COMPLETION COST TREND ANALYSIS

by

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COMPLETION COST TREND ANALYSIS

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ABSTRACT

J. Gordon Davis's article "Keeping Project Costs in Line" (Machine Design, December 1976) stated that managers who keep track of a project by analyzing cost reports are behind what is actually occurring on the site. Davis suggests the use of projected completion costs to analyze the project's cost control. He states that this method will better serve the project managers and allow them to respond to problem areas before they escalate. This paper will analyze Davis's approach through the use of simulation to determine if this method is reasonable in the construction industry.

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CHAPTER I INTRODUCTION

1.1 PROBLEM AND PURPOSE

In 1976 Gordon J. Davis wrote an article in Machine Design which described a method to predict project completion costs. Davis established a spreadsheet with accompanying chart that showed the relationship between the estimated cost at completion (ECAC) with the spreadsheet generated predicted cost at completion (PCAC). This method was to be used by project engineers to identify cost control problems in a project. Davis stated in his article that by analyzing periodic cost reports, the manager is at a disadvantage in that the reports are always lagging behind the actual progress of the project. His entire premise is that a new method must be instituted so that future costs can be forecasted and efforts undertaken prior to the escalation of a negative situation.

The goal of this research project is to determine if Davis's method is reasonable. A reasonable cost control method would be evaluated on practicality, usefulness, ease of use, and manipulation and customization of the method. In addition to the practicality of this method, the method is also compared to other current forecasting methods. The method is then reviewed to determine what changes are necessary to customize the spreadsheet to a users various requirements.

1.2 OBJECTIVE AND SCOPE

The objective of this research paper is to determine the usefulness of Davis's worksheet formula in construction projects. First an analysis of Davis's worksheet and chart is presented then the basic equations of the spreadsheet are determined. This report subsequently conducts a sensitivity analysis to observe the results of the spreadsheet given different conditions. Finally the spreadsheet and the sensitivity analysis are compared to determine if the spreadsheet can be improved.

1.3 REPORT FORMAT

This report begins with a detailed introduction to the problem and states the purpose for this report. Next, a comprehensive collection of currently used trend and forecasting methods are presented in Chapter 2. Chapter 3 is the main focus of the research project and provides an explanation of the spreadsheet, sensitivity analysis of the spreadsheet and finally several different ways to improve the spreadsheet. Chapter 4 summarizes the results of the research and Chapter 5 provides recommendations for the use of the spreadsheet and also suggests follow on research. Finally the report is concluded in Chapter 6.

1.4 STUDY METHODOLOGY

As can be seen in Figure 1.1, the study of Davis's predicated cost completion method begins with an analysis of the spreadsheet and chart. The spreadsheet columns are analyzed individually and then the formulas that are used within the spreadsheet are determined. A sensitivity analysis of the spreadsheet is performed to show the reaction of the predicted cost at completion (PCAC) when given the estimated cost at completion (ECAC). When reviewing these charts if must be understood that the ECAC is the best possible estimated cost at completion that the project manager can estimated after reviewing all available information. The PCAC is the predicted completion cost at completion provided with the assistance of Davis's spreadsheet.

Finally the sensitivity analysis and the formulas are compared to develop an improved spreadsheet.

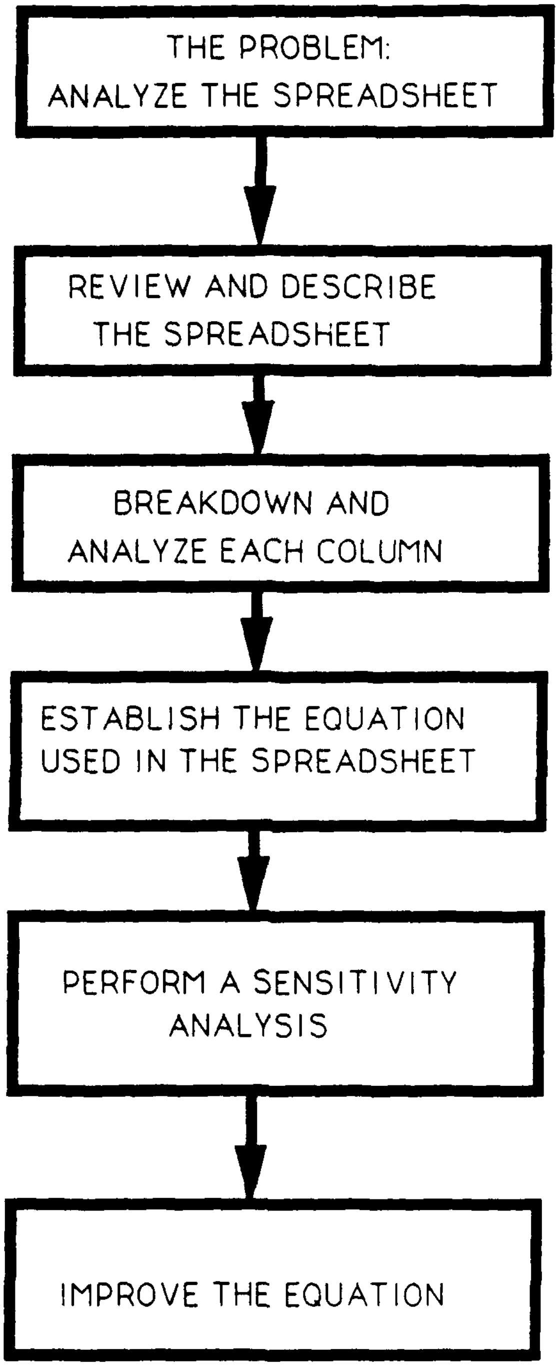


Figure 1.1 - Study Methodology

CHAPTER II CURRENT FORECASTING SYSTEMS

In a typical construction project, the company cost estimator develops an estimate which reflects all costs that are required to complete a specific project. These costs are usually broken down into specific cost categories which ease in the development and periodic monitoring of the project. The development of the estimate or budget is produced by a knowledgeable and experienced estimator. The budget is continuously reviewed to ensure accuracy and to minimize omissions. This estimate is extremely important, the company profit margin and ultimately it's life expectancy rests in the hands of the estimating staff. If the estimate is too low, large cost overruns might occur, if the estimate is too high, the company will lose business in the competitiveness of the construction industry.

Throughout the construction of the project, the project manager periodically reviews costs incurred and compares this data to the budget. Frequent monitoring of these costs are essential to control expenditures and insure that costs do not overrun the budget. This process of continuously monitoring, managing, reacting to variances and forecasting is termed cost control.

Every project manager has a strong incentive to monitor costs on the project. The company profit is directly related to how well the estimated budget was developed and the manner in which the expenditures were managed.

In this chapter, several different forecasting methods are presented. These methods are presented so that a comparison can be made between what is currently being used in the industry and what Davis's formula represents.

2.1 UNDERLYING THEORIES OF FORECASTING

In the past, cost reporting and control was performed by the on site field superintendent who also performed the forecasting of future costs. This function is now in the hands of the project manager due to the complexity and importance of cost control.

Forecasting is the process of predicting the future by using the analysis of all available data trends to ultimately calculate the final results required. In the construction industry this ultimately results in determining the final construction cost of the project through the analysis of past trends, experience, and any and all available data.

Forecasting in the construction industry can be broken into three separate theories, they are:

1. The performance of the construction project over the balance of the project will follow the estimate/budget. Therefore the projects overruns or underruns will remain the same for the rest of the project as stated on the report date. For example, if the project is currently at 35% with a cost overrun of $3,000, this forecasting theory states that the remaining 65% of the project will not have any variances, that is no additional cost overruns or underruns and therefore the completion cost will have an overrun of $3,000.

2. The performance of the construction project over the balance of the project will follow the overall past performance prior to the report date. For example, consider construction of a highway with a budget unit cost of $25,000 per mile, 12 mile project, for a total budget of $300,000. The current report shows 5 miles complete at a cost of $100,000, which is an average unit cost of $100,000/5 = $20,000 per mile. Therefore the forecasted completion cost of this project would by ($20,000 * 7 miles) + $100,000 = $240,000, a total cost underrun of $60,000.

3. The performance of the balance of the project is determined by the analysis of the productivity levels at the time of the report. Using the example in item 2 above, say the last mile completed, mile 5, cost $19,000 to construct. The forecasted completion cost of the project would then be ($19,000 * 7) + $100,000 = $233,000, an underrun of $67,000.

2.2 METHODS OF FORECASTING

Forecasting methods require a detailed cost summary produced periodically. These cost reports are usually produced on a monthly basis with each work item is broken down into a separate cost category for the purpose of recording and analyzing. Cost codes are frequently used and some companies have customized these codes to their specific requirements.

The monthly updates are a detailed accumulation of actual costs incurred as of the report date. These costs are then categorized into the specific cost codes and reported through a computer system.

The methods described in this section are a representation of currently used methods throughout the construction industry. Some of these methods have limited uses, some of the methods can be used in combination with other methods and others are customarily used by themselves. The optimum combination of the methods must be customized to the individual company requirements. But even with the best combination of the methods, the ultimate producer of the forecasted figure must apply experience and common sense to the final results. It should also be noted that many forecasting methods are not used until 20 to 25% of the project is completed (Bessa, 1983).

A. VARIANCE ANALYSIS

Variance analysis is the simple process of comparing the current performance with the expected performance. Typical items compared are:

1. Budget Cost vs Actual Cost
2. Budget Unit Cost vs Actual Unit Cost
3. Budget Manhours vs Actual Manhours
4. Budget % Complete vs Actual % Complete

This method is not meant to be used by itself but other contributing factors must be analyzed as well to obtain the whole picture. This method highlights cost categories that are not performing or are performing better than anticipated. To use this method, contributing factors such as the following must be scrutinized to affirm that there is trouble:

1. Poor initial estimate
2. Technical difficulties
3. Unexpected labor or material costs
4. Differing labor efficiencies.

Forecasting is easily computed using any of the three theories above with the available cost data. Examples are provided in the previous subchapter and in Table 2.1 - Variance Analysis.

Cost Code	Description	Expenditures To Date	Adjustments	Costs to Date			Estimate to Complete		
				Adj.Amt.	Quant.	Unit	Amount	Quant.	Unit
10	STRUCT EXCAV	651-		651-	1000	0.65	ø	ø	—
11	[illegible] BACKFILL	2070-		2070-	500	4.14	ø	ø	—
17	6" AGG BASE COURSE	342.50		342.50	90	3.80	ø	ø	—

Forecast of Final Cost			Original Estimate			Amount		%
Amount	Quant.	Unit	Amount	Quant.	Unit	Over	Under	
651-	1000	0.65	600-	1000	0.6	51-		108%
2070-	500	4.14	2000-	500	4.00	70-		89.1%
342.50	90	3.80	360-	90	4.00		17.50	71.8%

Table 2.1 - Variance Analysis

B. PRODUCTIVITY PROFILES

Experience shows that productivity does not remain constant throughout the term of a project but follows well established curves and patterns called productivity profiles. The typical curve begins with poor productivity rates and then increases to reach a maximum at the 30% to 80% range before tapering off to final completion. This slow start is sometimes called the learning curve of the process in that workers take time to organize and orientate themselves prior to becoming effective. The final 20 - 30% of the project is also a time of weak productivity as crew composition changes, rework and cleanup take an increased priority.

In the analysis of direct labor, the productivity profile is one of the better methods of trend analysis and forecasting available. The profile is a graphical representation of the productivity rate vs the % physical completion, Figure 2.1 - Productivity Profile. Productivity is defined as the Budget Unit Rate divided by the Actual Unit Rate.

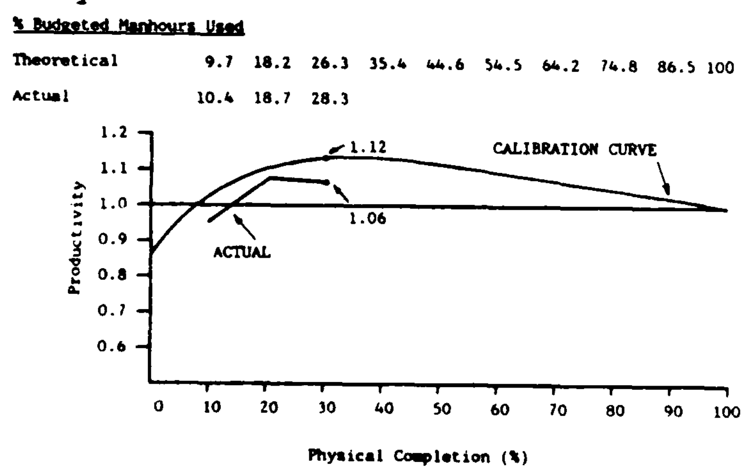


Figure 2.1 - Productivity Profile (Clark & Lorenzo, 1985)

Forecasting in this method involves the interpolation of the productivity profile with the latest cost report. The method begins with the comparison of the actual productivity rate and the estimated productivity rate. The difference is used to calculate the forecasted final productivity rate. For example, suppose the estimated productivity rate is 1.12 and the actual is 1.06 the difference being 0.06. The % difference of the rates is 0.06/1.12 = 5.4%. The final productivity rate would be 1.0-0.054 = 0.946. Predicted manhours for the entire cost code would be 50,000/0.946 = 52,854 manhours.

C. MANPOWER PERFORMANCE FACTOR

The manpower performance factor is a method of forecasting which relies on the theory that the future performance of a project can be measured by the average past performance of the project. The manpower performance factor is defined as (Riggs, 1987):

$$MPF = \frac{\text{ESTIMATED MANHOURS}}{\text{ESTIMATED QUANTITY}} * \frac{\text{TOTAL-TO-DATE QUANTITY}}{\text{TOTAL-TO-DATE MANHOURS}}$$

The manpower performance factor is the same as the Cost Performance Index which is defined as:

$$CPI = \frac{\text{EARNED MANHOURS OR DOLLARS}}{\text{ACTUAL MANHOURS OR DOLLARS}}$$

where,

$$\text{EARNED VALUE} = \frac{\text{ESTIMATED MANHOURS}}{\text{ESTIMATED QUANTITY}} * \text{ACTUAL QUANTITY}$$

The MPF factor is simply a ratio between the estimated rate of production and the actual rate of production. The estimated manhours to complete the project is therefore the MANPOWER PERFORMANCE FACTOR multiplied by the remaining quantity. The total projected manhours to complete the project would therefore be the total of the estimated manhours to complete plus the manhours to date. Projected cost of the activity would then be the estimated manhours to complete the task multiplied by the actual cost per manhour added to the cost incurred to date.

An example of this technique is described below (Riggs, 1987):

GIVEN: 1. ESTIMATE:
- Quantity: 4,000
- Manhours: 3,080
- Cost: $29,280

2. TOTAL TO DATE:
- Quantity: 3,990
- Manhours: 3,112
- Cost: $29,875

MPF= 3080/4000 * (3990/3112) = 0.99

ESTIMATED MANHOURS TO COMPLETE = MPF * REMAINING QUANTITY
= 0.99(4200-3990)
= 208 MANHOURS

PROJECTED MANHOURS = ESTIMATED MANHOURS TO COMPLETE * MANHOURS TO DATE
= 208 + 3112
= 3320 MANHOURS

ESTIMATED COST TO COMPLETE = ESTIMATED MANHOURS TO COMPLETE * ACTUAL $/MANHOURS
= 208 MANHOURS (9.60)
= $1,997

PROJECTED COST = ESTIMATED COST TO COMPLETE + COST TO DATE
= $1,997 + 29,875
= $31,872

D. COST PERFORMANCE INDEX

This method is similar to the manpower performance index but instead of using manpower productivity ratios this method utilizes the cost index. This method compares the differences between the estimated cost of the activity and the actual cost of the activity, this ratio is then applied to the remaining portion of the contract to determine the forecasted completion cost. For example (Riggs, 1987):

BUDGET COST TO DATE: 7650

ACTUAL COST TO DATE: 8370

TOTAL BUDGET COST: 21,000

CPI = BUDGET COST / ACTUAL COST = 7650 / 8370

= 0.914 < 1.0 therefore unfavorable

BUDGET COST OF REMAINING WORK = 21,000 - 7,650 = 13,350

ESTIMATE TO COMPLETE = 13,350 / 0.914 = $14,606

FORECAST AMOUNT = 8370 + 14606 = $22,976

E. TREND CURVES

Trend curves are curves plotted with the horizontal axis as percent complete and the vertical axis of manhours, cost or other productivity factors, Figure 2.2 - Trend Curve. It should be noted that this graph can be plotted directly from the productivity profile. By plotting dates with the percent complete the schedule can be integrated into the cost reporting aspect and a comparison can easily be made.

Forecasting with the trend curve is best described by the use of an example (Riggs, 1987):

1. ACTUAL MANHOURS COMPLETED:	43,000
2. LESS THEORETICAL MANHOURS	
AT 30% COMPLETE, (from the calibration curve)	40,700
3. OVERRUN MANHOURS	2,300
4. % OVERRUN = (2,300/40,700)*100	5.7%
5. TOTAL ADJUSTED MANHOURS	120,000
6. OVERRUN MANHOURS = 0.057(120,000)	6,800

This method assumes that there is no action taken to correct the problem and that the problem continues to compound at the rate calculated. A second assumption is that the manhours will remain a constant percentage relationship with the calibration curve.

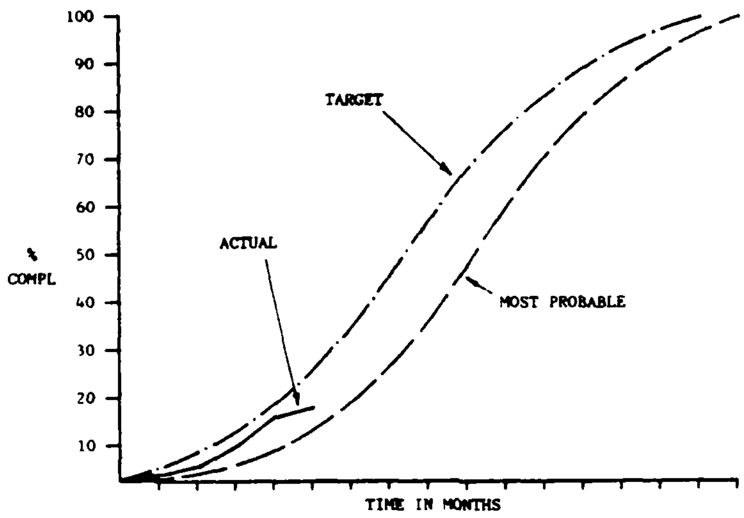


Figure 2.2 - Trend Curve (Riggs, 1987)

CHAPTER III SPREADSHEET ANALYSIS

Davis's article as shown in Appendix A describes a completion cost worksheet. This worksheet requires several inputs including the estimated cost of completion (ECAC), and determines the predicted cost of completion (PCAC). This chapter reviews the formation and column breakdown of the worksheet, the inputs of the spreadsheet, the formula used to calculate the spreadsheet and finally the results of the spreadsheet. With an understanding of the spreadsheet different scenarios were developed to analyze the cause and effects of several situations. From these scenarios the sensitivity of the worksheet is analyzed and finally several improvements are recommended.

3.1 SPREADSHEET DESCRIPTION AND COLUMN BREAKDOWN

Figure 3.1 and 3.2 show the worksheet and the graphical representation of the results, called the Worksheet Chart. The top portion of the worksheet is set aside as the title. The worksheet consists of 12 numbered columns that are labeled on the top of each column. A title of each column and the formula for the column is also stated above the numerical data. Reference columns at the beginning and end of the worksheet are used for

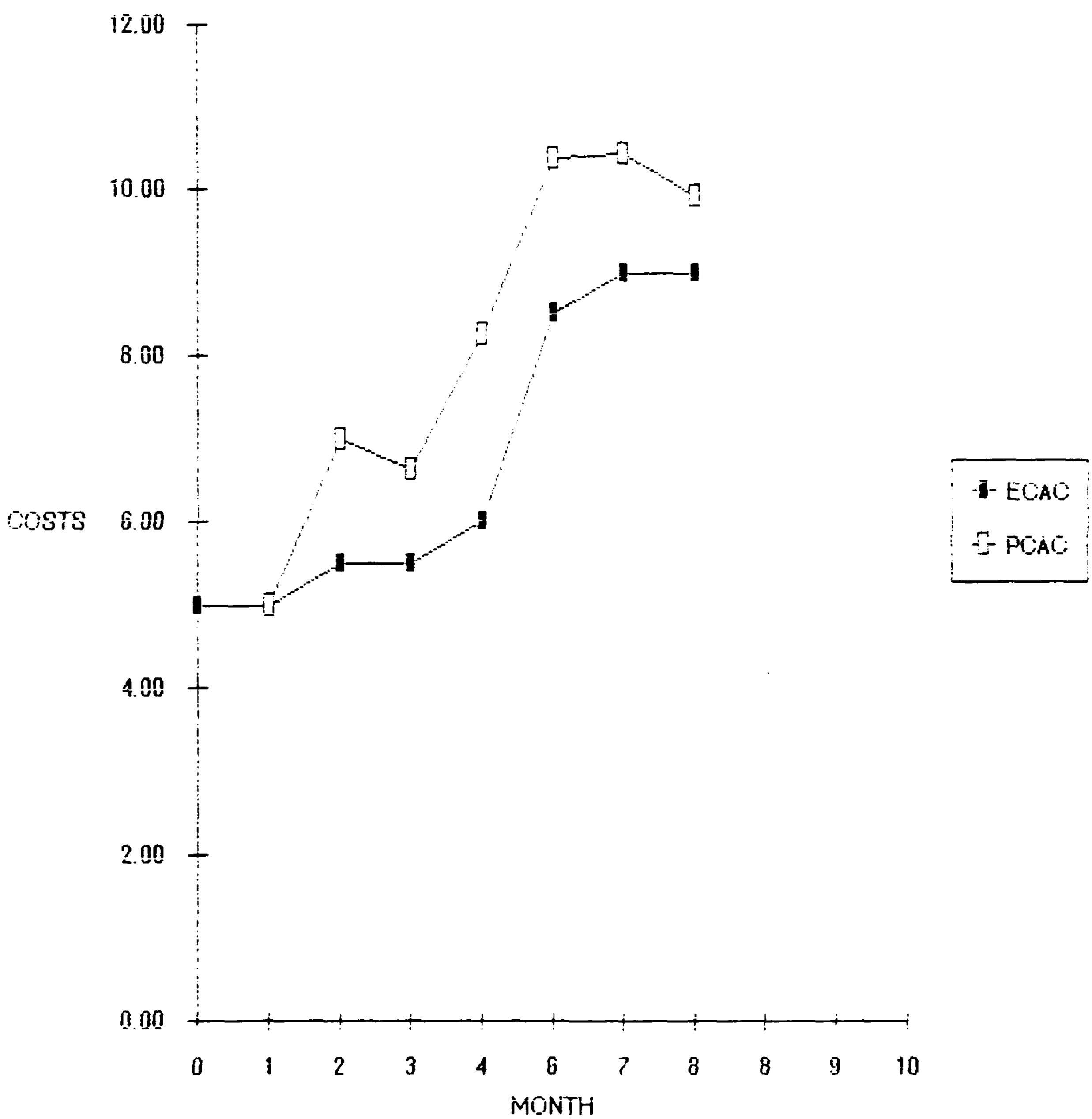
COST TREND WORKSHEET

DAVIS ORIGINAL ARTICLE

			DATE	25-May-90		
ORIGINAL COST=	5					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			6		5.00
REPORT 1	1	0	1	6	5	5.00
REPORT 2	2	1	1	8	6	5.50
REPORT 3	3	2	1	-8	5	5.50
REPORT 4	4	3	1	13.09	9.09	6.00
REPORT 5	6	4	2	9.77	3.77	8.50
REPORT 6	7	6	1	9.67	2.67	9.00
REPORT 7	8	7	1	9.75	1.75	9.00
REPORT 8	8	8	0		-8	
REPORT 9	9	9	0		-9	
REPORT 10	10	9	1		-10	

-	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	9/1^2	5x 12	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	5.00	REPORT 1
0.50	1.00	1.00	0.25	1.50	7.00	REPORT 2
0.50	1.00	2.00	0.22	1.11	6.61	REPORT 3
1.00	2.00	4.00	0.25	2.27	8.27	REPORT 4
3.50	14.00	19.00	0.50	1.89	10.39	REPORT 5
4.00	8.00	26.00	0.53	1.42	10.42	REPORT 6
4.00	9.00	34.00	0.53	0.93	9.93	REPORT 7
-5.00	0.00	34.00	0.53	-4.25		REPORT 8
-5.00	0.00	34.00	0.42	-3.78		REPORT 9
-5.00	-10.00	24.00	0.24	-2.40		REPORT 10

DAVIS ORIGINAL ARTICLE



reference of the specific rows.

