   TCOST   QUANT ');
    WRITELN(' ----------------------------- ');
    WITH BUDGET¢ACC! DO
      WRITELN(MHR:5,L:8,T:8,Q:6);
```

```
    WRITELN;
    WRITELN('          CURRENT    DATA              CUMULATIVE TO DATE ');
    WRITELN('          --------------               ------------------ ');
    WRITELN(' WK#     MHR    L$    Q     T$         MHR    L$     Q     T$');
    WRITELN(' -------------------------------------------------------------');
    WRITELN;
    FOR WK := 1 TO 19 DO
      IF (TRANS¢ACC,WK!.Q <> 0) THEN
      BEGIN
        WITH TRANS¢ACC,WK! DO
         WRITE(WK:4,MHR:6,L:6,Q:5,T:6);
        WITH ACUM¢ACC,WK! DO
         WRITELN(MHR:10,L:6,Q:5,T:6);
      END;
    WRITELN(' -------------------------------------------------------------');
    WRITELN('UNIT:    MHR  $$$  EACH  $$$        MHR  $$$    EACH   $$$ ');
    WRITELN('--------------------------------------------------------------');
    WRITE('SUM ');

    FOR WK := 1 TO 2 DO
    BEGIN
     WITH ACUM¢ACC,19! DO
       WRITE(MHR:6,L:6,Q:5,T:6);
     WRITE('     ');
    END;
    WRITELN;
    WRITELN('-------------------------------------------------------------');
    WRITELN;
    WRITELN;
    WRITELN('     ************************************      ');
    WRITELN;
    WRITELN;
  END;
END;

{ ********************************************* }

PROCEDURE SUMCONTROL ;

BEGIN
  WRITELN;
  WRITELN('THE SUMMARY OF CONTROL RATIOS :');
  WRITELN('-------------------------------');
  WRITELN;
  FOR ACC := 1 TO 25 DO
  IF (ACC IN ¢3,12,13,20,21,24,25!) THEN
  BEGIN
    WRITELN('FOR ACC# :',ACC:5);
    WRITELN('---------------');
    WRITELN;
    WRITE('               CURRENT  RATIOS            CUMULATIVE TO DATE');
    WRITELN('   PERFORMANCE IND. ');
    WRITE('               ---------------            ------------------');
    WRITELN('   ---------------- ');
    WRITE(' WK#     T/Q     L/MHR     MHR/Q       T/Q     L/MHR    MHR/Q');
    WRITELN('  T.COST L.COST  PROD');
    WRITE(' ------------------------------------------------------------');
    WRITELN('---------------------');
    WRITELN;
    FOR WK := 1 TO 19 DO
    IF (TRANS¢ACC,WK!.Q <> 0) THEN
    BEGIN
      WITH TRANS¢ACC,WK! DO
        WRITE(WK:4,TPERQ:8:2,LPERMHR:8:2,MHRPERQ:8:2);
      WITH ACUM¢ACC,WK! DO
        WRITE(TPERQ:12:2,LPERMHR:8:2,MHRPERQ:8:2);
```

```
      WRITELN(TQA¢ACC,WK!:8:2,LMHRA¢ACC,WK!:7:2,MHRQA¢ACC,WK!:7:2);
    END:
    WRITE('----------------------------------------------------');
    WRITELN('-------------------------');
    WRITE('BASE');
    FOR WK := 1 TO 2 DO
    BEGIN
       WITH BUDGET¢ACC! DO
          WRITE(TPERQ:8:2,LPERMHR:8:2,MHRPERQ:8:2);
       WRITE('     ');
    END;
    WRITELN('1.00    1.00    1.00');
    WRITELN;
    WRITE('LINE    $/EA     $/HR     MHR/EA        $/EA     $/HR     MHR/EA');
    WRITELN(' INDEX  INDEX  INDEX');
    WRITE('---------------------------------------------------------');
    WRITELN('----------------------');
    WRITELN;
    WRITELN('     ******************************************     ');
    WRITELN;
  END;
END;