The chart shown in Figure 3.2 is a graphical representation of the two curves, the ECAC and the PCAC. The horizontal axis represents the update interval, usually in months. The vertical axis represents the completion costs. With every chart provided in the report, both a title and chart key are added.

The most important columns of this worksheet are the input column number 6, the ESTIMATE COST AT COMPLETION (ECAC) and the resulting PREDICTED COST AT COMPLETION (PCAC) column 12.

The following is a column by column breakdown and description of the spreadsheet:

INITIATION OF THE WORKSHEET

TITLE: this space is provided to input the title of the construction project and any pertinent comments.

ORIGINAL COST: the original estimated cost at completion is inputed into this worksheet block.

REPORT NUMBER

Prior to column one, the worksheet presents a column showing the report number. In the analysis of this worksheet these updates are stated in monthly intervals. However the updates may be in any interval as long as the unit of the interval is consistent.

COLUMN 1: REPORT DATE

This column is a restatement of the previous column. The value of this column is used later in the spreadsheet, the word "REPORT" is therefore eliminated in order for the value to be used in the spreadsheet program. Similar to the first column this column shows the report date as a monthly update.

COLUMN 2: PREVIOUS REPORT DATE (INPUT)

This column simply states the last report date and is inputed as the number of the last report date.

COLUMN 3: UPDATE INTERVAL

The update interval is the difference between the first column and the second column. This shows the amount of time that the updating of this spreadsheet has lapsed.

COLUMN 4: PROJECTED COMPLETION DATE (INPUT)

This value is inputed into the spreadsheet as the estimated time to compete the project. Note that this value is part of the periodic updating of the spreadsheet. This value represents the total duration of the project, not the remaining completion time.

COLUMN 5: REMAINING TIME TO COMPLETE

This column is automatically calculated by subtracting COLUMN 1: REPORT DATE by COLUMN 5: PROJECTED COMPLETION DATE.

COLUMN 6: ESTIMATED COST AT COMPLETION (INPUT) (ECAC)

This input value is the most up-to-date completion cost estimate of the project. Usually a project manager uses a combination of the methods described in the previous chapter to determine this value.

COLUMN 7: ESTIMATED COST OVERRUN

Column 7 represents the estimated cost overrun for the given interval. This calculation is simply the difference between COLUMN 6: ESTIMATED COST AT COMPLETION and the ORIGINAL COST as imputed during the initiation phase of the setup.

COLUMN 8: CALCULATIONS

This calculation consists of multiplying the product of COLUMN 3: UPDATE INTERVAL and COLUMN 7: ESTIMATED COST OVERRUN by a factor of 2.

The reasons why the factor of 2 is applied is not apparent, in the sensitivity analysis section of this chapter this factor is discussed.

COLUMN 9: CALCULATIONS

This column is the summation of the previous column to the point of the update. For example, if the report date is number 5, then the value of this column would be the summation of the first five entries of COLUMN 8.

COLUMN 10: COST SLOPE

The cost slope is derived by dividing COLUMN 9 by the square of COLUMN 1: REPORT DATE. As can be seen from the graphical representation of this spreadsheet, the cost slope is the slope of this line between the two update intervals. Without the square root of the denominator this equation is basically the average of the interval cost overruns.

In Chapter 3.4 Sensitivity of the Worksheet, a discussion of why the denominator is squared is provided.

COLUMN 11: PREDICTED ADDITIONAL OVERRUN

This value is calculated by multiplying COLUMN 5: REMAINING

TIME TO COMPLETE by COLUMN 10: COST SLOPE.

COLUMN 12: PREDICTED COST AT COMPLETION (PCAC)

The final column represents the results of this spreadsheet and is calculated by the addition of COLUMN 6: ESTIMATED COST AT COMPLETION and COLUMN 11: PREDICTED ADDITIONAL OVERRUN.

3.2 THE FORMULA

The formula used in the spreadsheet can easily be broken down into two equations. These equations are:

$$\text{PREDICTED COST AT COMPLETION} = \text{ECAC} + \text{REMAINING TIME TO COMPLETE} * \text{COST SLOPE}$$

$$\text{COST SLOPE} = \frac{2(\text{UPDATE INTERVAL})(\text{INTERVAL ESTIMATE COST OVERRUN})}{(\text{REPORT DATE})^\wedge 2}$$

Two most important factors in these formulas are:

1. the square of the report date in the denominator of the cost slope, and
2. the factor of 2 in the numerator of the cost slope.

Both of these factors will be discussed in detail during the worksheet sensitivity and worksheet improvement sections of this chapter.

3.3 SIMULATED RESULTS OF TYPICAL SITUATIONS

To gain a better understanding of the spreadsheet and equations, several different scenarios were developed to show the cause and effect of the way in which the spreadsheet functions. The parameters of these simulations were held constant to enable comparisons of the different situations. The parameters for this simulation consisted of the following:

1. The time frame is held constant at 10 months.
2. The original cost is 20.
3. All changes in the ECAC deviated from the original 20.
4. Every worksheet was updated constantly and no reports were omitted.

All of the spreadsheet results are shown graphically on the accompanying chart. The graphing of the results allows the analysis of the different trends presented between the ECAC and the PCAC. In the graphs the horizontal scale represents the periodic intervals, in most cases this is on a monthly basis. The vertical scale represents the costs of the completed project. The two lines within the graph represent COLUMN 6: ESTIMATED COST AT COMPLETION referred to as the ECAC and COLUMN 12: PREDICTED COST AT COMPLETION referred to as the PCAC.

A. ORIGINAL SPIKE WITH FOLLOWING CONSISTENT ESTIMATES

1. INCREASE IN ESTIMATE: Figure 3.3 - Original Spike with

Consistent Following Estimates. This scenario was developed by changing an early ECAC at 20% and continuing this estimate for the remainder of the project. This would be similar to a project manager finding a problem in his estimate at an early date and then continuing with the revised estimate for the remainder of the project. In this simulation, the ECAC for the second interval increased 25% but the PCAC increased 125% over the initial estimated cost, from 20 to 45.

2. DECREASE IN ESTIMATE: Figure 3.4 - Initial Spike with Consistent following Estimates. This plot was developed the same way the above "spike plot" was simulated. This plot is completely unreasonable in that the PCAC drops below zero, in other words, the predicted cost at completion of this project is zero. This plot shows one of the major flaws in Davis's premise, a PCAC less than zero.

B. STEADILY CHANGING ESTIMATE

1. DECREASING: Figure 3.6 - Steadily Increasing Estimate The ECAC was steadily decreased at a straight line rate of 5% of the original cost estimate. The PCAC as plotted shows a drastic drop in the first interval and then differences between the ECAC and the PCAC in subsequent intervals are

not as drastic. This affect is also referred to the convergence to the PCAC curve to the ECAC as the update intervals approach the completion of the project. This would indicate that changes in the ECAC at an early date in the project are more critical then in the late stages of the project.

2. INCREASING - This plot is similar to the preceding plot except the steady changes in the ECAC are increasing. Again the profile of a large deviation at the beginning is slowly minimized by the typical convergence of the PCAC to the ECAC towards the end of the project.

C. THE DOUBLE SPIKE

Figure 3.7 - Double Spike in the ECAC of Equal Magnitude details two jumps in the ECAC of equal magnitude at different times in the progress of the project. These jumps produce different results. The first jump in the ECAC of 25% (25/20) resulted in an increase of the PCAC by 64% (32.78/20) whereas the second jump increased the PCAC by only 24% (26.22/21.11). The differences between the ECAC in the first jump was 32.78 - 25 = 7.78 or 31% of the ECAC in the second jump the difference was 26.22 - 25 = 1.22 or 5% of the ECAC. This difference of 31% towards the beginning of the project and the 5% difference at the end of the project is also a factor of the convergence trait of

this spreadsheet formula.

D. INCREASE SPIKE AND THEN A DECREASE SPIKE

Figure 3.8 - Double Spoke int he ECAC, One Increase and One Decrease shows the behavior of the PCAC curve due to two jumps in the ECAC. The first jump is similar to the first jump in the preceding simulation but the second jump is the same magnitude however opposite directions. Note that the two curves (ECAC and the PCAC) converge at the second jump and continue with identical values throughout the remainder of the project.

ORIGINAL SPIKE WITH CONSISTENT FOLLOWING ESTIMATES

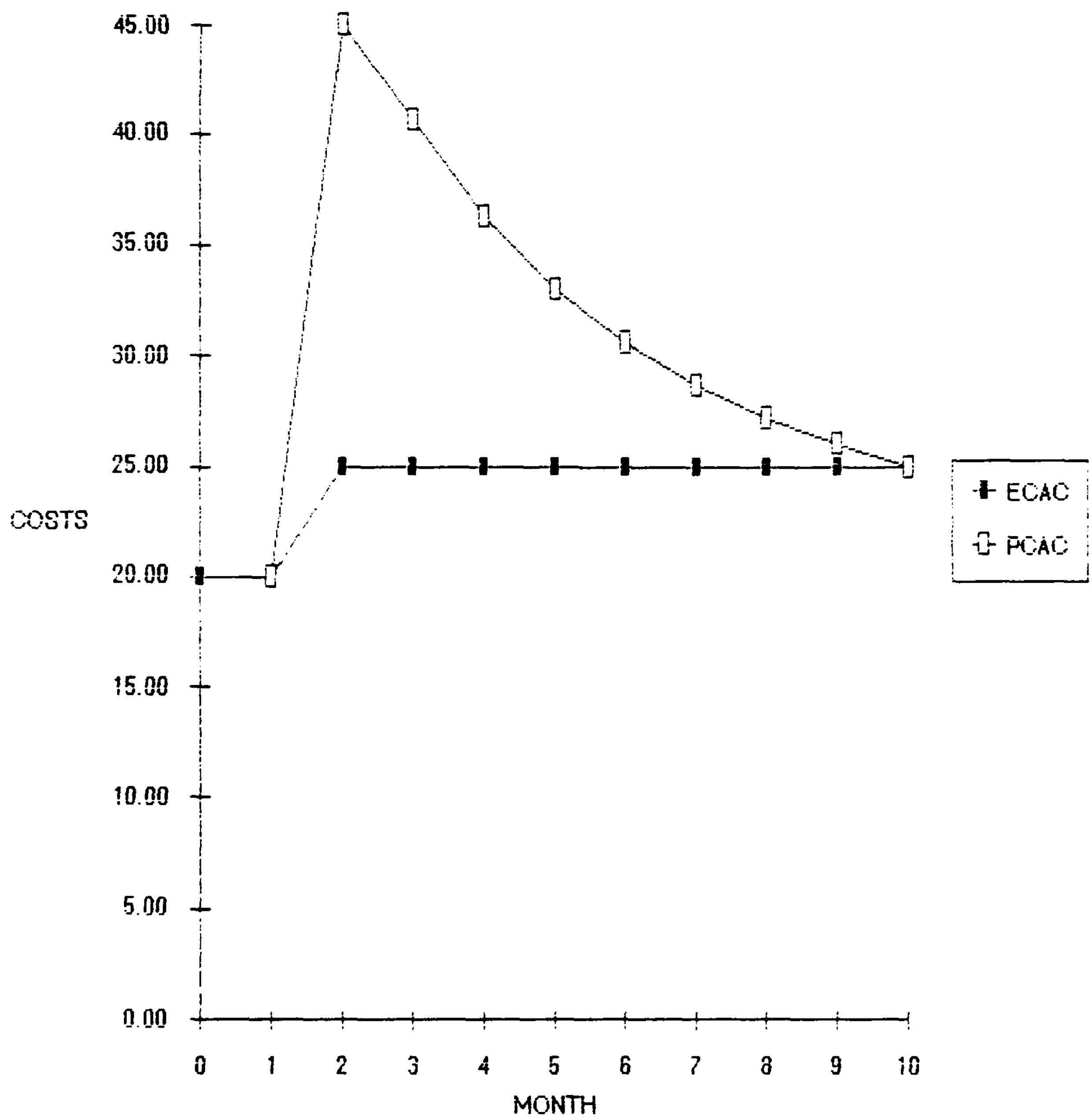


Figure 3.3 - Original Spike, Increase in the Estimate

COST TREND WORKSHEET

ORIGINAL SPIKE WITH CONSISTENT FOLLOWING ESTIMATES

			DATE	5-Jun-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
REPORT NUMBER	REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	PROJECTED COMPLETION DATE INPUT	REMAINING TIME TO COMPLETE COL4 -COL1	ESTIMATED COST AT COMPLETION INPUT ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	25.00
REPORT 4	4	3	1	10	6	25.00
REPORT 5	5	4	1	10	5	25.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	25.00
REPORT 8	8	7	1	10	2	25.00
REPORT 9	9	8	1	10	1	25.00
REPORT 10	10	9	1	10	0	25.00
7	8	9	10	11	12	
ESTIMATED COST OVERRUN 6- ORIG COST	2(8x7)	SUM 8	COST SLOPE 9/1^2	PREDICTED ADDITIONAL OVERRUN 5x 10	PREDICTED COST AT COMPLETION 6+11 PCAC	REPORT NUMBER
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
5.00	10.00	20.00	2.22	15.56	40.56	REPORT 3
5.00	10.00	30.00	1.88	11.25	36.25	REPORT 4
5.00	10.00	40.00	1.60	8.00	33.00	REPORT 5
5.00	10.00	50.00	1.39	5.56	30.56	REPORT 6
5.00	10.00	60.00	1.22	3.67	28.67	REPORT 7
5.00	10.00	70.00	1.09	2.19	27.19	REPORT 8
5.00	10.00	80.00	0.99	0.99	25.99	REPORT 9
5.00	10.00	80.00	0.80	0.00	25.00	REPORT 10

Figure 3.3 - Original Spike, Increase in the Estimate

INITIAL SPIKE WITH CONSISTENT FOLLOWING ESTIMATES

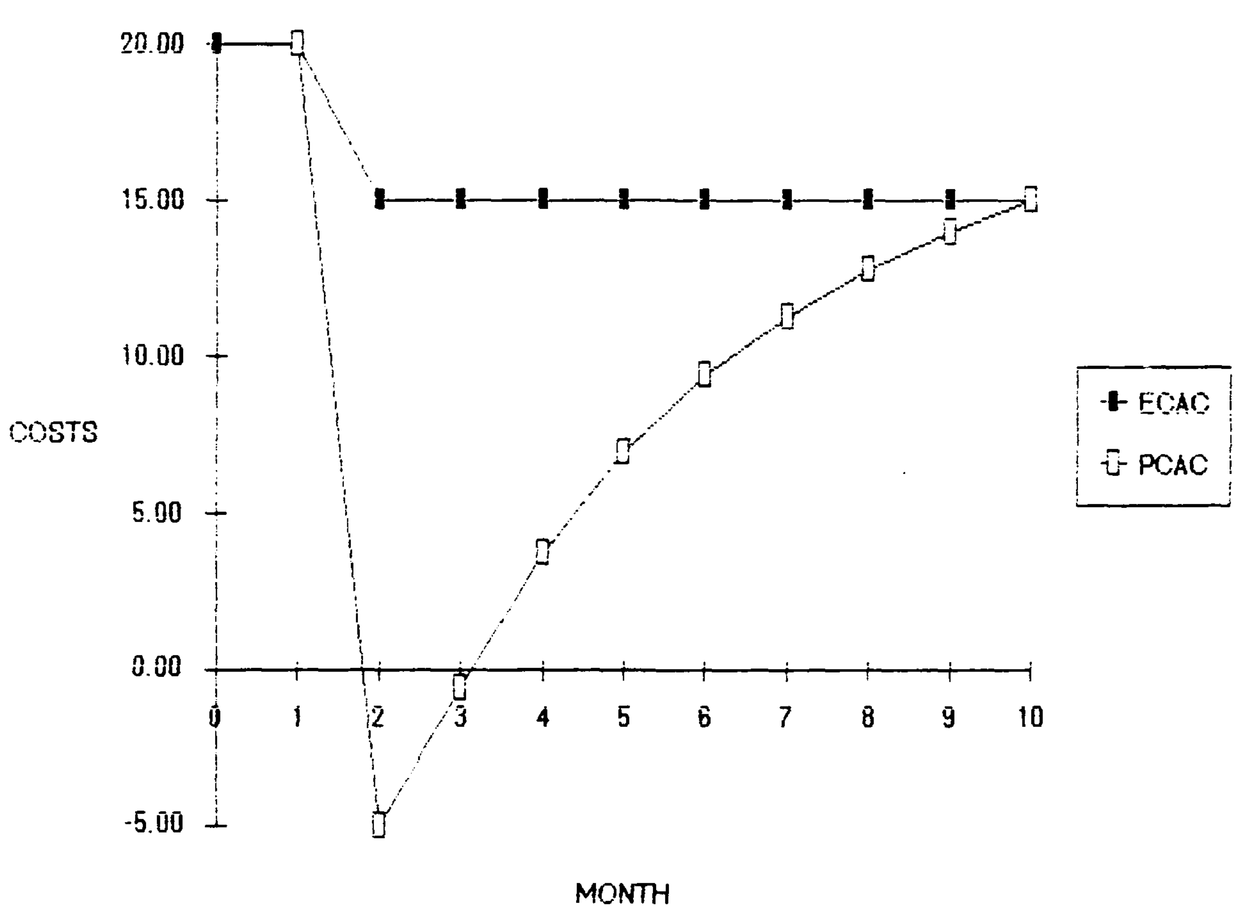


Figure 3.4 - Original Spike, Decrease in the Estimate

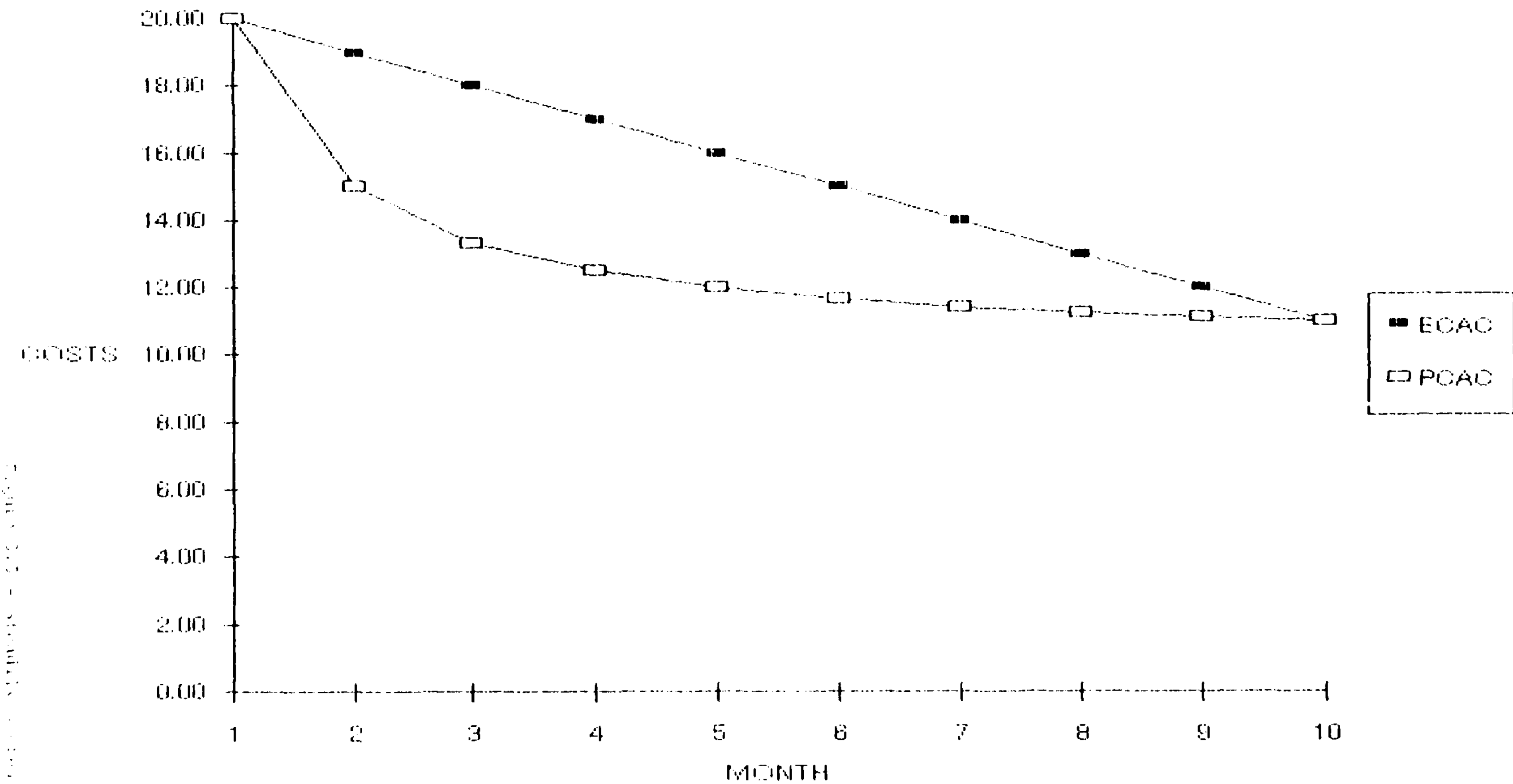
COST TREND WORKSHEET						
INITIAL SPIKE WITH CONSISTENT FOLLOWING ESTIMATES						
			DATE	28-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	15.00
REPORT 3	3	2	1	10	7	15.00
REPORT 4	4	3	1	10	6	15.00
REPORT 5	5	4	1	10	5	15.00
REPORT 6	6	5	1	10	4	15.00
REPORT 7	7	6	1	10	3	15.00
REPORT 8	8	7	1	10	2	15.00
REPORT 9	9	8	1	10	1	15.00
REPORT 10	10	9	1	10	0	15.00
7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(6x7)	SUM 8	8/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
-5.00	-10.00	-10.00	-2.50	-20.00	-5.00	REPORT 2
-5.00	-10.00	-20.00	-2.22	-15.56	-0.56	REPORT 3
-5.00	-10.00	-30.00	-1.88	-11.25	3.75	REPORT 4
-5.00	-10.00	-40.00	-1.60	-8.00	7.00	REPORT 5
-5.00	-10.00	-50.00	-1.39	-5.56	9.44	REPORT 6
-5.00	-10.00	-60.00	-1.22	-3.67	11.33	REPORT 7
-5.00	-10.00	-70.00	-1.09	-2.19	12.81	REPORT 8
-5.00	-10.00	-80.00	-0.99	-0.99	14.01	REPORT 9
-5.00	-10.00	-90.00	-0.90	0.00	15.00	REPORT 10

Figure 3.4 - Original Spike [illegible]
Response in the Estimate

INDEPENDENT RESEARCH PROJECT

STEADILY DECREASING ESTIMATE

NO CHANGE IN COMPLETION TIME



COST TREND WORKSHEET

STEADILY DECREASING ESTIMATE

			DATE	18 - May - 90		
ORIGINAL COST =	20					
	1	2	3	4	5	6
REPORT NUMBER	REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	PROJECTED COMPLETION DATE INPUT	REMAINING TIME TO COMPLETE COL4 – COL1	ESTIMATED COST AT COMPLETION INPUT ECAC
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	19.00
REPORT 3	3	2	1	10	7	18.00
REPORT 4	4	3	[illegible]	10	6	17.00
REPORT 5	5	4	1	10	5	16.00
REPORT 6	6	5	1	10	4	15.00
REPORT 7	7	6	1	10	3	14.00
REPORT 8	8	7	1	10	2	13.00
REPORT 9	9	8	1	10	1	12.00
REPORT 10	10	9	1	10	0	11.00

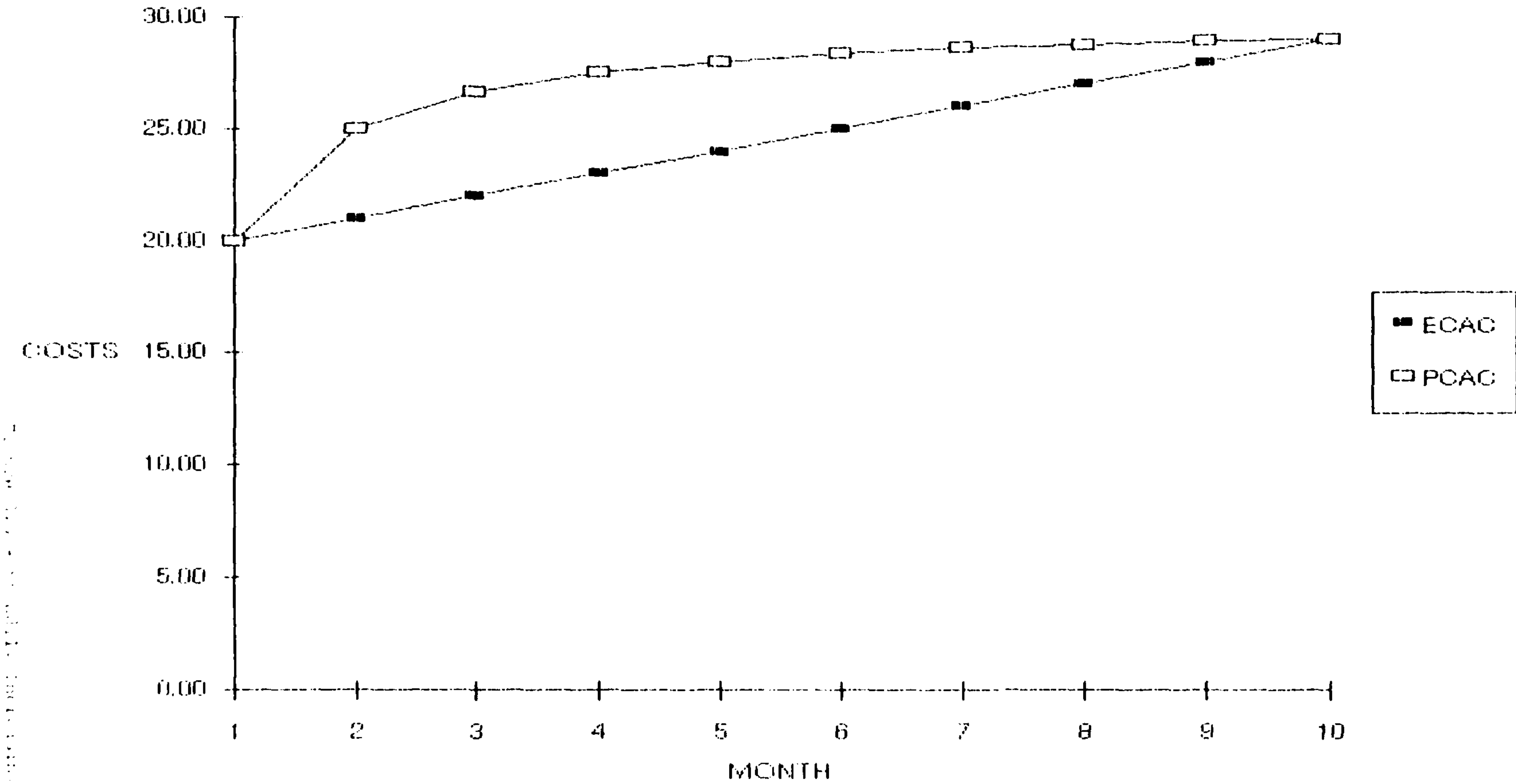
7	8	9	10	11	12	
ESTIMATED COST OVERRUN - ORIG COST	2(3x7)	SUM 8	COST SLOPE 9/1 ^ 2	PREDICTED ADDITIONAL OVERRUN 5x 12	PREDICTED COST AT COMPLETION 6 + 11 PCAC	REPORT NUMBER
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
–1.00	–2.00	–2.00	–0.50	–4.00	15.00	REPORT 2
–2.00	–4.00	–6.00	–0.67	–4.67	13.33	REPORT 3
–3.00	–6.00	–12.00	–0.75	–4.50	12.50	REPORT 4
–4.00	–8.00	–20.00	–0.80	–4.00	12.00	REPORT 5
–5.00	–10.00	–30.00	–0.83	–3.33	11.6[illegible]	REPORT 6
–6.00	–12.00	–42.00	–0.86	–2.57	11.[illegible]3	REPORT 7
–7.00	–14.00	–56.00	–0.88	–1.75	11.[illegible]5	REPORT 8
–8.00	–16.00	–72.00	–0.89	–0.89	11.[illegible]1	REPORT 9
–9.00	–18.00	–90.00	–0.90	0.00	11.00	REPORT 10

Figure 3.[illegible] - Steadily Decreasing Estimate

INDEPENDENT RESEARCH PROJECT

STEADILY INCREASING ESTIMATE

NO CHANGE IN COMPLETION TIME



COST TREND WORKSHEET

STEADILY INCREASING ESTIMATE

			DATE	18--May--90		
ORIGINAL COST =	20					
	1	2	3	4	5	6
REPORT NUMBER	REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	PROJECTED COMPLETION DATE INPUT	REMAINING TIME TO COMPLETE COL4 --COL1	ESTIMATED COST AT COMPLETION INPUT ECAC
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	21.00
REPORT 3	3	2	1	10	7	22.00
REPORT 4	4	3	1	10	6	23.00
REPORT 5	5	4	1	10	5	24.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	26.00
REPORT 8	8	7	1	10	2	27.00
REPORT 9	9	8	1	10	1	28.00
REPORT 10	10	9	1	10	0	29.00

7	8	9	10	11	12	
STIMATED COST OVERRUN - ORIG COST	2(3x7)	SUM 8	COST SLOPE 9/1 ^ 2	PREDICTED ADDITIONAL OVERRUN 5x 12	PREDICTED COST AT COMPLETION 6 + 11 PCAC	REPORT NUMBER
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
1.00	2.00	2.00	0.50	4.00	25.00	REPORT 2
2.00	4.00	6.00	0.67	4.67	26.67	REPORT 3
3.00	6.00	12.00	0.75	4.50	27.50	REPORT 4
4.00	8.00	20.00	0.80	4.00	28.00	REPORT 5
5.00	10.00	30.00	0.83	3.33	28.33	REPORT 6
6.00	12.00	42.00	0.86	2.57	28.57	REPORT 7
7.00	14.00	56.00	0.88	1.75	28.75	REPORT 8
8.00	16.00	72.00	0.89	0.89	28.89	REPORT 9
9.00	18.00	90.00	0.90	0.00	29.00	REPORT 10

Figure 3.3 - Steadily Increasing Estimate

DOUBLE SPIKE IN THE ECAC OF EQUAL MAGNITUDE

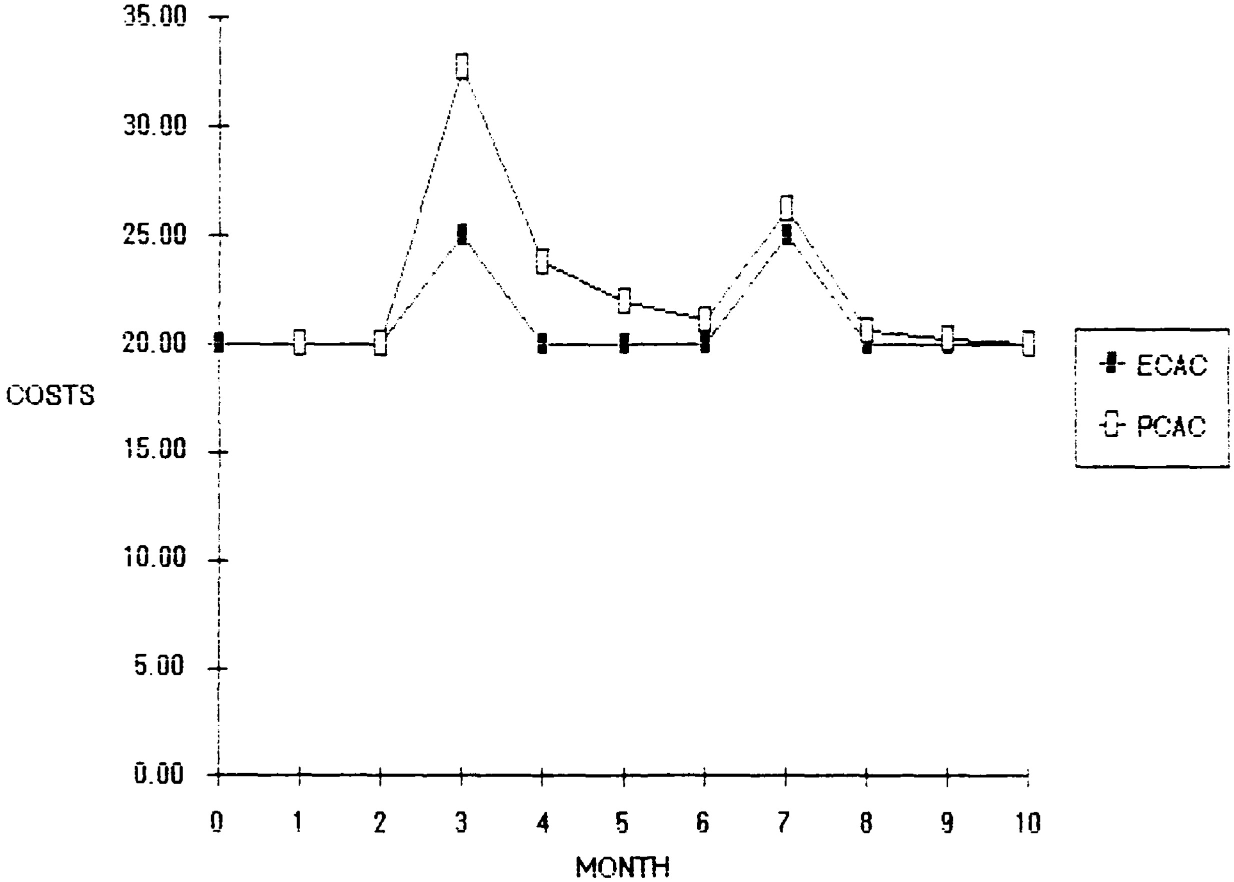


Figure 3.7 - Double Spike

COST TREND WORKSHEET

DOUBLE SPIKE IN THE ECAC OF THE SAME MAGNITUDE

			DATE	23-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4-COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	20.00
REPORT 3	3	2	1	10	7	25.00
REPORT 4	4	3	1	10	6	20.00
REPORT 5	5	4	1	10	5	20.00
REPORT 6	6	5	1	10	4	20.00
REPORT 7	7	6	1	10	3	25.00
REPORT 8	8	7	1	10	2	20.00
REPORT 9	9	8	1	10	1	20.00
REPORT 10	10	9	1	10	0	20.00
7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	9/12	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 2
5.00	10.00	10.00	1.11	7.78	32.78	REPORT 3
0.00	0.00	10.00	0.63	3.75	23.75	REPORT 4
0.00	0.00	10.00	0.40	2.00	22.00	REPORT 5
0.00	0.00	10.00	0.28	1.11	21.11	REPORT 6
5.00	10.00	20.00	0.41	1.22	26.22	REPORT 7
0.00	0.00	20.00	0.31	0.63	20.63	REPORT 8
0.00	0.00	20.00	0.25	0.25	20.25	REPORT 9
0.00	0.00	20.00	0.20	0.00	20.00	REPORT 10

Figure 3.7 - Double Spike

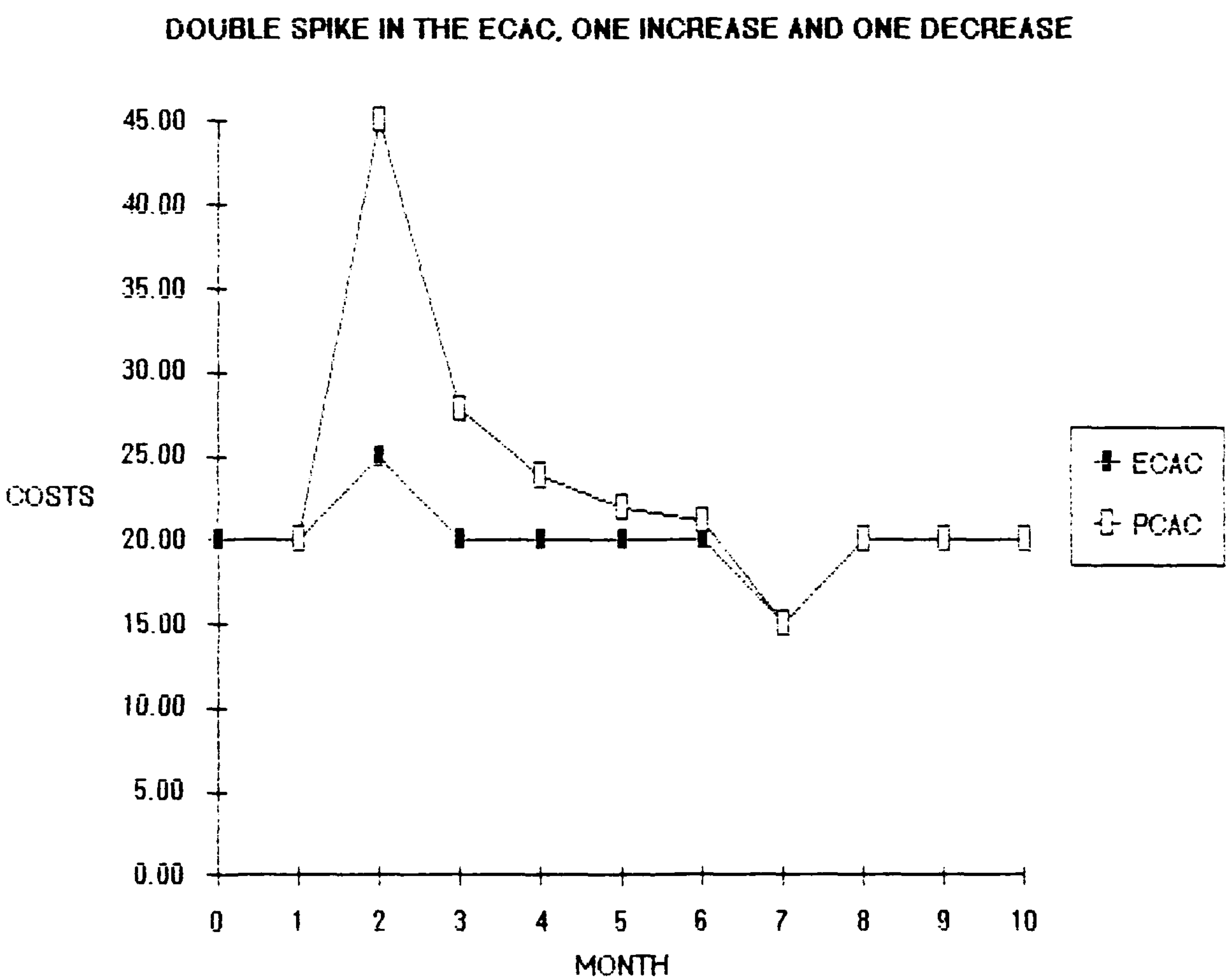


Figure [illegible] - Increase Spike with a Following Decrease Spike

COST TREND WORKSHEET

DOUBLE SPIKE IN THE ECAC, ONE INCREASE AND ONE DECREASE

			DATE	28-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	20.00
REPORT 4	4	3	1	10	6	20.00
REPORT 5	5	4	1	10	5	20.00
REPORT 6	6	5	1	10	4	20.00
REPORT 7	7	6	1	10	3	15.00
REPORT 8	8	7	1	10	2	20.00
REPORT 9	9	8	1	10	1	20.00
REPORT 10	10	9	1	10	0	20.00

7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	9/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
0.00	0.00	10.00	1.11	7.78	27.78	REPORT 3
0.00	0.00	10.00	0.63	3.75	23.75	REPORT 4
0.00	0.00	10.00	0.40	2.00	22.00	REPORT 5
0.00	0.00	10.00	0.28	1.11	21.11	REPORT 6
-5.00	-10.00	0.00	0.00	0.00	15.00	REPORT 7
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 8
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 9
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 10

Figure 3.5 - Increase Spike with a Following Decrease Spike

3.4 SENSITIVITY OF THE WORKSHEET

The formula used in the worksheet is described in subpart 3.2. The two most easily manipulated factors of the worksheet, without changing the integrity of the worksheet, are found in columns 8 and 10. Both of the factors are described below.

COLUMN 8: Column 8 is a calculation column, it multiplies the product of the update interval by the estimated cost overrun by a factor of 2. This factor of 2 is interesting in that it increases the cost overrun which is later compounded and then averaged to determine the predicted cost at completion, PCAC. If this factor is reduced, the PCAC is reduced. This can be seen by reviewing Figure 3.8 - Sensitivity Analysis, Column 8 Factor Set at 1.0. By reducing the factor in Column 8, from 2 to 1 the PCAC is reduced. This is shown by comparing the Altered PCAC Column 8 factor of 1 to the original PCAC, Column 8 factor of 2. When the factor was increased, from 2 to 3, the PCAC increased, Figure 3.9 - Sensitivity Analysis, Column 8 Factor Set at 3.0. This is shown graphically by comparing the Altered PCAC, Column 8 factor set at 3 and the original PCAC, Column 8 factor set at 2.0.