{ ********************************************   }

PROCEDURE SUM2 ;

BEGIN
  WRITELN;
  WRITELN;
  WRITELN('THE ACUAL COST DATA WEEKLY : ');
  WRITELN('---------------------------- ');
  WRITELN;
  FOR WK := 1 TO 19 DO
  BEGIN
    WRITELN('FOR WEEK # :',WK:5);
    WRITELN('-----------------');
    WRITELN;
    WRITE('          CURRENT  DATA            CUMULATIVE TO DATE ');
    WRITELN('       CONTROL BUDGET ');
    WRITE('          -------------            ------------------ ');
    WRITELN('       -------------- ');
    WRITE(' ACC    MHR     L$     Q    T$        MHR   L$     Q     T$');
    WRITELN('      MHR    L$     T$     Q');
    WRITE(' -----------------------------------------------------');
    WRITELN('---------------------');
    WRITELN;
    FOR ACC := 1 TO 25 DO
    IF (ACUM¢ACC,WK!.Q <> 0) THEN
    BEGIN
      WITH TRANS¢ACC,WK! DO
        WRITE(ACC:4,MHR:6,L:6,Q:5,T:6);
      WITH ACUM¢ACC,WK! DO
        WRITE(MHR:8,L:6,Q:5,T:6);
      WITH BUDGET¢ACC! DO
        WRITELN(MHR:8,L:6,T:6,Q:5);
    END;
    WRITE('------------------------------------------------------------');
    WRITELN('-----------------');
    WRITELN;
    WRITELN('     ***************************************  ');
    WRITELN;
    WRITELN;
  END;
END;
```

```
{ ********************************************** }

PROCEDURE CONTROL2 ;

BEGIN
  WRITELN;
  WRITELN;
  WRITELN('THE WEEKLY CONTROL RATIOS :');
  WRITELN('---------------------------');
  WRITELN;
  FOR WK := 1 TO 19 DO
  BEGIN
    WRITELN('FOR WEEK # :',WK:5);
    WRITELN('-----------------');
    WRITELN;
    WRITE('          CURRENT RATIOS          CUMULATIVE TO DATE    ');
    WRITELN('   PERFORMANCE INDICES ');
    WRITE('          ------------            ------------------    ');
    WRITELN('   ------------------- ');
    WRITE(' ACC   T/Q   L/MHR   MHR/Q      T/Q   L/MHR   MHR/Q');
    WRITELN('    T.COST   LCOST    PROD');
    WRITE(' ---------------------------------------------------');
    WRITELN('--------------------------');
    WRITELN;
    FOR ACC := 1 TO 25 DO
    IF (ACUM¢ACC,WK!.Q <>0) THEN
    BEGIN
      WITH TRANS¢ACC,WK! DO
        WRITE(ACC:4,TPERQ:7:2,LPERMHR:7:2,MHRPERQ:7:2);
      WITH ACUM¢ACC,WK! DO
        WRITE(TPERQ:11:2,LPERMHR:7:2,MHRPERQ:7:2);
      WRITELN(TQA¢ACC,WK!:10:2,LMHRA¢ACC,WK!:8:2,MHRQA¢ACC,WK!:8:2);
    END;
    WRITE('---------------------------------------------------');
    WRITELN('------------------------');
    WRITELN;
    WRITELN('    *********************************     ');
    WRITELN;
  END;
END;

{ **********************************************    }

FUNCTION SMALL(X,Y : REAL):REAL;
BEGIN
   IF (X < Y) THEN SMALL := X
   ELSE SMALL := Y;
END;

{ **********************************************    }

FUNCTION LARGE(X,Y : REAL):REAL;
BEGIN
  IF (X > Y) THEN LARGE:= X
  ELSE LARGE := Y;
END;

{ **********************************************    }

PROCEDURE REPORT ;

BEGIN
  WRITELN;
  WRITELN;
  WRITELN('THE INFORMATION ANALYSIS REPORT :');
  WRITELN('---------------------------------');
```