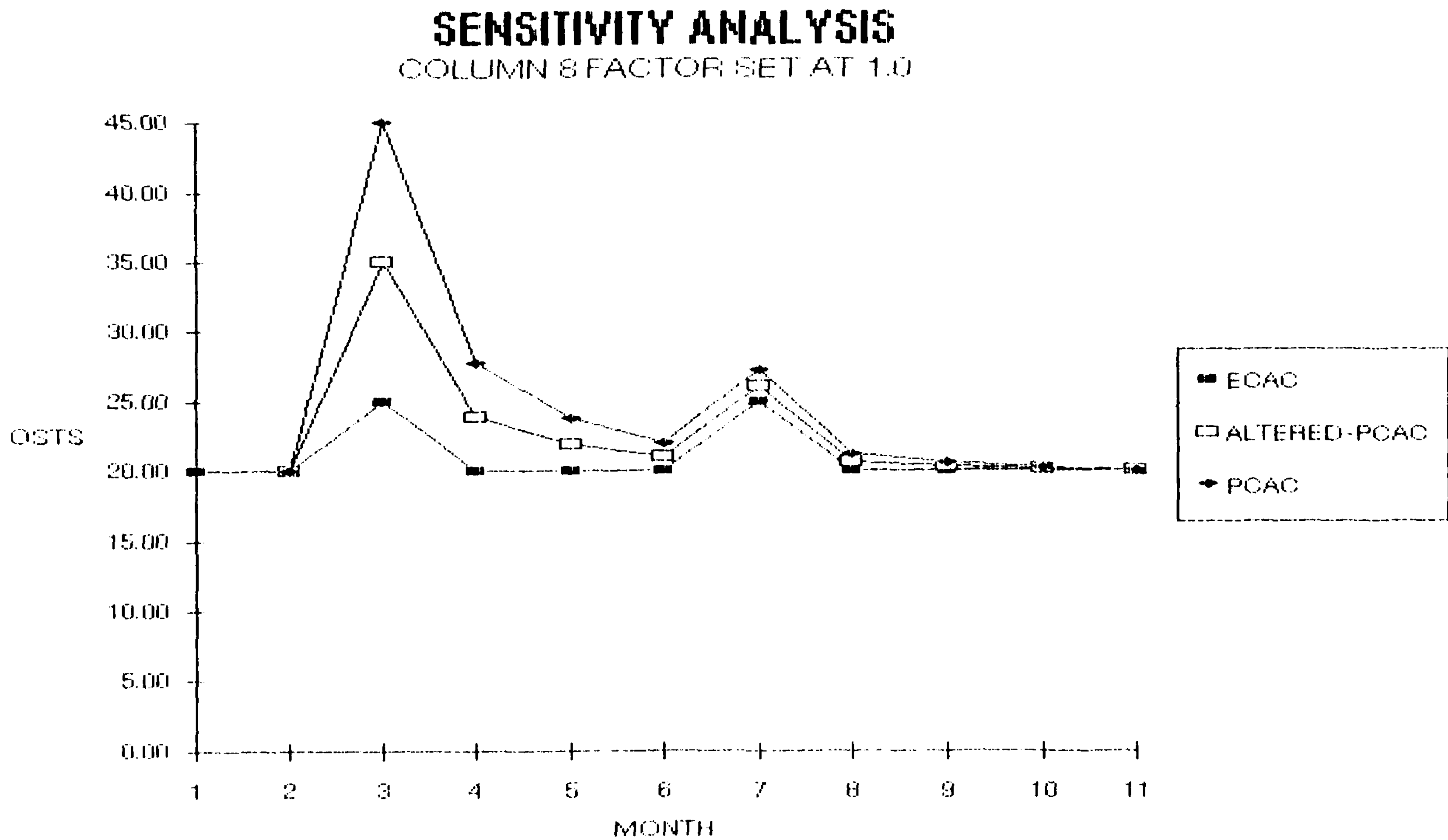


Figure 2.3 - Sensitivity Analysis, Column 8 Factor Set at 1.0

COST TREND WORKSHEET

SENSITIVITY ANALYISIS - COLUMN 8 FACTOR SET AT 1.0

			DATE	25-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	20.00
REPORT 4	4	3	1	10	6	20.00
REPORT 5	5	4	1	10	5	20.00
REPORT 6	6.	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	20.00
REPORT 8	8	7	1	10	2	20.00
REPORT 9	9	8	1	10	1	20.00
REPORT 10	10	9	1	10	0	20.00
7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	9/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
0.00	0.00	10.00	1.11	7.78	27.78	REPORT 3
0.00	0.00	10.00	0.63	3.75	23.75	REPORT 4
0.00	0.00	10.00	0.40	2.00	22.00	REPORT 5
5.00	10.00	20.00	0.56	2.22	27.22	REPORT 6
0.00	0.00	20.00	0.41	1.22	21.22	REPORT 7
0.00	0.00	20.00	0.31	0.63	20.63	REPORT 8
0.00	0.00	20.00	0.25	0.25	20.25	REPORT 9
0.00	0.00	20.00	0.20	0.00	20.00	REPORT 10

Figure 3.3 - Sensitivity Analysis
Column 8 Factor Set at 1.0

COST TREND WORKSHEET

7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	(3x7)	SUM 8	9/1^2	5x 10	6+11	
					ALTERED-PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	5.00	5.00	1.25	10.00	35.00	REPORT 2
0.00	0.00	5.00	0.56	3.89	23.89	REPORT 3
0.00	0.00	5.00	0.31	1.88	21.88	REPORT 4
0.00	0.00	5.00	0.20	1.00	21.00	REPORT 5
5.00	5.00	10.00	0.28	1.11	26.11	REPORT 6
0.00	0.00	10.00	0.20	0.61	20.61	REPORT 7
0.00	0.00	10.00	0.16	0.31	20.31	REPORT 8
0.00	0.00	10.00	0.12	0.12	20.12	REPORT 9
0.00	0.00	10.00	0.10	0.00	20.00	REPORT 10

Figure 3.[illegible] - Sensitivity Analysis
Column [illegible] Factor set at 1.0

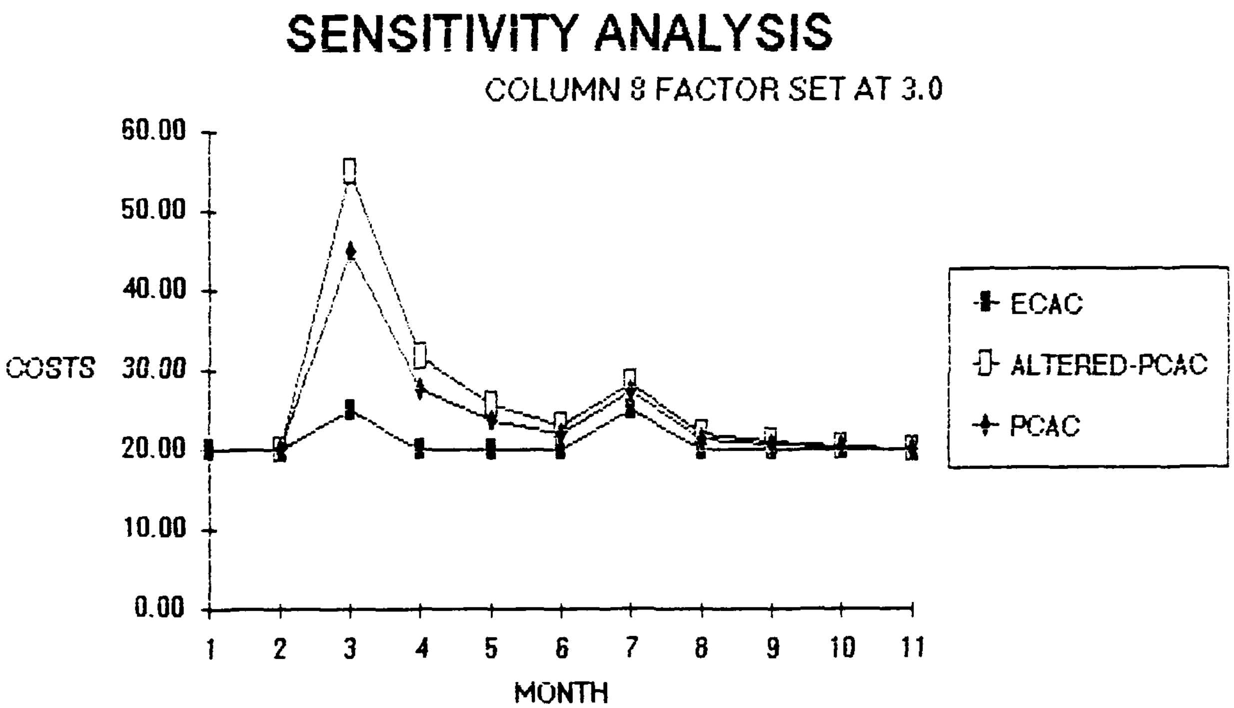


Figure 3.10 - Sensitivity Analysis, Column 8 Factor Set at 3.0

COST TREND WORKSHEET						
SENSITIVITY ANALYSIS - COLUMN 8 FACTOR SET AT 3.0						
			DATE	25-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	20.00
REPORT 4	4	3	1	10	6	20.00
REPORT 5	5	4	1	10	5	20.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	20.00
REPORT 8	8	7	1	10	2	20.00
REPORT 9	9	8	1	10	1	20.00
REPORT 10	10	9	1	10	0	20.00
7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	9/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
0.00	0.00	10.00	1.11	7.78	27.78	REPORT 3
0.00	0.00	10.00	0.63	3.75	23.75	REPORT 4
0.00	0.00	10.00	0.40	2.00	22.00	REPORT 5
5.00	10.00	20.00	0.56	2.22	27.22	REPORT 6
0.00	0.00	20.00	0.41	1.22	21.22	REPORT 7
0.00	0.00	20.00	0.31	0.63	20.63	REPORT 8
0.00	0.00	20.00	0.25	0.25	20.25	REPORT 9
0.00	0.00	20.00	0.20	0.00	20.00	REPORT 10

Figure 3.10 - Sensitivity Analysis, Column 8 Factor Set at 3.0

COST TREND WORKSHEET

7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	***3*(3x7)***	SUM 8	9/1^2	5x 10	6+11	
					ALTERED-PCAC	
0.00	***0.00***	0.00	0.00	0.00	20.00	REPORT 1
5.00	***15.00***	15.00	3.75	30.00	55.00	REPORT 2
0.00	***0.00***	15.00	1.67	11.67	31.67	REPORT 3
0.00	***0.00***	15.00	0.94	5.63	25.63	REPORT 4
0.00	***0.00***	15.00	0.60	3.00	23.00	REPORT 5
5.00	***15.00***	30.00	0.83	3.33	28.33	REPORT 6
0.00	***0.00***	30.00	0.61	1.84	21.84	REPORT 7
0.00	***0.00***	30.00	0.47	0.94	20.94	REPORT 8
0.00	***0.00***	30.00	0.37	0.37	20.37	REPORT 9
0.00	***0.00***	30.00	0.30	0.00	20.00	REPORT 10

Figure 3.10 - Sensitivity Analysis,
Column 8 Factor Set at 3.0

COLUMN 10: Column 10 calculates the cost slope by dividing the sum of the estimated cost overruns by the report date squared. The factor to be considered in this column is the square of the report date. If the report date is raised to a power greater than two, the PCAC will be reduced further. If the report date is raised to a power less than two the PCAC will increase. Figures 3.11 and 3.12 show the change in the PCAC when the report date is raised to the power of 4 and when the report date factor is not raised to any factor. Figure 3.13 - Sensitivity Analysis - Cost Slope Factor Analysis shows a one time increase in the ECAC with consistent ECAC's following. This figure shows that with a Cost Slope factor of 1, the profile of the Altered PCAC arcs shortly after the increase in the ECAC therefore continuing the amplification scare factor for 3 additional reports after the ECAC has increased.

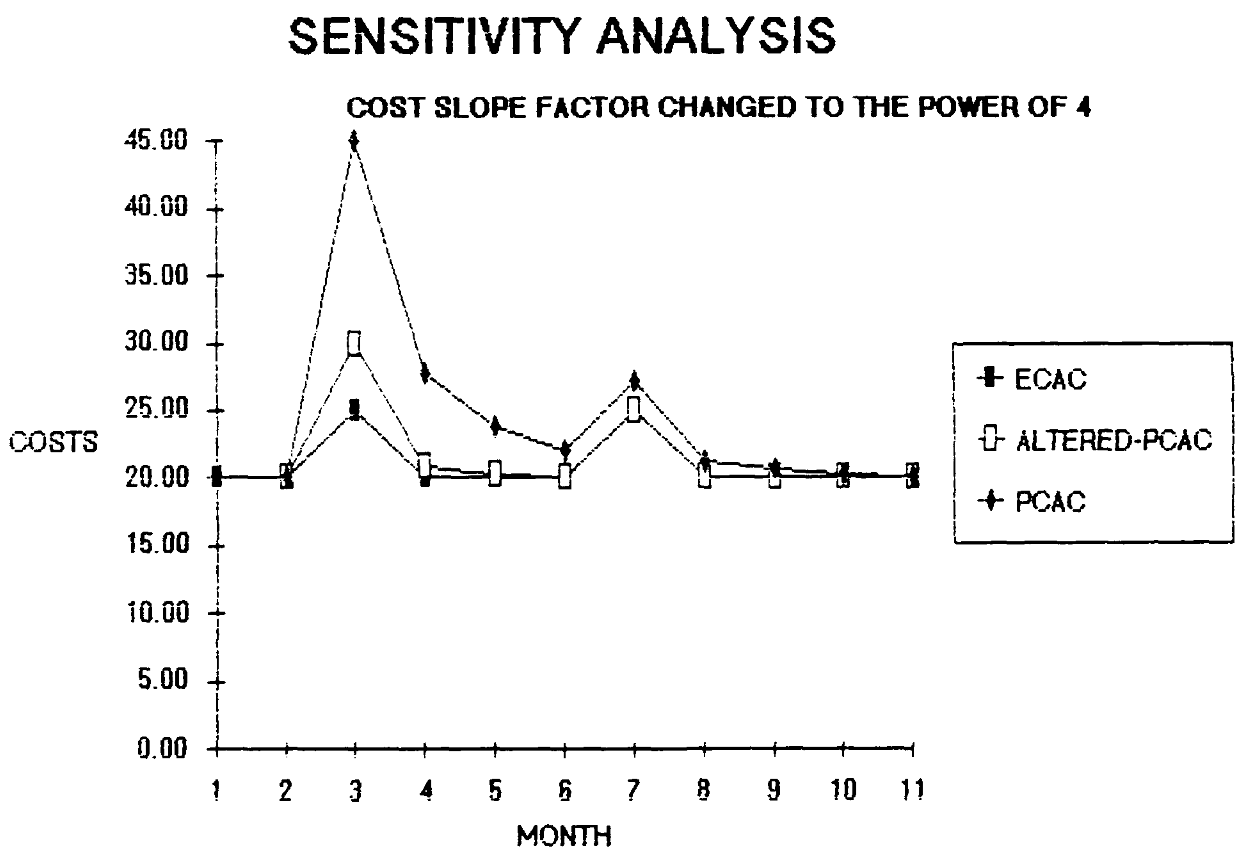


Figure 3.11 - Sensitivity Analysis,
Cost Slope Factor Changed
to the Power of 4

	COST TREND WORKSHEET					
NSITIVITY ANALYSIS - COST SLOPE FACTOR CHANGED TO THE POWER OF 4						
			DATE	25-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	20.00
REPORT 4	4	3	1	10	6	20.00
REPORT 5	5	4	1	10	5	20.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	20.00
REPORT 8	8	7	1	10	2	20.00
REPORT 9	9	8	1	10	1	20.00
REPORT 10	10	9	1	10	0	20.00
7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	9/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
0.00	0.00	10.00	1.11	7.78	27.78	REPORT 3
0.00	0.00	10.00	0.63	3.75	23.75	REPORT 4
0.00	0.00	10.00	0.40	2.00	22.00	REPORT 5
5.00	10.00	20.00	0.56	2.22	27.22	REPORT 6
0.00	0.00	20.00	0.41	1.22	21.22	REPORT 7
0.00	0.00	20.00	0.31	0.63	20.63	REPORT 8
0.00	0.00	20.00	0.25	0.25	20.25	REPORT 9
0.00	0.00	20.00	0.20	0.00	20.00	REPORT 10

Figure 3.11 - Sensitivity Analysis, Cost Slope Factor Changed to the Power of 4

COST TREND WORKSHEET

7	8	9	10	11	12	
ESTIMATED COST OVERRUN			**COST SLOPE**	PREDICTED ADDITIONAL OVERRUN	PREDICTED COST AT COMPLETION	REPORT NUMBER
6- ORIG COST	2*(3x7)	SUM 8	***9/1^4***	5x 10	6+11	
					ALTERED-PCAC	
0.00	0.00	0.00	***0.00***	0.00	20.00	REPORT 1
5.00	10.00	10.00	***0.63***	5.00	30.00	REPORT 2
0.00	0.00	10.00	***0.12***	0.86	20.86	REPORT 3
0.00	0.00	10.00	***0.04***	0.23	20.23	REPORT 4
0.00	0.00	10.00	***0.02***	0.08	20.08	REPORT 5
5.00	10.00	20.00	***0.02***	0.06	25.06	REPORT 6
0.00	0.00	20.00	***0.01***	0.02	20.02	REPORT 7
0.00	0.00	20.00	***0.00***	0.01	20.01	REPORT 8
0.00	0.00	20.00	***0.00***	0.00	20.00	REPORT 9
0.00	0.00	20.00	***0.00***	0.00	20.00	REPORT 10

Figure 3.11 - Sensitivity Analysis, Cost Slope Factor Changed to the Power of 4

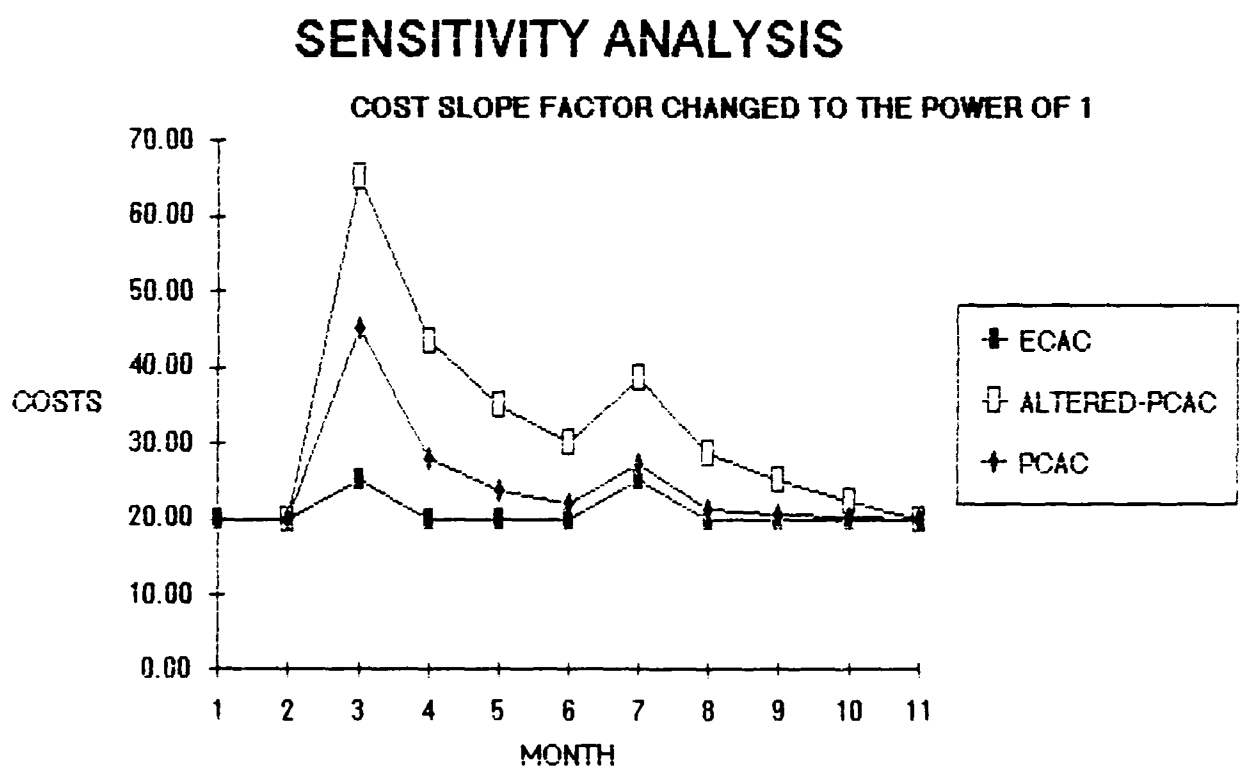


Figure 3.12 - Sensitivity Analysis, Cost Slope Factor Changed to the Power of 1

COST TREND WORKSHEET

COST TREND WORKSHEET						
SENSITIVITY ANALYSIS - COST SLOPE FACTOR CHANGED TO THE POWER OF 1						
			DATE	25-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	20.00
REPORT 4	4	3	1	10	6	20.00
REPORT 5	5	4	1	10	5	20.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	20.00
REPORT 8	8	7	1	10	2	20.00
REPORT 9	9	8	1	10	1	20.00
REPORT 10	10	9	1	10	0	20.00
7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	3/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
0.00	0.00	10.00	1.11	7.78	27.78	REPORT 3
0.00	0.00	10.00	0.63	3.75	23.75	REPORT 4
0.00	0.00	10.00	0.40	2.00	22.00	REPORT 5
5.00	10.00	20.00	0.56	2.22	27.22	REPORT 6
0.00	0.00	20.00	0.41	1.22	21.22	REPORT 7
0.00	0.00	20.00	0.31	0.63	20.63	REPORT 8
0.00	0.00	20.00	0.25	0.25	20.25	REPORT 9
0.00	0.00	20.00	0.20	0.00	20.00	REPORT 10

Figure 3.12 - Sensitivity Analysis,
Cost Slope Factor Changed
to the Power of 1

COST TREND WORKSHEET

7	8	9	10	11	12	
ESTIMATED			***COST***	PREDICTED	PREDICTED	
COST			***SLOPE***	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2*(3x7)	SUM 8	***'9/1***	5x 10	6+11	
					ALTERED-PCAC	
0.00	0.00	0.00	***0.00***	0.00	20.00	REPORT 1
5.00	10.00	10.00	***5.00***	40.00	65.00	REPORT 2
0.00	0.00	10.00	***3.33***	23.33	43.33	REPORT 3
0.00	0.00	10.00	***2.50***	15.00	35.00	REPORT 4
0.00	0.00	10.00	***2.00***	10.00	30.00	REPORT 5
5.00	10.00	20.00	***3.33***	13.33	38.33	REPORT 6
0.00	0.00	20.00	***2.86***	8.57	28.57	REPORT 7
0.00	0.00	20.00	***2.50***	5.00	25.00	REPORT 8
0.00	0.00	20.00	***2.22***	2.22	22.22	REPORT 9
0.00	0.00	20.00	***2.00***	0.00	20.00	REPORT 10

Figure 3.12 - [illegible]
[illegible] Slope [illegible] Changed
to the Power of [illegible]

SENSITIVITY ANALYSIS

COST SLOPE FACTOR ANALYSIS

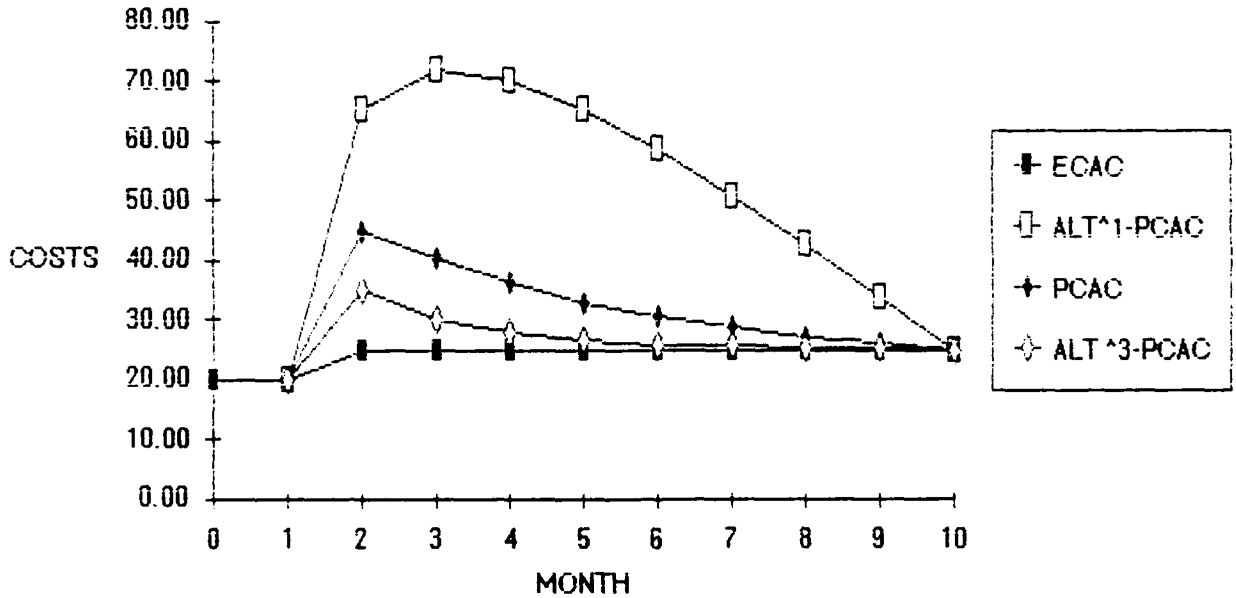


Figure 3.13 - Sensitivity Analysis,
Cost Slope Factor Analysis

COST TREND WORKSHEET						
SENSITIVITY ANALYSIS - COST SLOPE FACTOR MODIFICATION						
			DATE	27-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	25.00
REPORT 4	4	3	1	10	6	25.00
REPORT 5	5	4	1	10	5	25.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	25.00
REPORT 8	8	7	1	10	2	25.00
REPORT 9	9	8	1	10	1	25.00
REPORT 10	10	9	1	10	0	25.00
7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	9/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
5.00	10.00	20.00	2.22	15.56	40.56	REPORT 3
5.00	10.00	30.00	1.88	11.25	36.25	REPORT 4
5.00	10.00	40.00	1.60	8.00	33.00	REPORT 5
5.00	10.00	50.00	1.39	5.56	30.56	REPORT 6
5.00	10.00	60.00	1.22	3.67	28.67	REPORT 7
5.00	10.00	70.00	1.09	2.19	27.19	REPORT 8
5.00	10.00	80.00	0.99	0.99	25.99	REPORT 9
5.00	10.00	90.00	0.90	0.00	25.00	REPORT 10

Figure 3.13 - Sensitivity Analysis, Cost Slope Factor Analysis

COST TREND WORKSHEET

COST SLOPE FACTOR SET AT 1.0						
7	8	9	10	11	12	
ESTIMATED			**COST**	PREDICTED	PREDICTED	
COST			**SLOPE**	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2*(3x7)	SUM 8	**'9/1**	5x 10	6+11	
					ALT^1-PCAC	
0.00	0.00	0.00	**0.00**	0.00	20.00	REPORT 1
5.00	10.00	10.00	**5.00**	40.00	65.00	REPORT 2
5.00	10.00	20.00	**6.67**	46.67	71.67	REPORT 3
5.00	10.00	30.00	**7.50**	45.00	70.00	REPORT 4
5.00	10.00	40.00	**8.00**	40.00	65.00	REPORT 5
5.00	10.00	50.00	**8.33**	33.33	58.33	REPORT 6
5.00	10.00	60.00	**8.57**	25.71	50.71	REPORT 7
5.00	10.00	70.00	**8.75**	17.50	42.50	REPORT 8
5.00	10.00	80.00	**8.89**	8.89	33.89	REPORT 9
5.00	10.00	90.00	**9.00**	0.00	25.00	REPORT 10

COST SLOPE FACTOR SET AT 3.0						
7	8	9	10	11	12	
ESTIMATED			**COST**	PREDICTED	PREDICTED	
COST			**SLOPE**	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2*(3x7)	SUM 8	**'9/1^3**	5x 10	6+11	
					ALT^3-PCAC	
0.00	0.00	0.00	**0.00**	0.00	20.00	REPORT 1
5.00	10.00	10.00	**1.25**	10.00	35.00	REPORT 2
5.00	10.00	20.00	**0.74**	5.19	30.19	REPORT 3
5.00	10.00	30.00	**0.47**	2.81	27.81	REPORT 4
5.00	10.00	40.00	**0.32**	1.60	26.60	REPORT 5
5.00	10.00	50.00	**0.23**	0.93	25.93	REPORT 6
5.00	10.00	60.00	**0.17**	0.52	25.52	REPORT 7
5.00	10.00	70.00	**0.14**	0.27	25.27	REPORT 8
5.00	10.00	80.00	**0.11**	0.11	25.11	REPORT 9
5.00	10.00	90.00	**0.09**	0.00	25.00	REPORT 10

Figure 3.13 - Sensitivity Analysis,
Cost Slope Factor Analysis

Table 3.1 - Results of the Sensitivity Analysis tabulates the results of the Sensitivity charts and worksheets. For each different change in the worksheet a row is provided showing the percent change in the ECAC, percent change in the PCAC and the percent change in the Altered PCAC. For each item the percent change in the ECAC and the PCAC are kept constant therefore a comparison can be make to the Altered PCAC. The 30% and the 70% project completion status is also shown for each change in the different sensitivity analysis charts.

By reviewing this table, it can be noted that changes at the 30% level of completion can easily be manipulated to change the amplification factor. For example, be changing the Column 8 factor from 1 to 3 the amplification factor increased from 75 to 175%. The lowest amplification factor is 50% at the 30% complete time period for the Cost Slope Power equal to 4.0.

SENSITIVITY ANALYSIS RESULTS

CHANGE IN THE FORMULA	% CHANGE IN THE ECAC		% CHANGE IN THE PCAC		% CHANGE IN THE ALTERNATE PCAC	
PERCENT COMPLETE	30 %	70%	30%	70%	30%	70%
COLUMN 8, FACTOR = 1.0	25%	25%	125%	23%	75%	24%
COLUMN 8, FACTOR = 3.0	25%	25%	125%	23%	175%	23%
COST SLOPE, POWER = 1.0	25%	25%	125%	23%	225%	28%
COST SLOPE, POWER = 4.0	25%	25%	125%	23%	50%	25%

Table 3.1 - Results of the Sensitivity Analysis

Several deductions can be made by analyzing the sensitivity analysis:

1. It is easy to manipulate this worksheet.

2. Davis's intention was to have a large amplification factor, which would shock the project manager into action.

3. Very small changes at the 70% level compared to changes at the 30% level. This is called the convergence of the PCAC to the ECAC. Davis is stating that the estimate "busts" at the beginning of the project are more critical that the same estimate "busts" towards the end of the project.

3.5 IMPROVING THE SPREADSHEET

The two problems raised so far in the analysis of the spreadsheet is that the amplification factor is too large and that the convergence of the PCAC and the ECAC is not fast enough. Since we have determined that the worksheet is easily manipulated by changing the two factors in columns 8 and 10 as discussed earlier, we can now improve the spreadsheet with the ultimate goal of reducing the amplification factor and increasing the convergence.

To reduce the amplification factor the Column 8 factor is held constant and Column 10 factor is increased to 3.0. It should be noted that the amplification factor can also be decreased by simply reducing the Column 8 factor, but this solution would do little to increase the convergence of the PCAC to the ECAC. Therefore the ultimate solution that would solve both of the improvement parameters is to increase the Cost Slope factor to 3.0. These results can be seen by reviewing Figure 3.14 - Improvement Analysis. This chart shows the difference between the two options detailed below:

Alternative A: Cost Slope Set at 3.0 and the Column 8 Factor set at 2.0.

Alternative B: Cost Slope Set at 3.0 and the Column 8 Factor set at 3.0.

It would seem that Alternative B is the optimum solution due to the large scare factor but with an accelerated convergence.

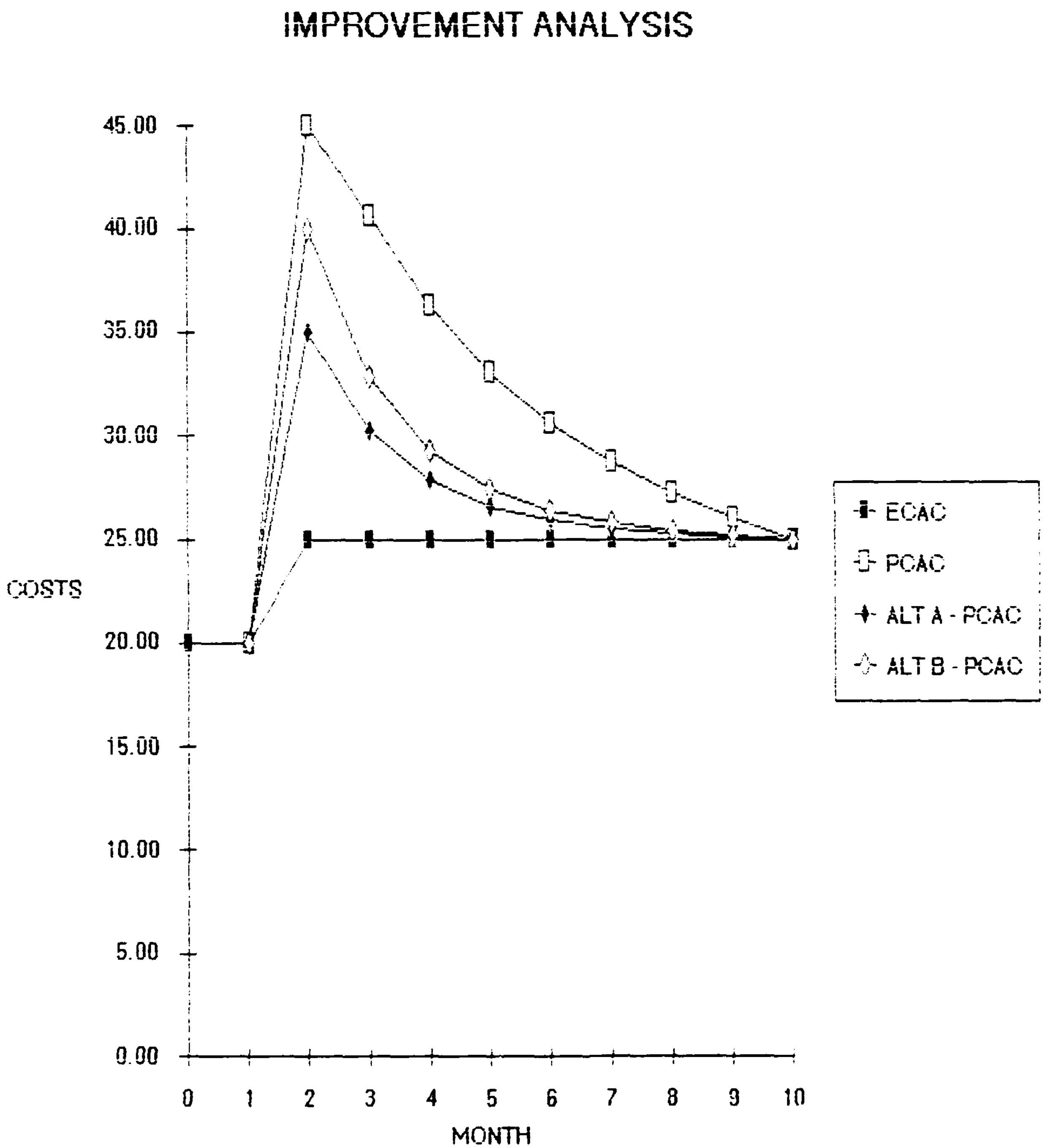
Other factors to consider in improving the worksheet are the following items:

1. ECAC reduction so large that PCAC becomes negative. There are several ways in which thus situation can be corrected:

a. Program spreadsheet to decrease the PCAC only by a fraction of the normal amplification factor. Therefore have two methods one of increases in the ECAC and a less drastic method for decreases in the ECAC.

b. A much more simpler method would be to decrease the amplification factor, but by doing this the original intent of Davis's spreadsheet is lost.

2. Begin method at the 20 to 255 work in place stage. In Chapter 2 several current methods of forecasting were introduced. In the majority of theses cases the project managers did not begin using the method until the 20 to 25% work in place stage of the project. This method should also be used in the same manner, if used prior to the 25% complete stage the amplification factor is largest and might be neglected by the project manager.



[illegible] 3.13 - Improvement [illegible]

		COST TREND WORKSHEET				
			IMPROVEMENT ANALYSIS			
			DATE	5-Jun-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4 -COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	25.00
REPORT 4	4	3	1	10	6	25.00
REPORT 5	5	4	1	10	5	25.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	25.00
REPORT 8	8	7	1	10	2	25.00
REPORT 9	9	8	1	10	1	25.00
REPORT 10	10	9	1	10	0	25.00
7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(8x7)	SUM 8	9/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
5.00	10.00	20.00	2.22	15.56	40.56	REPORT 3
5.00	10.00	30.00	1.88	11.25	36.25	REPORT 4
5.00	10.00	40.00	1.60	8.00	33.00	REPORT 5
5.00	10.00	50.00	1.39	5.56	30.56	REPORT 6
5.00	10.00	60.00	1.22	3.67	28.67	REPORT 7
5.00	10.00	70.00	1.09	2.19	27.19	REPORT 8
5.00	10.00	80.00	0.99	0.99	25.99	REPORT 9
5.00	10.00	90.00	0.90	0.00	25.00	REPORT 10

Figure 7.14 - Improvement Analysis

COST TREND WORKSHEET

COST SLOPE FACTOR SET AT 3.0 AND COL 8 FACTOR AT 2						
7	8	9	10	11	12	
ESTIMATED			***COST***	PREDICTED	PREDICTED	
COST			***SLOPE***	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2*(3x7)	SUM 8	***9/(1^3)***	5x 10	6+11	
					ALT A - PCAC	
0.00	0.00	0.00	***0.00***	0.00	20.00	REPORT 1
5.00	10.00	10.00	***1.25***	10.00	35.00	REPORT 2
5.00	10.00	20.00	***0.74***	5.19	30.19	REPORT 3
5.00	10.00	30.00	***0.47***	2.81	27.81	REPORT 4
5.00	10.00	40.00	***0.32***	1.60	26.60	REPORT 5
5.00	10.00	50.00	***0.23***	0.93	25.93	REPORT 6
5.00	10.00	60.00	***0.17***	0.52	25.52	REPORT 7
5.00	10.00	70.00	***0.14***	0.27	25.27	REPORT 8
5.00	10.00	80.00	***0.11***	0.11	25.11	REPORT 9
5.00	10.00	90.00	***0.09***	0.00	25.00	REPORT 10

COST SLOPE FACTOR SET AT 3.0 AND COL 8 FACTOR AT 3						
7	8	9	10	11	12	
ESTIMATED			***COST***	PREDICTED	PREDICTED	
COST			***SLOPE***	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	3*(3x7)	SUM 8	***9/(1^3)***	5x 10	6+11	
					ALT B - PCAC	
0.00	0.00	0.00	***0.00***	0.00	20.00	REPORT 1
5.00	15.00	15.00	***1.88***	15.00	40.00	REPORT 2
5.00	15.00	30.00	***1.11***	7.78	32.78	REPORT 3
5.00	15.00	45.00	***0.70***	4.22	29.22	REPORT 4
5.00	15.00	60.00	***0.48***	2.40	27.40	REPORT 5
5.00	15.00	75.00	***0.35***	1.39	26.39	REPORT 6
5.00	15.00	90.00	***0.26***	0.79	25.79	REPORT 7
5.00	15.00	105.00	***0.21***	0.41	25.41	REPORT 8
5.00	15.00	120.00	***0.16***	0.16	25.16	REPORT 9
5.00	15.00	135.00	***0.14***	0.00	25.00	REPORT 10

Figure 3.14 - Improvement Analysis

3.6 MACRO PROGRAM FOR EXCEL

A macro program was developed on an IBM Excel Spreadsheet. This macro was developed in conjunction with this research to aid the novice user of this forecasting method in the use of the spreadsheet and chart. The macro utilizes the customization assets of the Excel Spreadsheet to form interactive programmable boxes to guide the user throughout the initiation, periodic updating and printing of the results. The macro program is detailed in Appendix D.

CHAPTER IV RESULTS

In Chapter III a detailed analysis of Davis's spreadsheet was presented. Several different scenarios were discussed as well as a detailed sensitivity analysis. The different results as discussed in the last chapter are summarized below:

1. The spreadsheet is easy to learn, use and modify.

2. The different scenarios used to analyze the spreadsheet all showed the special convergence feature of this process. The convergence of the ECAC to the PCAC reflects the idea that changes in the ECAC in the beginning of the project are more critical than the same changes at the end of the project.

3. The different scenarios also showed the amplification factor of this process, this amplification factor is defined as the difference between the ECAC and the PCAC. This factor is extremely noticeable in the beginning of the project and is reduced as the project progresses. Amplification factors of 180% are common in the beginning whereas they reduce to 0 at the completion of the project.

4. The macro developed in the research is extremely easy to use and can be given to a novice computer user to initiate the spreadsheet and to provide periodic updates as well as reports.

5. The basic theory behind this spreadsheet is that changes in the ECAC will be continuous throughout the remainder of the

contract. These changes therefore should be calculated and then multiplied by the remaining portion of the contract to determine the PCAC.

6. The spreadsheet does not function when faced with an ECAC that shows large decreases, the PCAC due to the amplification facto will reflect negative values.

7. Additional modification of the spreadsheet increases the complexity and will require additional programming of the equations. This increase in complexity will be difficult to learn for the novice computer user and will decrease the user-friendliness of the current spreadsheet.

CHAPTER V RECOMMENDATIONS

From the results section of this report several recommendations can be provided in the use of this worksheet. First, the spreadsheet should be customized to the individual company's requirements. The amplification factor should be analyzed and the factor should be discussed and agreed upon prior to using the spreadsheet. Along with the amplification factor other customizing factors should be considered including the cost slope and whether to include several different PCAC's on the chart.

This spreadsheet should not be used alone in determining courses of action due to cost overruns. This process is only used to identify that a problem exists, it does not identify the location of the problem. Other methods discussed in Chapter 2 should be used in addition to this process to determine the location and the extent of the problems.

Future research in this area should include the combination of the methods described in Chapter 2 and this method and then programming this combination with the cost accounting of the project to derive a final predicted completion cost which can identify problem location and extent. The references provided in the Reference section of this paper will aid any new research.

CHAPTER VI CONCLUSIONS

The main objective of this research paper was to analyze Davis's spreadsheet and chart to determine if this method of forecasting was reasonable and practical in the construction industry. Several currently used forecasting methods were discussed so that a comparison of Davis's method could be made. The equation and spreadsheet were discussed in detail and then a sensitivity analysis was performed on the spreadsheet and chart to determine the cause and affect of different scenarios.

After the analysis of the simulation, several factors were identified in the spreadsheet that required changes. One of these changes was the amplification factor which is identified as the difference between the ECAC and the PCAC. Another change suggested was that the converfence of th ePCAC to the ECAC by accelerated. Both of these factors were combined to improve the function of the spreadsheet and make the spreadsheet more practical.

In the results section of this paper several items were discussed including the ease of use of this particular forecasting method. Another advantage of this method is that it is easy to manipulate and therefore a project manager can easily change the equations within the spreadsheet so that the results can better show the trend of the project to date.

Another major problem of this spreadsheet is that the amplification factor is to large. This factor, if used too often can be a detriment to the project manager. If every little change in the ECAC produced a large change in the PCAC, the manager is more likely to look upon the PCAC as just another annoying factor of his job and will eventually ignore the warning signs. One way to reduce this problem is to limit the use of the forecast method to the last 80% of the project life, the amplification factor gets smaller as the project progresses.

The convergence of the PCAC into the ECAC curve is an interesting aspect of this forecasting method. This convergence aspect shows that differentials early in the project's progress are more important that the same differentials in the later phases of the project. This part of Davis's equation is realistic, an estimate that has large cost differences in the beginning of the project is more likely to have additional cost differences throughout the term of the project thus compounding the problem.

The underlying theory of this forecasting method is that a predicted cost at completion can be determined by analyzing differentials in the estimated cost at completion during specific times in the process of the project. This theory would be extremely hard to sell to any construction manager. Variance analysis of cost codes provide the same *information without* enlarging the variance due to the time of the estimate. The spreadsheet as presented is unreasonable and should never by used as a sole source of forecasting.

The formula used in conjunction with other methods however could be a valuable tool in alerting managers to future problems. Other methods such as variance analysis, productivity curves and the managers experience could all be used together to establish an effective forecasting method.

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APPENDICES

A. COST TREND CHART WORKSHEET OPERATION MANUAL

B. DAVIS'S ARTICLE

C. MISCELLANEOUS PLOTS AND SPREADSHEETS

D. EXCEL SPREADSHEET AND CHART MACRO

APPENDIX A

COST TREND CHART WORKSHEET OPERATION MANUAL

COST TREND CHART WORKSHEET
OPERATION MANUAL

INTRODUCTION

In 1976 Gordon Davis developed a Cost Trend Chart and Worksheet that would calculate the Predicted Cost at Completion (PCAC) when provided with periodic updates of the Estimated Cost at Completion (ECAC). This worksheet computes the difference between the Estimated Completion Cost (ECAC) inputed for the current period and the input for the previous period. This difference is then multiplied by the number of remaining periods in the project to determine the Predicted Completion Cost (PCAC). Caution must excercised in the use of this spreadsheet and chart, other methods of trend analysis and forecasting must be utilized to formulate the final completion costs. This equation tends to yield early results that some may consider rather large completion costs due to minor differences in the estimated cost at completion.

The spreadsheet and chart are provided in the next few pages. The spreadsheet is rather easy to intiate, first the title and original estimated cost are inputed at the beginning. Periodic updates only require that the update number, projected completion date, and the estiamted cost at completion be inputed. The final result is then automatically calculated through the equations and listed in Column 12, the predicted cost at completion

The chart is simply the graphical representation of the ECAC compared to the PCAC. The horizontal axis is the Cost Report Date and the vertical axis is the completion cost. The input and the result is plotted for the purpose of comparing the ECAC to the PCAC.