```
 WRITELN;
 FOR WK := 1 TO 19 DO
 BEGIN
   WRITELN;
   WRITELN('FOR WEEK # :',WK:5);
   WRITELN('-----------------');
   WRITELN;
   WRITE('        OPTIMISTIC     PESSIMISTIC        VARIANCE       ');
   WRITE('    COST ANALYSIS          LABOR               PERFORM');
   WRITELN('ANCE    ');
   WRITE('          FORECAST         FORECAST         EXPECTED       ');
   WRITE('   VARIANCE DUE TO       VAR DUE TO          MEASURED ');
   WRITELN('IN TERM');
   WRITE('        -----------     -----------     -----------    ');
   WRITE(' --------------------    ------------    ------------');
   WRITELN('--------');
   WRITE('ACC     $$$      MHR      $$$      MHR      $$$      MHR     ');
   WRITE(' PROD   LCOST   MAT¢L    RATE      MIX     COST     PROD');
   WRITELN('   LCOST');
   WRITE('---     -----------     -----------     -----------    ');
   WRITE(' --------------------    ------------    ------------');
   WRITELN('--------');
   WRITE('        F1       F2        F1       F2       F3       F4     ');
   WRITE(' F5       F6       F7       F8       F9     F10      F11');
   WRITELN('     F12 ');
   WRITELN;

   TF1M := O;
   TF1L := O;
   TF2M := O;
   TF2L := O;
   TF3  := O;
   TF4  := O;
   TF5  := O;
   TF6  := O;
   TF7  := O;
   TF8  := O;
   TF9  := O;

   FOR ACC := 1 TO 25 DO
   BEGIN
     QB   := BUDGET¢ACC!.Q;
     TPQA := ACUM¢ACC,WK!.TPERQ;
     QA   := ACUM¢ACC,WK!.Q;
     TPQT := TRANS¢ACC,WK!.TPERQ;
     MPQA := ACUM¢ACC,WK!.MHRPERQ;
     MPQT := TRANS¢ACC,WK!.MHRPERQ;
     TB   := BUDGET¢ACC!.T;
     MHRB := BUDGET¢ACC!.MHR;
     MHRT := TRANS¢ACC,WK!.MHR;
     MHRA := ACUM¢ACC,WK!.MHR;
     LPMB := BUDGET¢ACC!.LPERMHR;
     LPMT := TRANS¢ACC,WK!.LPERMHR;
     LPMA := ACUM¢ACC,WK!.LPERMHR;

       C1 := QB * TPQA;
   C2 := QA * TPQA + (QB-QA) * TPQT;
       M1 := QB * MPQA;
       M2 := QA * MPQA + (QB-QA) * MPQT;
       V1 := TB - (C1 + C2)/2;
  F3 := ROUND(V1);
V2 := MHRB - (M1 + M2)/2 ;
F4 := ROUND(V2);
P1 := (MHRB - M1) * LPMA ;
P2 := MHRB*LPMB - MHRA*LPMA -(QB-QA)*MPQT *LPMT;
       P  := (P1 + P2)/2 ;
```

```
        F5  := ROUND(P);
        L1  := MHRB*LPMB - MHRB*LPMA ;
L2  := MHRB*LPMB - MHRA*LPMA - (MHRB - MHRA)*LPMT ;
  L3  := MHRB*LPMB - M1*LPMA ;
L4  := MHRB*LPMB - MHRA*LPMA - (M1 - MHRA)*LPMT ;
L5  := MHRB*LPMB - M2*LPMA ;
L6  := MHRB*LPMB - MHRA*LPMA - (M2 - MHRA)*LPMT ;
LT  := (L1 + L2 + L3 + L4 + L5 + L6)/ 6 ;
F6  := ROUND(LT) ;
F7  := ROUND(V1 - P - LT) ;
R1  := MHRB * (LPMB - LPMA);
R2  := M1   * (LPMB - LPMA);
R3  := M2   * (LPMB - LPMA);
R   := (R1 + R2 + R3)/ 3 ;
F8  := ROUND(R) ;
C   := LT - R;
F9  := ROUND(C);
F10:= TQA¢ACC,WK!;
F11:= MHRQA¢ACC,WK!;
F12:= LMHRA¢ACC,WK!;
F1M:= ROUND(SMALL(C1,C2));
F1L:= ROUND(LARGE(C1,C2));
F2M:= ROUND(SMALL(M1,M2));
F2L:= ROUND(LARGE(M1,M2));
IF (C1 = 0) THEN
        BEGIN
          F1M  := TB;
          F1L  := TB;
   END;
       IF (M1 = 0) THEN
 BEGIN
   F2M  := MHRB;
   F2L  := MHRB;
 END;

 IF (WK > 1) AND (ACUM¢ACC,WK!.Q <> 0)THEN
          IF (ACUM¢ACC,WK!.Q = ACUM¢ACC,WK-1!.Q) THEN
          BEGIN
     F1M  := ACUM¢ACC,WK!.T ;
     F1L  := F1M ;
     F2M  := ACUM¢ACC,WK!.MHR;
     F2L  := F2M;
   END;

TF1M  := TF1M + F1M ;
TF1L  := TF1L + F1L ;
       TF2M  := TF2M + F2M;
 TF2L  := TF2L + F2L ;
TF3   := TF3  + F3 ;
TF4   := TF4  + F4 ;
TF5   := TF5  + F5 ;
TF6   := TF6  + F6 ;
TF7   := TF7  + F7 ;
TF8   := TF8  + F8 ;
TF9   := TF9  + F9 ;

WRITE(ACC:2,F1M:10,F2M:8,F1L:8,F2L:8,F3:8,F4:8,F5:8,F6:8);
       WRITELN(F7:8,F8:8,F9:8,F10:8:2,F11:8:2,F12:8:2);
     END;
     FOR ACC := 1 TO 116 DO
  WRITE('-');
     WRITELN;
     WRITE('SUM:',TF1M:8,TF2M:8,TF1L:8,TF2L:8,TF3:8,TF4:8,TF5:8);
     WRITELN(TF6:8,TF7:8,TF8:8,TF9:8);
     FOR ACC := 1 TO 116 DO
  WRITE('-');
```

```
      WRITELN;
      WRITELN;
   END;
END;

{ ******************************************    }
{    THE  MAIN       }

BEGIN
   WRITELN;
   INITIALIZE;
   FILLBUDGET;
   FILLTRANS ;
   FILLACUM  ;
   INDICES;
   SUMTRANS  ;
   SUMCONTROL;
   SUM2 ;
   CONTROL2;
   REPORT;
END.
```

VITA

Neil N. Eldin

Candidate for the Degree of

Doctor of Philosophy

Thesis: METHODOLOGY FOR PROJECT MANAGEMENT CONTROL IN THE CONSTRUCTION INDUSTRY

Major Field: Civil Engineering

Biographical:

Personal Data: Born in Cairo, Egypt, February 25, 1950. Married and father of two girls.

Education: Received Bachelor of Science degree in Civil Engineering from Cairo University in July, 1972; received Master of Science degree in Building science from Concordia University in 1978; received Master of Engineering degree in Geotechnical Engineering from McGill University in 1979; Completed the requirements for the Doctor of Philosophy degree in Civil Engineering, Construction Management, at Oklahoma State University in December 1987.

Professional Experience: Instructor and Laboratory Engineer, Cairo University, August, 1972, to August, 1974; Teaching Assistant, McGill University, September, 1974, to September, 1976; Project Coordinator, CEGECO Design and Construction, November, 1976, to January, 1978; Cost and Scheduling Engineer, Brown & Root Inc., July, 1978, to April, 1980; Controls Engineer, Bechtel Inc, April to November, 1980; Project Engineer, ARAMCO (The Arabian American oil Company), November, 1980, to August, 1985; Instructor, Oklahoma State University, January, 1986 to present.