SPREADSHEET EXPLANATION

The following is a column by column breakdown and description of the spreadsheet:

A. INITIATION OF THE WORKSHEET

1. TITLE: this space is provided to input the title of the construction project and any pertinent comments.

2. ORIGINAL COST: the original estimated cost at

completion is imputed into this
worksheet block.

B. DESCRIPTION OF THE COLUMNS

REPORT NUMBER

Prior to column one, the worksheet presents a column showing the report number. In the analysis of this worksheet these updates are stated in monthly intervals. However the updates may be in any interval as long as the unit of the interval is consistent.

COLUMN 1: REPORT DATE

This column is a restatement of the previous column. The value of this column is used later in the spreadsheet, the word "REPORT" is therefore eliminated in order for the value to be used in the spreadsheet program. Similar to the first column this column shows the report date as a monthly update.

COLUMN 2: PREVIOUS REPORT DATE (INPUT)

This column simply states the last report date and is inputed as the number of the last report date.

COLUMN 3: UPDATE INTERVAL

The update interval is the difference between the first column and the second column. This shows the amount of time that the updating of this spreadsheet has lapsed.

COLUMN 4: PROJECTED COMPLETION DATE (INPUT)

This value is imputed into the spreadsheet as the estimated time to compete the project. Note that this value is part of the periodic updating of the spreadsheet. This value represents the total duration of the project, not the remaining completion time.

COLUMN 5: REMAINING TIME TO COMPLETE

This column is automatically calculated by subtracting COLUMN 1: REPORT DATE by COLUMN 5: PROJECTED COMPLETION DATE.

COLUMN 6: ESTIMATED COST AT COMPLETION (INPUT) (ECAC)

This input value is the most up-to-date completion cost estimate of the project. Usually a project manager uses a combination of the methods described in the previous chapter to determine this value.

COLUMN 7: ESTIMATED COST OVERRUN

Column 7 represents the estimated cost overrun for the given interval. This calculation is simply the difference between COLUMN 6: ESTIMATED COST AT COMPLETION and the ORIGINAL COST as imputed during the initiation phase of the setup.

COLUMN 8: CALCULATIONS

This calculation consists of multiplying the product of COLUMN 3: UPDATE INTERVAL and COLUMN 7: ESTIMATED COST OVERRUN by a factor of 2.

The reasons why the factor of 2 is applied is not apparent, in the sensitivity analysis section of this chapter this factor is discussed.

COLUMN 9: CALCULATIONS

This column is the summation of the previous column to the point of the update. For example, if the report date is number 5, then the value of this column would be the summation of the first five entries of COLUMN 8.

COLUMN 10: COST SLOPE

The cost slope is derived by dividing COLUMN 9 by the square of COLUMN 1: REPORT DATE. As can be seen from the graphical representation of this spreadsheet, the cost slope is the slope of this line between the two update intervals. Without the square root of the denominator this equation is basically the average of the interval cost overruns.

In the sensitivity analysis of this spreadsheet formulas the discussion of why the denominator is squared is discussed.

COLUMN 11: PREDICTED ADDITIONAL OVERRUN

This value is calculated by multiplying COLUMN 5: REMAINING TIME TO COMPLETE by COLUMN 10: COST SLOPE.

COLUMN 12: PREDICTED COST AT COMPLETION (PCAC)

The final column represents the results of this spreadsheet and is calculated by the addition of COLUMN 6: ESTIMATED COST AT COMPLETION and COLUMN 11: PREDICTED ADDITIONAL OVERRUN.

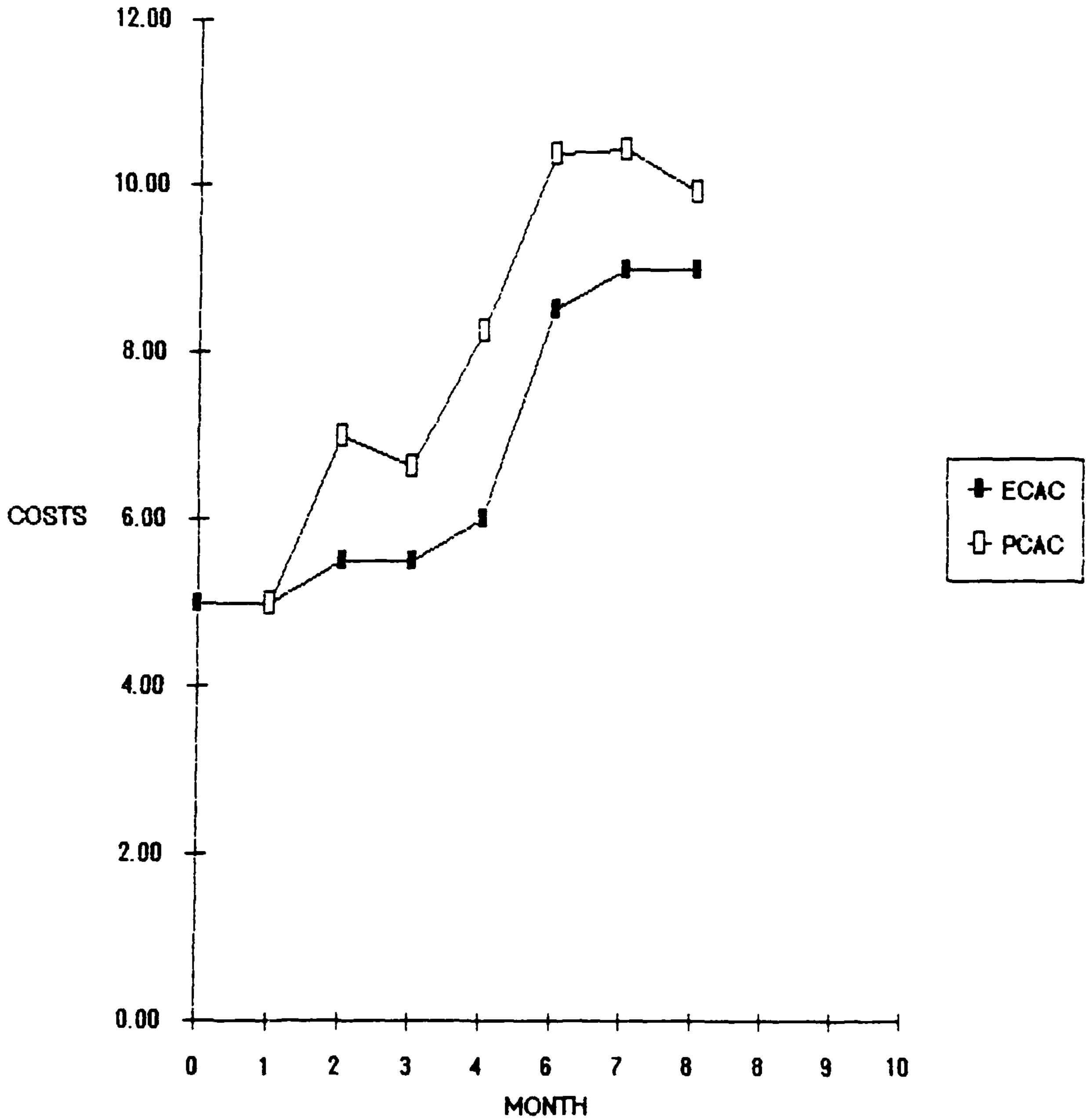
COST TREND WORKSHEET

DAVIS ORIGINAL ARTICLE

			DATE	25-May-90		
ORIGINAL COST=	5					
	1	2	3	4	5	6
REPORT NUMBER	REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	PROJECTED COMPLETION DATE INPUT	REMAINING TIME TO COMPLETE COL4 -COL1	ESTIMATED COST AT COMPLETION INPUT ECAC
ORIGINAL	0			6		5.00
REPORT 1	1	0	1	6	5	5.00
REPORT 2	2	1	1	8	6	5.50
REPORT 3	3	2	1	8	5	5.50
REPORT 4	4	3	1	13.09	9.09	6.00
REPORT 5	6	4	2	9.77	3.77	8.50
REPORT 6	7	6	1	9.67	2.67	9.00
REPORT 7	8	7	1	9.75	1.75	9.00
REPORT 8	8	8	0		-8	
REPORT 9	9	9	0		-9	
REPORT 10	10	9	1		-10	

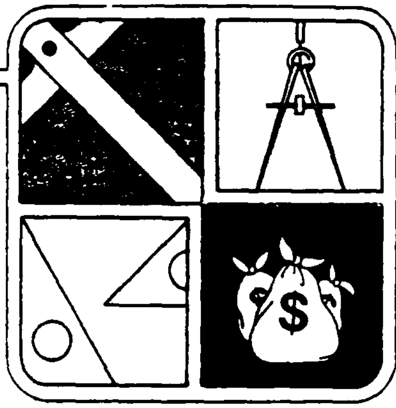
7	8	9	10	11	12	
ESTIMATED COST OVERRUN 6- ORIG COST	2(3x7)	SUM 8	COST SLOPE 9/1^2	PREDICTED ADDITIONAL OVERRUN 5x 12	PREDICTED COST AT COMPLETION 6+11 PCAC	REPORT NUMBER
0.00	0.00	0.00	0.00	0.00	5.00	REPORT 1
0.50	1.00	1.00	0.25	1.50	7.00	REPORT 2
0.50	1.00	2.00	0.22	1.11	6.61	REPORT 3
1.00	2.00	4.00	0.25	2.27	8.27	REPORT 4
3.50	14.00	18.00	0.50	1.89	10.39	REPORT 5
4.00	8.00	26.00	0.53	1.42	10.42	REPORT 6
4.00	8.00	34.00	0.53	0.93	9.93	REPORT 7
-5.00	0.00	34.00	0.53	-4.25		REPORT 8
-5.00	0.00	34.00	0.42	-3.78		REPORT 9
-5.00	-10.00	24.00	0.24	-2.40		REPORT 10

DAVIS ORIGINAL ARTICLE



APPENDIX B

DAVIS'S ARTICLE



J. GORDON DAVIS
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Systems/Project Management
Atlanta, Georgia

Keeping Project Costs In Line

For most projects, profitability depends upon effective cost control. Unfortunately, many cost-control systems are inadequate and even misleading. The reporting plan and analysis discussed here should go a long way toward eliminating these difficulties.

MANY ENGINEERING MANAGERS try to keep on top of project costs by merely reviewing cost reports as they become available. This procedure is forever lagging behind what is actually occurring. What is needed is a method for forecasting costs and completion dates so that efforts to keep costs in line can be launched before things get out of hand.

It's The Trend That Counts

The typical cost report contains a breakdown of project estimates into categories, as shown in Fig. 1. The cost figures presented for each line item start with an Original Estimate, the estimate at the time the project was funded. The Current Estimate frequently includes only the Original Estimate plus any change orde[illegible] to label th[illegible] [illegible] Current Estima[illegible] showing [illegible] mos[illegible] [illegible]ent estimate, funded or not, of what the item should cost. Actual

The Actual-To-Date figure should include all charges for work accomplished to date, not just payments actually made. The Committed-To-Date figure includes all contractural obligations for future delivery of work or products. The Estimate-To-Complete figure is the current estimate for the work neither completed nor under contract.

The Expected-Total-Cost figure is the sum of the Actual, Committed, and Estimate-To-Complete figures. Its deviation from the Current Estimate is a measure of performance. Its deviation from Funded Estimate is a measure of profitability, although many managers try to use this deviation figure to measure performance. Its deviation from Original Estimate is essentially meaningless. Yet, it is this comparison which some managers use exclusively.

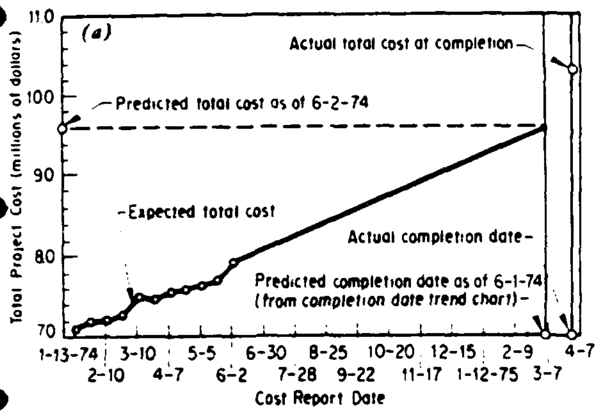
Many cost reporting systems omit the Estimate-To-Complete figure and, thus, give little indication of an impending cost overrun for a line item. Such systems may nevertheless be of some use if a large number of line items are involved because only a small percentage of the line items are ever in progress at one time.

Looking at one or even a series of cost reports will not give a good picture of what costs can be expected for a project, even if the report totals up the expected total project cost. It is the trend in this total cost figure which gives a basis for forecasting the project cost at completion.

The Expected-Total-Cost graph is a useful [illegible] [illegible] [illegible]uild pro[illegible] shown i[illegible] first few project cost reports came through [illegible]

032275	JOB COST STATUS REPORT		XYZ CORPORATION			ALPHA PROJECT			
CODE	COST CATEGORY	ORIGINAL	CHG ORDERS	CURRENT	ACTUAL	COMMITTED	ESTIMATE TO COMPLETE	EXPECTED TOTAL COST	DEVIATION FROM CURRENT ESTIMATE
0117	Electrical one-line	13,500	850	14 350	5 150	2 500	8.000	15.650	1.300 +

Fig. 1—The typical cost report is a record of various estimates and running costs for each line item of a project. The most important indication of a project's performance provided by such a report is the deviation of Expected Total Cost from the Current Estimate.



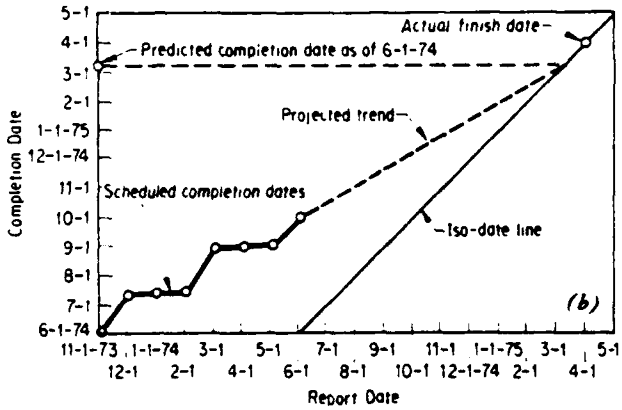


Fig. 2—The importance of a forecasting procedure is illustrated by the **Expected-Total-Cost graph** of an actual design/build project *(a)*. *Instead of merely plotting cost figures as they were reported, the manager of this project could have developed the cost trend (dotted line) inherent in those* figures. By applying the same projection procedure to the scheduled completion date of the project *(b)*, he would have had an early warning of the cost problems that were building. Instead, his reports were always behind what was actually happening.

T[illegible]oject was strictly an engineering project at this time, and the word soon came back from engineering that costs were under control. But the graph shows that engineering hadn't really gotten control of costs. If management had possessed a forecasting procedure, it might have predicted a trend line such as the dashed line shown on the graph. How far should the trend line be projected? To the project completion date, of course. But the project completion date is having troubles too, Fig. 2*b*. If this trend continues, the project completion wouldn't occur until the trend line crossed the iso-date line. It is this project completion date to which the cost trend line should be projected (see Fig. 2*a*).

Trend analysis is crucial to controlling project costs. It tends to remove the bias of tight or loose schedules, low or high cost estimates, and good or bad performance. The typical result of trend analysis is to get management disturbed much earlier than it otherwise would be. This early warning prompts management to invoke control measures while a great number of options are open.

Step-by-step procedures for creating proper completion-date and total-cost trend charts are detailed in the box entitled "Predicting Principal Project Parameters."

P[illegible]g Down Total Costs

Engineering-cost overruns are so commonplace that there is usually no uproar until the percentage overrun reaches at least double-digit proportions. An attitude of "we'll just have to live with it" is frequently a cover for uncertainty as to whether there is something wrong with engineering performance or whether the estimate is bad, or both. This attitude may also indicate uncertainty as to what actions can be taken if the problem stems from poor engineering productivity. Engineering cost control also suffers from the fact that engineering costs are typically only a small percentage of total project cost.

The magnitude of engineering cost overruns is all too often underestimated because the ripple effects are not included. If an engineer takes 50 hours more for a task than estimated, the increase in cost will be insignificant on a million-dollar project. However, an increased number of man-hours is frequently the result of a change in a preliminary design feature. Such a change can lead to changes in the cost of materials and equipment, the cost of design modifications on related portions of the system, the cost of producing or constructing the system, and/or indirect costs which vary with project length.

While these changes could be cost reductions, they usually are cost increases. The engineer is much more likely to beef up the preliminary design than to trim it down.

[illegible] cost aspects of engineering changes can be accomplished through the use of work breakdown packages. These packages can be used from the proposal stage through project

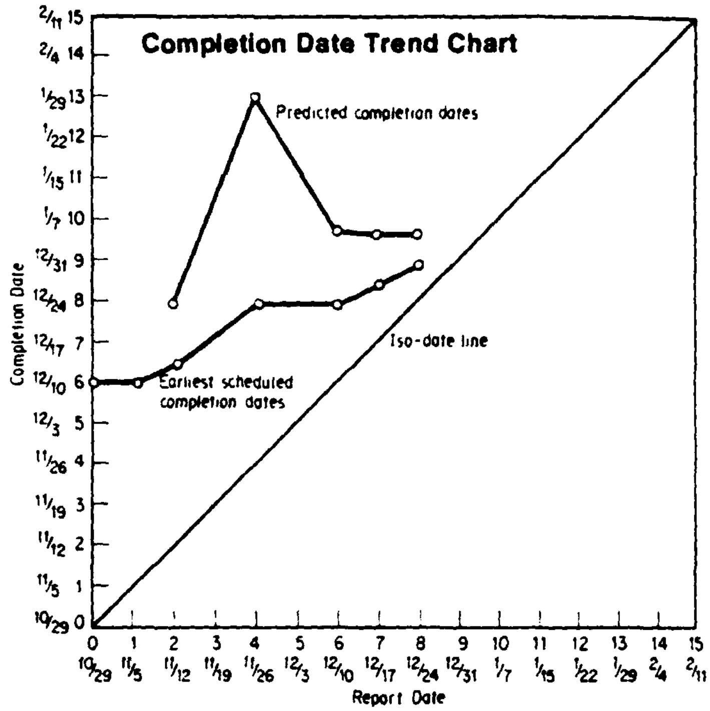
Predicting Principal Project Parameters

Completion Dates

The Completion Date Trend Chart is set up with one calendar date scale on the bottom axis and another on the left-hand axis of a daily or weekly grid. The bottom calendar should start with the date of the project. This scale should be labeled Update Date, Report Date, or Effective Date of Schedule Information. The vertical calendar should start six to eight weeks ahead of the completion date initially scheduled for project completion or any other milestone which is to be tracked. This scale should be labeled Completion Date. An iso-date line is then drawn. This is the straight line passing through all points for which both calendar scales give the same date. This 45-deg line is the target line in the sense that trend lines will be projected to their intersection with the iso-date line.

The points to be plotted on this chart are the Earliest Scheduled Completion Dates for the milestone activities being tracked. Each entry is made by finding, on the bottom axis, the date on which the latest schedule update was accomplished, then moving vertically to a point which shows the completion date resulting from the latest update.

If the initial schedule never had to be revised—that is, actual progress exactly matched the initial schedule—the completion date trend line would develop as a horizontal line. This line would intersect the iso-date line on the day that the milestone activity was completed. If progress toward that milestone was slower than scheduled, the line would have a positive slope. Conversely, better-than-scheduled performance would result in a negative slope to the trend line. Regardless of the level of performance, the trend line can be projected beyond the last plotted point to an intersection with the iso-date line. The point of intersection has a value on the Completion Date axis which may be interpreted as the Predicted Completion Date.



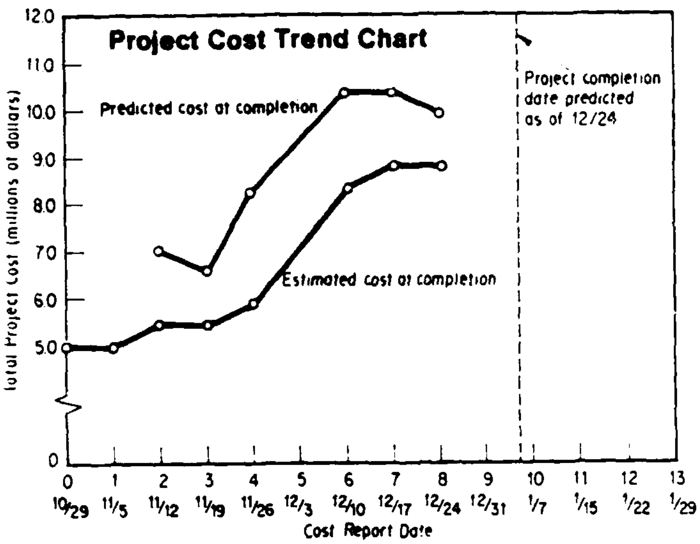
Assume first that the performance level, whether high or low relative to scheduled performance, is a constant. This means that the trend line is straight and that a projection can be made by simply extending the trend line. Thus, a project on which time estimates were too low will show a trend line with a positive slope, and the projection will result in a predicted completion date greater than the currently scheduled earliest completion date. Similarly, a project on which time estimates were too high will develop a trend line with a negative slope, and its predicted completion date will be earlier than that resulting from the most recent update.

The visual projection of the trend line formed by the Earliest-Scheduled-Completion-Date points is subject to a great deal of variation. To standardize this projection, the following procedure should be used:

1. Assign week numbers starting with zero to each end-of-week point on each axis. Let X equal the week number on the Report Date axis and Y equal the week number on the Completion Date axis.

COMPLETION DATE TREND CHART WORKSHEET

Y orig = 6	1	2	3	4	5	6	7	8	9	10	11	12
	REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	EARLIEST SCHED COMPLETION	SLIPPAGE TO DATE	2(3 × 5)	Σ 6	7 − 1²	1 × 8	4 − 9	1 − 8	PREDICTED COMPLETION WEEK
			1 − 2		4 − Y orig							10 [illegible]
Original Sched	0			6.0								
	[illegible]		[illegible]	6.0	0	0	0	0	0	6.0	1.0	[illegible]
	2			5.5	0.5	1.0	1.0	0.25	0.30	6.0	0.75	[illegible]
	[illegible]						3			[illegible]	0.44	
	6											
	7											
	8	7	1	9.0	3.0	6.0	28.0	.33				



. Set up the Completion Date
ıd Chart Worksheet as shown.
. After each update, start a
/ :sheet row by filling in
ɹı...s 1 and 4.

:. Calculate the entries for each
ıaining column in numerical
er. Column 12 is the projected
npletion time expressed in work
ːks from the start of the job.
ɜ. The number in Column 12 may
plotted on the Completion Date
nd Chart to assist in its
ːrpretation.

tal Costs

The Project Cost Trend Chart
set up with a calendar date
ıle on the bottom axis and a
ɜt scale on the left axis of a
rectangular grid. The calendar scale should start with the starting date of the project. This scale should be labeled Cost Report Date. The cost scale should start approximately 10% below the initial estimated project cost. This scale should be labeled Total Project Cost.

The points to be plotted on this chart are the sum of Actual Costs to Date plus Committed Costs To Date plus Estimated Additional Costs to Complete. Refer to these points as Estimated Costs at Completion. These data are taken directly from the Job Cost Status Report (See Fig. 1).

The resulting adjacent points may be joined by straight lines to make it easier to visualize the trend of these points. If the original estimate and the project execution were both perfect, this line would be horizontal. However, many factors tend to cause the *Estimated Cost at Completion* to *rise from* one cost report to the next. Projection of this trend to the anticipated project completion date will give a Predicted Cost at Completion. The anticipated project completion date should be the *Predicted Completion Date* from the *Completion* Date Trend Chart, rather than the Earliest Scheduled Completion-date—which could occur only if all factors causing project slippage were suddenly eliminated.

The visual projection of the cost trend line is subject to a great deal of variation. This projection can be made mathematically by use of the accompanying Cost Trend Chart Worksheet. The following procedure should be used:

1. On the Cost Trend Chart, assign week numbers starting with zero to each end-of-week point on the Report Date axis. Let X equal the week number on this axis. Let C equal the cost figure on the Total Project Cost axis.

2. After each update on the Job *Cost Status Report*, start a new worksheet row by filling in Columns 1, 4, and 6. Column 12 of the Completion Date Trend Chart Worksheet is the source of Column 4 of the Cost Trend Chart Worksheet. If a cost figure is generated for a date on which no schedule update has been made, the most recent Predicted Completion Date should be the Column 4 entry on the Cost Trend Chart Worksheet.

3. Calculate the entries for each remaining column in numerical order. Column 12 is the predicted project cost at completion. This figure may be plotted on the Cost Trend Chart to assist in its interpretation.

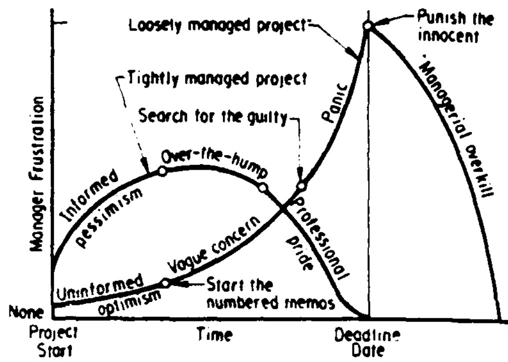
TREND CHART WORKSHEET

1	2	3	4	5	6	7	8	9	10	11	12
REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	PROJECTED COMPLETION DATE	REMAINING TIME TO COMPLETE	ESTIMATED COST AT COMPLETION	ESTIMATED COST OVERRUN	2(3 × 7)	Σ 8	COST SLOPE	PREDICTED ADDITIONAL OVERRUN	PREDICTED COST AT COMPLETION
(INPUT)		1 − 2	(INPUT)	4 − 1	(INPUT)	6 − C orig			9 ÷ 1²	5 × 10	6 + 11
0			6 0		5 0						
1	0	1	6 0	5 0	5 0	0 0	0 0	0 0	0 0	0 0	5 0
2	1	1	8 0	6 0	5 5	0 5	1 0	1 0	0 25	1 5	7 0
3	2	1	(8 0)	5 0	5 5	0 5	1 0	2 0	0 22	1 1	6 6
4	3	1	13 09	9 09	6 0	1 0	2 0	4 0	0 25	2 27	8 27
6	4	2	9 77	3 77	8 5	3 5	14 0	18 0	0 50	1 89	10 39
7	6	1	9 67	2 67	9 0	4 0	8 0	26 0	0 53	1 42	10 42
8	7	1	9 75	1 75	9 0	4 0	8 0	34 0	0 53	93	9 93

How Well Do You Manage?

You can diagnose how well you manage your projects by the pattern of frustration you experience over the life of a given project. The two basic patterns of frustration can be illustrated for the extremes of loosely-managed and tightly-managed projects. The first curve in the graph shows the pattern of a loosely-managed project. During the early stages—usually the period in which most of the engineering takes place—the manager lives in a condition of uninformed optimism. A false sense of well-being exists because there is no data indicating anything amiss. This period draws to a close with the appearance of a vague concern. Here the project manager starts issuing serially numbered memos in a process known as "cover your rear".

As engineering winds down and production or construction gets underway, the frustration climbs at an increasing rate. The cost and schedule data are beginning to filter through and the result is the start of an effort to "search for the guilty". This marks the start of the terminal phase, called "panic". As deadlines are missed and cost overruns become real, the manager usually indulges in the final rite of "punishing the innocent". At this point traumatic changes in organization take place, and the project is made



to wallow to a conclusion—late, overspent, and disruptive to the organization.

On the other hand, if a project is tightly managed, the manager will be keeping track of schedule and cost trends. If the initial data is bad, the manager's early informed pessimism will lead him to take action while many options are still open. If these actions are successful, his frustration will peak as the flow of new problems drops below the solution rate on the problems already discovered.

completion to give a uniform basis for providing the Current Estimate.

By starting with an estimate which goes to a reasonable level of detail, a basis is established for picking up cost changes. Each engineer involved in the design can be assigned tasks which relate to a specific set of one or more work packages. These packages will carry cost estimates for direct engineering costs, materials, and equipment purchase prices as well as direct construction costs. Each package will be estimated in terms of unit quantities and unit prices. Thus, an engineering task carries with it the requirement for quantifying all design decisions in terms of the cost determinations which result.

These cost determinations must not only include engineering, procurement, and fabrication, but must also cover those same factors on work packages which are affected by the package in question. The engineer releases a work package only after summarizing the total cost change which has resulted from his work on that package.

The advantage of this approach is that the designer has had a goal to shoot for, which is important in at least two ways. First, he is forced to examine the preliminary or proposal stage design in an effort to stay within its cost boundaries; thus, his feedback to the estimating system is much more precise than would otherwise be the case. Too frequently, the engineer strikes out afresh to design his portion of the project, taking the attitude that the origi... ...posed d... ...s done merely to allow an estimate to be made. Second, the knowledge that a certain number of man-hours have been budgeted for his activity helps the engineer determine the quality level that can be afforded on this activity.

The engineer's release of a work package will be followed by its tentative updating in the cost control system. A threshold can be established such that increases of more than, say, 5% over the previous Current Estimate are singled out for management review. Alternatively, the review threshold could be an absolute amount of cost increase in all related work packages. Management then has the option of rejecting costly design changes before they are irretrievably assimilated into the total system design.

The completion of work packages within the estimated man-hours is dependent upon the adequacy of the estimate. Estimating standards which are too tight create an atmosphere in which the futility of staying within the estimate leads to an attitude of ignoring the estimate, because it is obviously invalid. If the tightness of standards is the result of a managerial decision to set high goals, an improper and ineffective use of the cost control system results.

Standards should represent expected values, such that the sum of all the estimates for each work package will lead to the expected project cost. If management decides to compete with other organizations for a project, and wishes to bid a low total pri... ...normal ...estimate sh...

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package, it is imp
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engineering task
man-hours by on
to consist of pha
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broken down as fo
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- Review propo
- Preliminary s
- Calculations—
- Review of su
- Final sketche
- Specifications

With this kind
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man-hours availab
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exactly as it would for a project bid at a normal profit margin. The managerial decision on competitiveness of the bid should have its effect confined to the size of the mark-up for profit, unless a conscious decision is made to lower the quality of work performed below existing standards.

Estimating standards may be too tight or too loose because feedback reflecting actual performance is not available in a form that leads to updating of the standards. Unit costs can be updated independent of performance, but unit quantities cannot. The estimating standards should reflect what the organization's performance leads one to expect for the next project. Improvements in performance through procedure analysis, management improvement, motivation, or any other factor should not be anticipated by the estimating system unless actual performance data is available.

Scheduling For The Short Haul

Assuming that good standards are in effect, engineering cost control then focuses on obtaining a performance which meets or betters these standards. Whether we are talking about overall project life or the life of an engineering task on one work package, it is important to identify the components of the work early and determine the implications of the work for the immediate future. In engineering tasks, this means the short-range scheduling of work in intervals of as little as one-half hour. An engineering task having an estimate of, say, 20 man-hours by one man should be planned so as to consist of phases or activities with identifiable end points. For instance, such a task might be broken down as follows:

- Planning—0.5 hr
- Review proposal—1.0 hr
- Preliminary sketches—6.0 hr
- Calculations—2.0 hr
- Review of supply catalogs—1.5 hr
- Final sketches—7.0 hr
- Specifications—2.0 hr

With this kind of breakdown, the engineer can better track his own progress toward the 20-hour completion goal. The engineering supervisor can exert control by having the engineer report once each day, giving a statement of the progress anticipated during the next day and the progress achieved during the past day. Even if the supervisor never rejects the goals set or criticizes actual performance, making a short-range commitment will normally improve engineering productivity.

One factor that must be accounted for in scheduling the 20 man-hours of work is the number of man-hours available per day for unscheduled work. Answering the telephone, responding to questions from associates, handling correspondence, and other similar tasks frequently consume much of the engineer's day. In practice, it is advisable to assume that some negotiated figure, say 60%, is the proper factor to represent available time. Thus, one would expect the engineer to average 4.8 hr per day on scheduled production. This figure can be revised after the short-range scheduling system has been in effect long enough to be debugged.

Work sampling by the engineers themselves can lead to a refinement in the estimate of nonscheduled work load. For instance, each man can tally his activities into scheduled or nonscheduled categories every half hour for a week. The category percentages will be good estimates of the total week's time distribution. Again, the effect is to make people more aware of the degree to which nonscheduled activities are allowed to interrupt scheduled work. The engineer may decide to group his nonscheduled activities to some extent, reducing the effects of interruptions and shifts in type of activity.

Assign A Project Manager

A project is frequently allowed to wander through the various functional groups involved without a real advocate who is in close touch with current status and has the authority to make expediting decisions. The project manager should be assigned during the proposal stage, even though the majority of such assignments will not lead to funded projects. This timing avoids the problem of having an accepted proposal handed to a project manager who immediately begins to find flaws in the concept, the estimate, and the schedule.

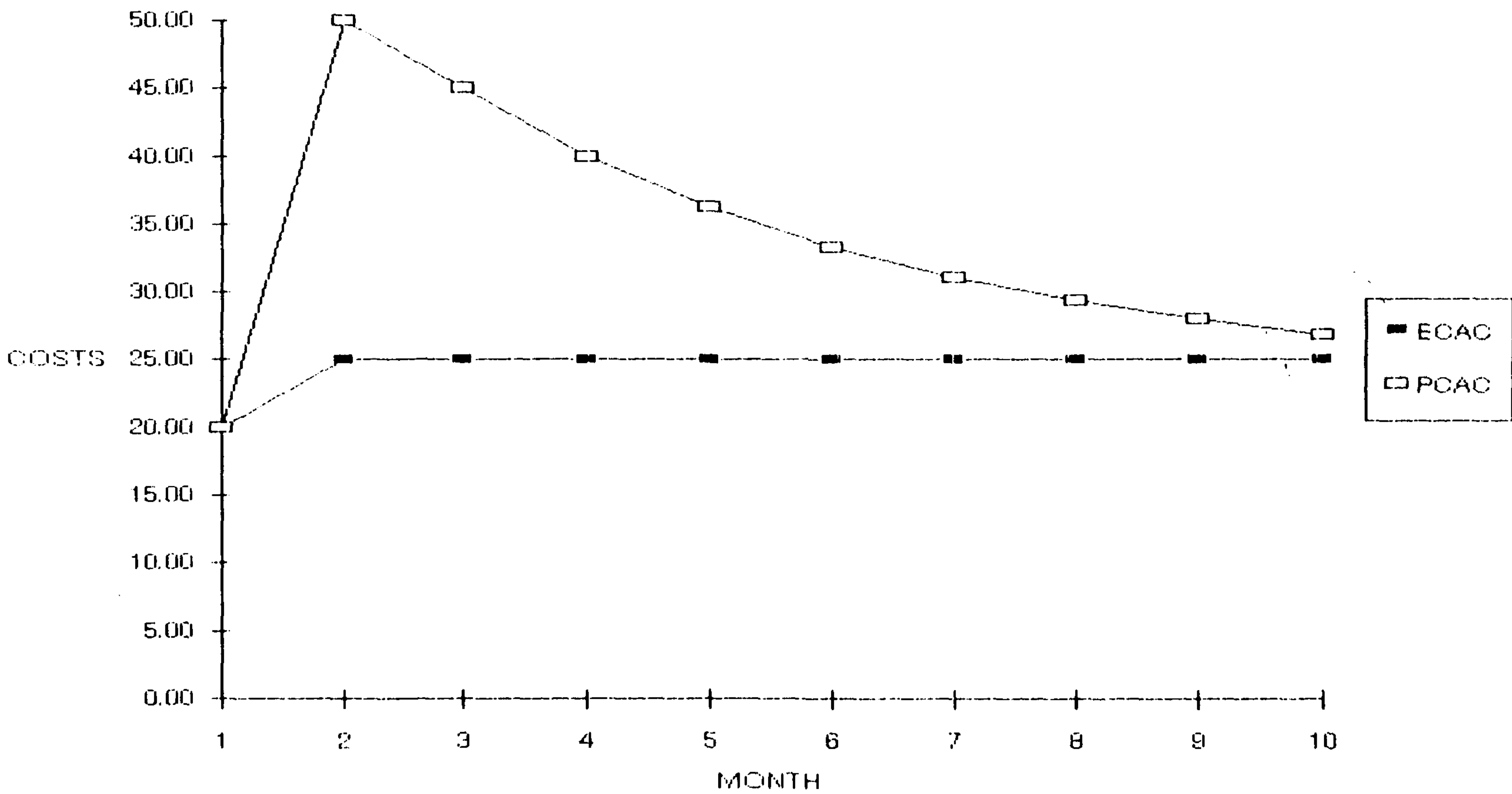
The project manager must be given the opportunity to set up the control system which allows him to accurately determine project status. He must be supported by an estimating system which is aligned to the realities of the organization and keeps the estimate revised to reflect current knowledge. He must also have the support of top management so that he is a true project manager not merely a coordinator with no authority.

Engineering cost control is not likely to succeed unless the system is thoroughly planned and debugged before implementation. Computerized estimating systems are necessary if responsiveness to design changes is to be adequate and feedback for adjustment of standards is to be thorough. The systems should be designed so as to require as little input effort as possible from the individuals carrying out the activities. The rewards for paying the initial price are large, with payout on initial costs frequently being as short as six months into the first project. □

APPENDIX C

MISCELLANEOUS PLOTS AND SPREADSHEETS

INCREASE IN ESTIMATE WITH ADDITIONAL TIME



COST TREND WORKSHEET

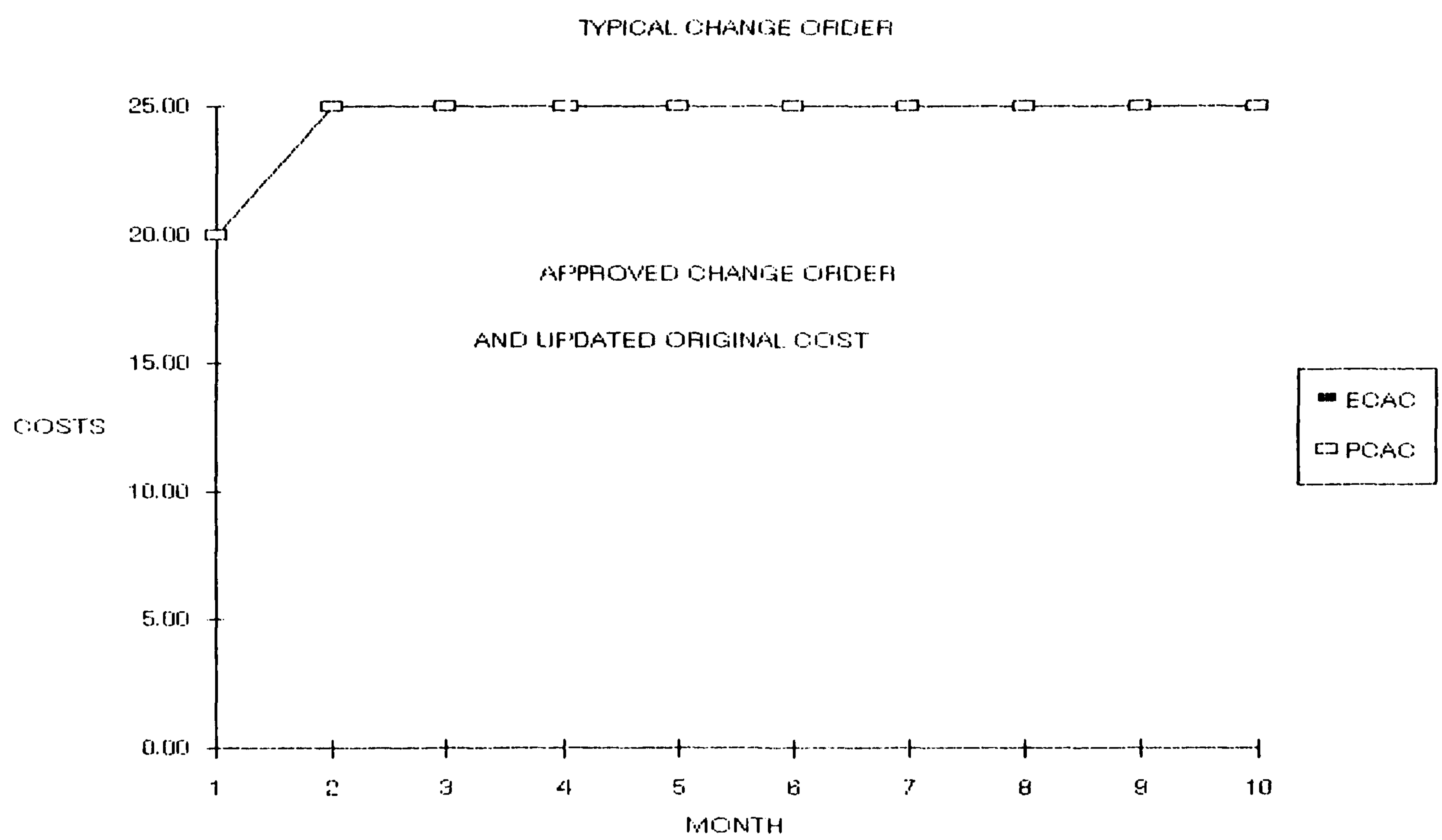
COST TREND WORKSHEET

INCREASE IN ESTIMATE WITH ADDITIONAL TIME

			DATE	18--May--90		
ORIGINAL COST =	20					
	1	2	3	4	5	6
REPORT NUMBER	REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	PROJECTED COMPLETION DATE INPUT	REMAINING TIME TO COMPLETE COL4 --COL1	ESTIMATED COST AT COMPLETION INPUT ECAC
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	12	10	25.00
REPORT 3	3	2	1	12	9	25.00
REPORT 4	4	3	1	12	8	25.00
REPORT 5	5	4	1	12	7	25.00
REPORT 6	6	5	1	12	6	25.00
REPORT 7	7	6	1	12	5	25.00
REPORT 8	8	7	1	12	4	25.00
REPORT 9	9	8	1	12	3	25.00
REPORT 10	10	9	1	12	2	25.00

7	8	9	10	11	12	
ESTIMATED COST OVERRUN 6-- ORIG COST	2(3x7)	SUM 8	COST SLOPE 9/1 ^ 2	PREDICTED ADDITIONAL OVERRUN 5x 12	PREDICTED COST AT COMPLETION 6+11 PCAC	REPORT NUMBER
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	25.00	50.00	REPORT 2
5.00	10.00	20.00	2.22	20.00	45.00	REPORT 3
5.00	10.00	30.00	1.88	15.00	40.00	REPORT 4
5.00	10.00	40.00	1.60	11.20	36.20	REPORT 5
5.00	10.00	50.00	1.39	8.33	33.33	REPORT 6
5.00	10.00	60.00	1.22	6.12	31.12	REPORT 7
5.00	10.00	70.00	1.09	4.38	29.38	REPORT 8
5.00	10.00	80.00	0.99	2.96	27.96	REPORT 9
5.00	10.00	90.00	0.90	1.80	26.80	REPORT 10

INDEPENDENT RESEARCH PROJECT



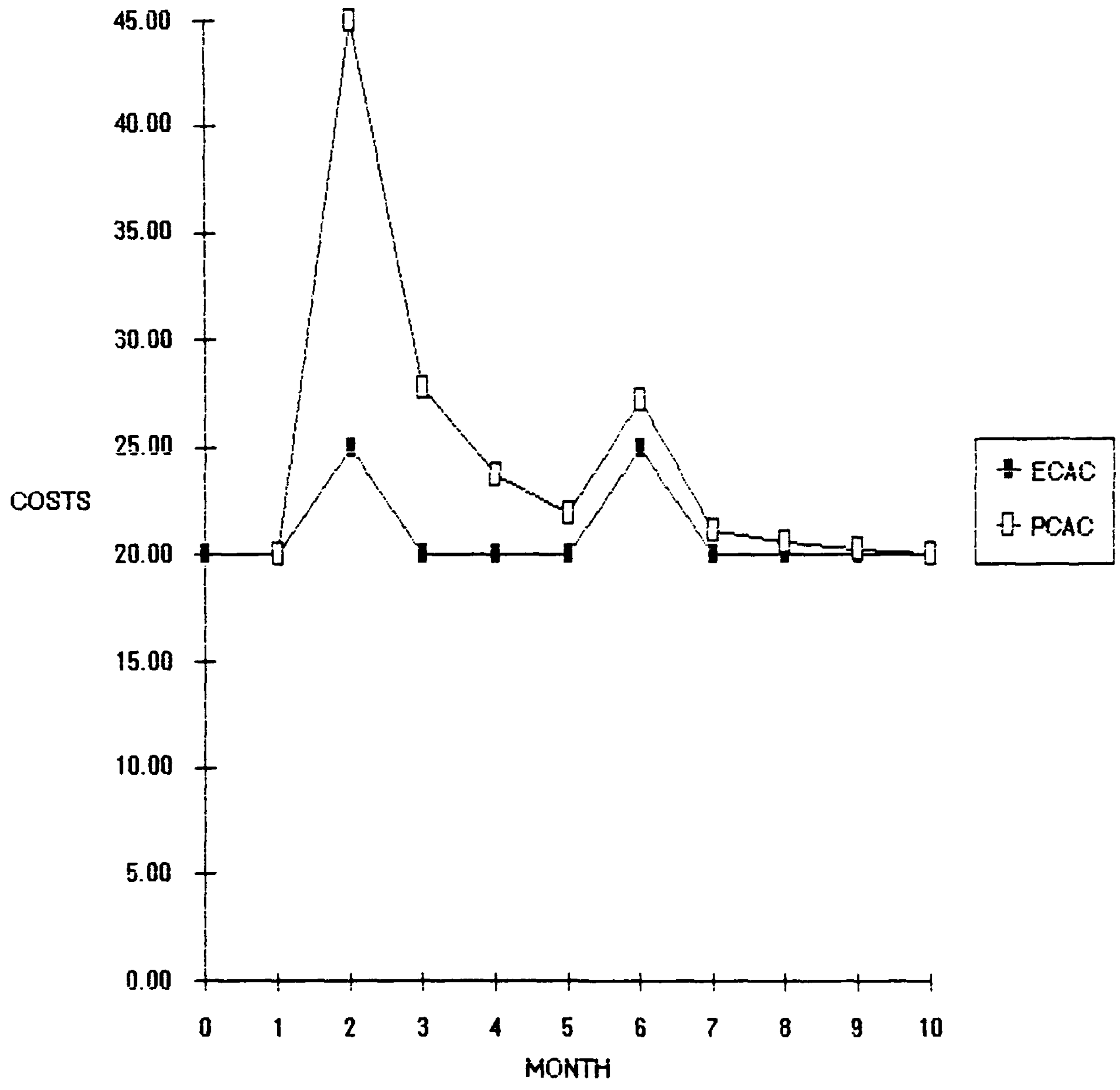
COST TREND WORKSHEET

CHANGE ORDER WITH TIME EXTENSION

			DATE	18-May-90		
ORIGINAL COST --	20					
CHANGE ORDER --	25					
	1	2	3	4	5	6
REPORT NUMBER	REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	PROJECTED COMPLETION DATE INPUT	REMAINING TIME TO COMPLETE COL4 -- COL1	ESTIMATED COST AT COMPLETION INPUT ECAC
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	12	10	25.00
REPORT 3	3	2	1	12	9	25.00
REPORT 4	4	3	1	12	8	25.00
REPORT 5	5	4	1	12	7	25.00
REPORT 6	6	5	1	12	6	25.00
REPORT 7	7	6	1	12	5	25.00
REPORT 8	8	7	1	12	4	25.00
REPORT 9	9	8	1	12	3	25.00
REPORT 10	10	9	1	12	2	25.00

7	8	9	10	11	12	
ESTIMATED COST OVERRUN 6 -- ORIG COST	2(3x7)	SUM 8	COST SLOPE 9/1 ^ 2	PREDICTED ADDITIONAL OVERRUN 5x 12	PREDICTED COST AT COMPLETION 6+11 PCAC	REPORT NUMBER
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 2
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 3
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 4
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 5
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 6
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 7
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 8
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 9
0.00	0.00	0.00	0.00	0.00	25.00	REPORT 10

TWO SPIKES


45.00
40.00
35.00
30.00
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COSTS
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COST TREND WORKSHEET

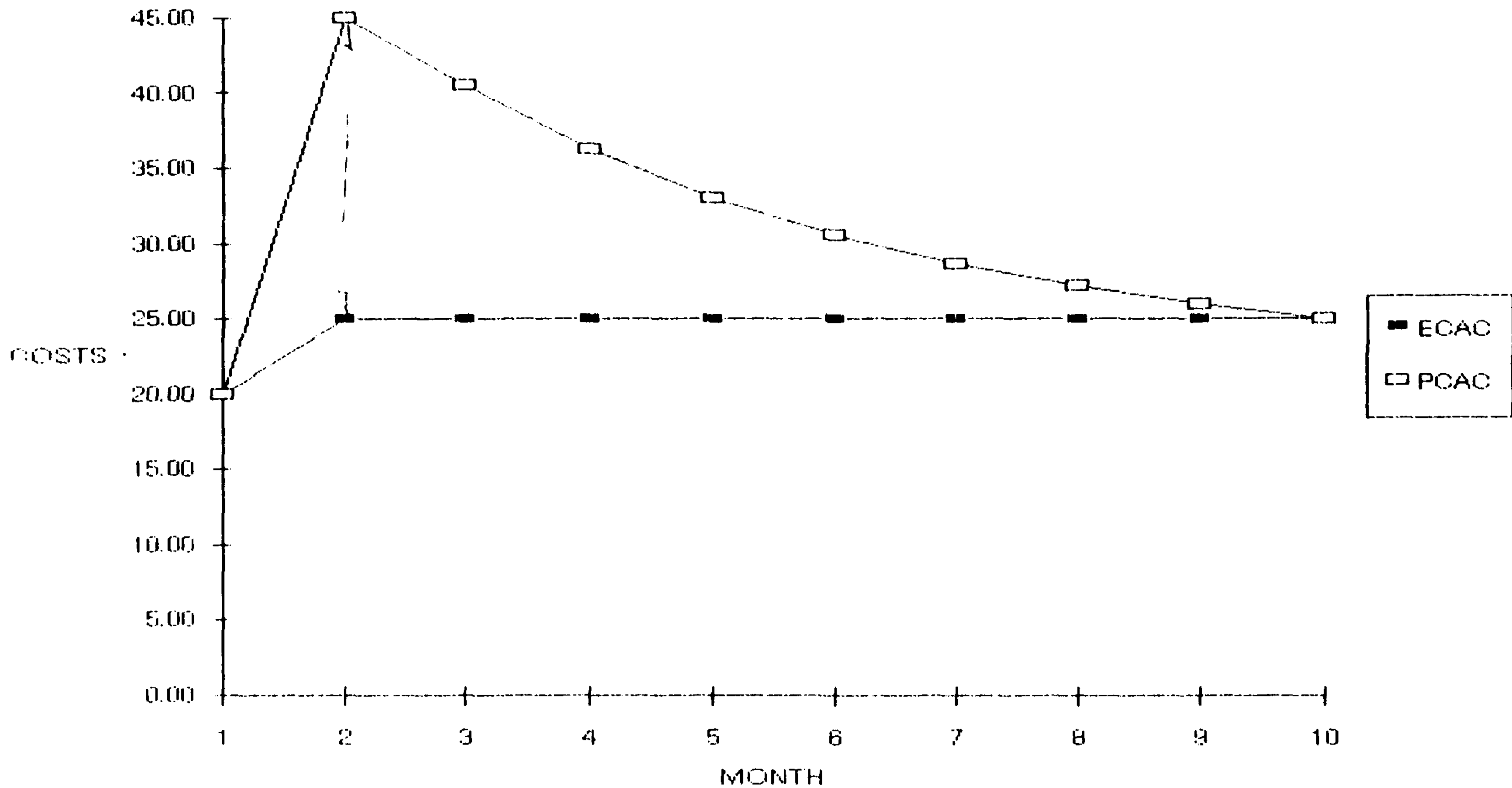
TWO SPIKES

			DATE	25-May-90		
ORIGINAL COST=	20					
	1	2	3	4	5	6
		PREVIOUS		PROJECTED	REMAINING	ESTIMATED
REPORT	REPORT	REPORT	UPDATE	COMPLETION	TIME	COST AT
NUMBER	DATE	DATE	INTERVAL	DATE	TO COMPLETE	COMPLETION
				INPUT	COL4-COL1	INPUT
						ECAC
ORIGINAL	0			10		20.00
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	20.00
REPORT 4	4	3	1	10	6	20.00
REPORT 5	5	4	1	10	5	20.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	20.00
REPORT 8	8	7	1	10	2	20.00
REPORT 9	9	8	1	10	1	20.00
REPORT 10	10	9	1	10	0	20.00

7	8	9	10	11	12	
ESTIMATED			COST	PREDICTED	PREDICTED	
COST			SLOPE	ADDITIONAL	COST AT	REPORT
OVERRUN				OVERRUN	COMPLETION	NUMBER
6- ORIG COST	2(3x7)	SUM 8	9/1^2	5x 10	6+11	
					PCAC	
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
0.00	0.00	10.00	1.11	7.78	27.78	REPORT 3
0.00	0.00	10.00	0.63	3.75	23.75	REPORT 4
0.00	0.00	10.00	0.40	2.00	22.00	REPORT 5
5.00	10.00	20.00	0.56	2.22	27.22	REPORT 6
0.00	0.00	20.00	0.41	1.22	21.22	REPORT 7
0.00	0.00	20.00	0.31	0.63	20.63	REPORT 8
0.00	0.00	20.00	0.25	0.25	20.25	REPORT 9
0.00	0.00	20.00	0.20	0.00	20.00	REPORT 10

INITITIAL SPIKE WITH CONSISTENT FOLLOWING ESTIMATES

NO CHANGE IN COMPLETION TIME

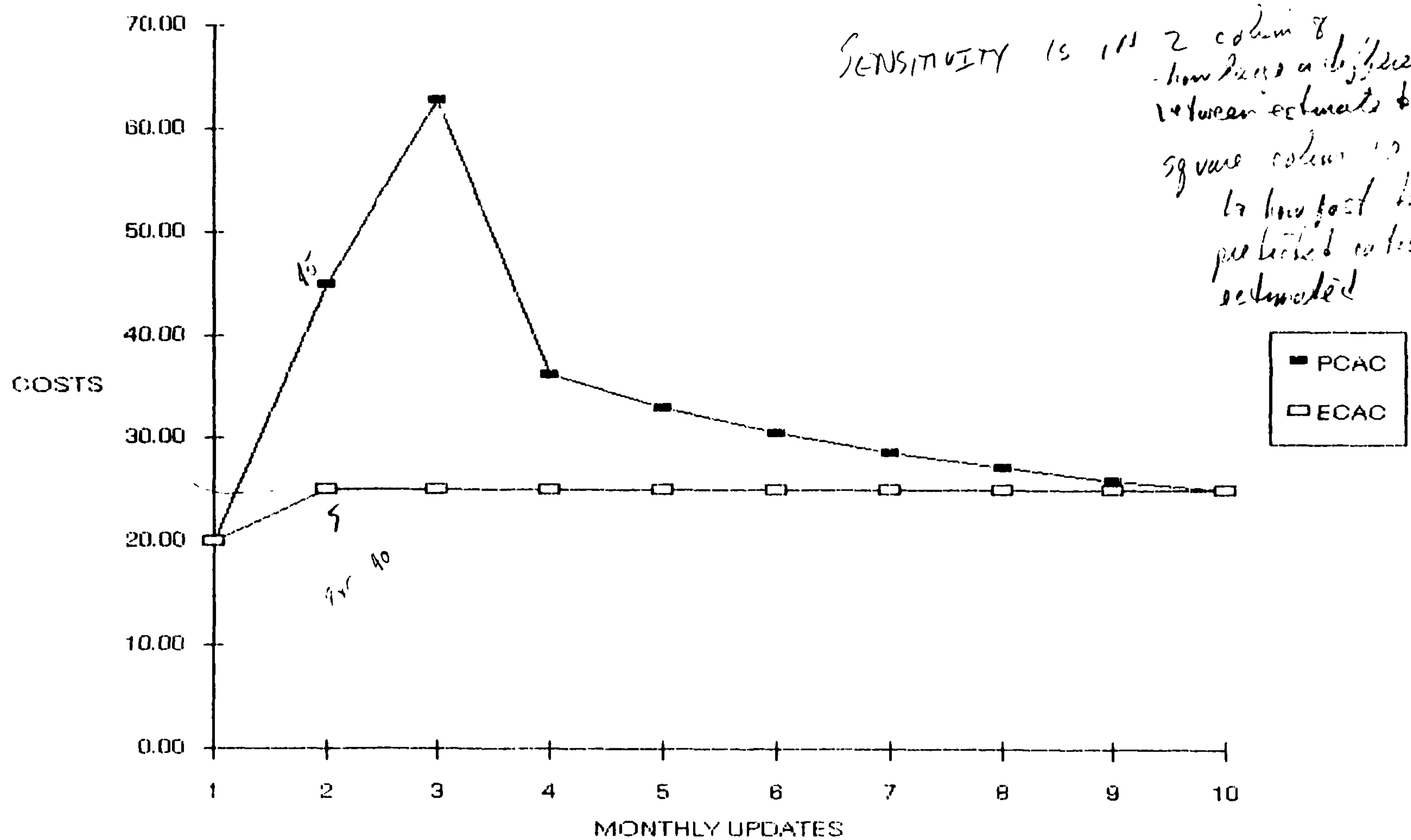


COST TREND WORKSHEET

COST TREND WORKSHEET						
ORIGINAL COST =	20		DATE	18-May-90		
REPORT NUMBER	1 REPORT DATE	2 PREVIOUS REPORT DATE	3 UPDATE INTERVAL	4 PROJECTED COMPLETION DATE INPUT	5 REMAINING TIME TO COMPLETE COL4 - COL1	6 ESTIMATED COST AT COMPLETION INPUT ECAC
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	10	7	25.00
REPORT 4	4	3	1	10	6	25.00
REPORT 5	5	4	1	10	5	25.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	25.00
REPORT 8	8	7	1	10	2	25.00
REPORT 9	9	8	1	10	1	25.00
REPORT 10	10	9	1	10	0	25.00

7 ESTIMATED COST OVERRUN 6 - ORIG COST	8 2(3x7)	9 SUM 8	10 COST SLOPE 9/1^2	11 PREDICTED ADDITIONAL OVERRUN 5x10	12 PREDICTED COST AT COMPLETION 6+11 PCAC	REPORT NUMBER
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
5.00	10.00	20.00	2.22	15.56	40.56	REPORT 3
5.00	10.00	30.00	1.88	11.25	36.25	REPORT 4
5.00	10.00	40.00	1.60	8.00	33.00	REPORT 5
5.00	10.00	50.00	1.39	5.56	30.56	REPORT 6
5.00	10.00	60.00	1.22	3.67	28.67	REPORT 7
5.00	10.00	70.00	1.09	2.19	27.19	REPORT 8
5.00	10.00	80.00	0.99	0.99	25.99	REPORT 9
5.00	10.00	90.00	0.90	0.00	25.00	REPORT 10

ORIGINAL SPIKE WITH CONSISTENT FORECASTS



COST TREND WORKSHEET

COST TREND WORKSHEET						
			DATE	3-Apr-90		
ORIGINAL COST =	20					
	1	2	3	4	5	6
REPORT NUMBER	REPORT DATE	PREVIOUS REPORT DATE	UPDATE INTERVAL	PROJECTED COMPLETION DATE INPUT	REMAINING TIME TO COMPLETE COL4 – COL1	ESTIMATED COST AT COMPLETION INPUT ECAC
REPORT 1	1	0	1	10	9	20.00
REPORT 2	2	1	1	10	8	25.00
REPORT 3	3	2	1	20	17	25.00
REPORT 4	4	3	1	10	6	25.00
REPORT 5	5	4	1	10	5	25.00
REPORT 6	6	5	1	10	4	25.00
REPORT 7	7	6	1	10	3	25.00
REPORT 8	8	7	1	10	2	25.00
REPORT 9	9	8	1	10	1	25.00
REPORT 10	10	9	1	10	0	25.00
7	8	9	10	11	12	
ESTIMATED COST OVERRUN 6 – ORIG COST	2(3x7)	SUM 8	COST SLOPE 9/1 ^ 2	PREDICTED ADDITIONAL OVERRUN 5x 10	PREDICTED COST AT COMPLETION 6+11 PCAC	REPORT NUMBER
0.00	0.00	0.00	0.00	0.00	20.00	REPORT 1
5.00	10.00	10.00	2.50	20.00	45.00	REPORT 2
5.00	10.00	20.00	2.22	37.78	62.78	REPORT 3
5.00	10.00	30.00	1.88	11.25	36.25	REPORT 4
5.00	10.00	40.00	1.60	8.00	33.00	REPORT 5
5.00	10.00	50.00	1.39	5.56	30.56	REPORT 6
5.00	10.00	60.00	1.22	3.67	28.67	REPORT 7
5.00	10.00	70.00	1.09	2.19	27.19	REPORT 8
5.00	10.00	80.00	0.99	0.99	25.99	REPORT 9
5.00	10.00	90.00	0.90	0.00	25.00	REPORT 10

← why double this?

APPENDIX D

EXCEL SPREADSHEET AND CHART MACRO

	A
1	testRecord1
2	=DIALOG.BOX(BOX)
3	=IF(A2=FALSE,GOTO #REF!)
4	
5	=OPEN("COSTTR.XLS",1)
6	=OPEN("COSTTRE.XLC",1)
7	
8	
9	
10	
11	=ACTIVATE("COSTTR.XLS")
12	
13	
14	=DIALOG.BOX(MENU)
15	=IF(I12=1,GOTO(INITIATE))
16	=IF(I12=2,GOTO(UPDATE))
17	=IF(I12=3,GOTO(preport))
18	=IF(I12=4,GOTO(PCHART))
19	=IF(I12=5,GOTO(EXIT))
20	
21	
22	=INPUT("INPUT THE PROJECT NAME",2,"PROJECT TITLE")
23	=SELECT("R11C3:R21C7")
24	=CLEAR(3)
25	=SELECT("R30C1:R39C6")
26	=CLEAR(3)
27	=INPUT("INPUT THE ESTIMATE COST OF THE CONTRACT",1,"TOTAL ESTIMATE COST")
28	=INPUT("INPUT LENGTH OF PROJECT IN MONTHS",1,"LENGTH OF PROJECT")
29	=SELECT(!C2)
30	=FORMULA(A22)
31	
32	=SELECT(!B4)
33	=FORMULA(A27)
34	=SELECT(!E12)
35	=FORMULA(A28)
36	=GOTO(MAINMENU)
37	=INPUT("ENTER THE REPORT DATE",1,"REPORT DATE")
38	=INPUT("INPUT THE ESTIMATED COST AT COMPLETION",1,"ESTIMATED COST AT COMPLETIC
39	=INPUT("INPUT THE PROJECTED COMPLETION TIME FRAME",1,"PROJECTED COMPLETION D/
40	REPORT DATE
41	=SELECT(!B12)
42	=IF(GET.CELL(5)<>A37,SELECT("R[+1]C"),GOTO(PREVIOUS))
43	=GOTO(A42)
44	PREVIOUS
45	=SELECT("R[-1]C[+1]")
46	=IF(GET.CELL(8)<>3,SELECT("R[-1]C"),GOTO(FOUND))
47	=GOTO(A46)
48	FOUND

	A
49	=SELECT("RC[-1]")
50	=GET.CELL(5)
51	INSERT ALL VALUES
52	=SELECT(!B12)
53	=IF(GET.CELL(5)<>A37,SELECT("R[+1]C"),GOTO(INSERT))
54	=GET.CELL(5)
55	=GOTO(A53)
56	
57	INSERT
58	=SELECT("RC[+1]")
59	=ALIGNMENT(3)
60	=FORMULA(A50)
61	=SELECT("RC[+1]")
62	=IF(A37=1,FORMULA(1),FORMULA(A54-A50))
63	=SELECT("RC[+1]")
64	=FORMULA(A39)
65	=SELECT("RC[+1]")
66	=FORMULA("=RC[-1]-RC[-4]")
67	
68	=SELECT("RC[+1]")
69	=FORMULA(A38)
70	
71	=SELECT("R[+18]C[-6]")
72	=GET.CELL(5,!B4)
73	=FORMULA(A38-A72)
74	=SELECT("RC[+1]")
75	=FORMULA("=RC[-1]*R[-18]C[+2]*2")
76	
77	
78	=SELECT("RC[+1]")
79	=FORMULA("=RC[-1]+R[-1]C")
80	
81	=SELECT("RC[+1]")
82	=FORMULA("=RC[-1]/((R[-18]C[-2])^2)")
83	
84	
85	=SELECT("RC[+1]")
86	=FORMULA("=R[-18]C[+1]*RC[-1]")
87	
88	=SELECT("RC[+1]")
89	=FORMULA("=R[-18]C[+1]+RC[-1]")
90	=ACTIVATE("COSTTRE.XLC")
91	=CALCULATE.NOW()
92	=ACTIVATE("COSTTR.XLS")
93	=GOTO(MAINMENU)
94	
95	preport
96	=SELECT(!A1:G39)

	A
97	=SET.PRINT.AREA()
98	=PRINT(1,,,1,FALSE,FALSE,1)
99	
100	=GOTO(MAINMENU)
101	
102	
103	
104	print chart
105	
106	
107	
108	=ACTIVATE("COSTTRE.XLC")
109	
110	=ATTACH.TEXT(1)
111	=FORMULA(A22)
112	=PRINT(1,,,1,FALSE,FALSE,1)
113	=ACTIVATE("COSTTR.XLS")
114	
115	
116	=GOTO(MAINMENU)
117	
118	
119	
120	
121	
122	
123	
124	=RETURN()
125	
126	

	C	D	E	F	G
1					
2	5	8	12		
3	5	8	30		
4	5	8	48		
5	1	43	110	64	
6	2	177	111	64	
7					
8					
9	SELECT ONE DIALO				
10		111	70	320	144
11	14	8	6	200	111
12	11	0	0		
13	12	16	21		18
14	12	16	39		18
15	12	16	57		18
16	12	16	75		18
17	12	16	93		18
18	1	234	13	64	
19	2	233	82	64	

	H
1	
2	COMPLETION COST WORKSHEET MACRO
3	CREATED BY JOHN BAKER
4	PURDUE UNIVERSITY
5	OK
6	Cancel
7	
8	
9	
10	
11	MAIN MENU
12	
13	INITIATE REPORT
14	UPDATE REPORT
15	PRINT SPREADSHEET
16	PRINT CHART
17	EXIT MACRO
18	OK
19	Cancel