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EFFECT OF PRIME CONTRACTOR FINANCIAL POSITION
ON MAJOR WEAPON SYSTEM COST AND
DELIVERY PERFORMANCE

by

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This thesis investigates the relationship of prime contractor cost and delivery performance with prime contractor financial health. The analysis used DOD major acquisition programs measures reflecting cost and schedule growth and summary indexes of financial health, constructed using indexes computed from financial distress models. The summary indexes were used to indicate contractor financial health, and change in financial health, before before and during both development and production phases of a program. Major findings indicate that a relationship does exist between financial condition and contractor performance, but the relationship is small.

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Effect of Prime Contractor Financial Position on Major Weapon System Cost and Delivery Performance

by

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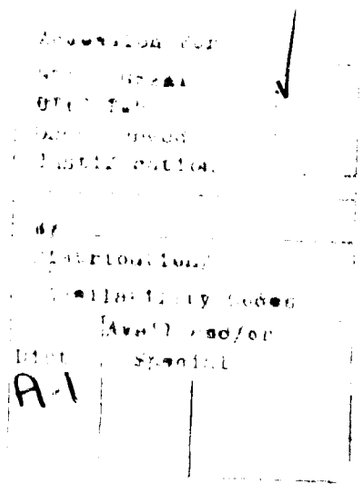
ABSTRACT

This thesis investigates the relationship of prime contractor cost and delivery performance with prime contractor financial health. The analysis used DOD major acquisition programs. Regression was used to analyze the relationship between outcome measures reflecting cost and schedule growth and summary indexes of financial health, constructed using indexes computed from financial distress models. The summary indexes were used to indicate contractor financial health, and change in financial health, before and during both development and production phases of a program. Major findings indicate that a relationship does exist between financial condition and contractor performance, but the relationship is small.



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I. INTRODUCTION

How the United States Government spends the tax dollars it collects receives a great deal of attention from the news media. One of the areas that has received a large amount of often critical attention is the overall cost and cost overruns for weapons systems acquisitions programs of the Department of Defence (DOD). The B-2 bomber and Apache attack helicopter are just two examples of these programs. In addition to the examination of specific programs, the way the DOD deals with the companies that make up the defenses industrial base has been the focus of large amounts of press review. One well-known example of this would be the government bail-out of Lockheed Corporation. In response to this media attention several studies have been initiated to review the acquisition practices of the DOD in an attempt to identify factors that impact weapon systems overall cost and cost overruns.

A. BACKGROUND

One response to the attention given to DOD acquisition policy is for a commission to be appointed to study the problems. There have been many of these spanning the last four decades. Three of the most recent examples are: The Packard Commission (Blue Ribbon Commission on Defense Management), 1986 [Ref. 1], The Grace Commission (President's

Private Sector Survey on Cost Control), 1984 [Ref. 2], and The Defense Resource Management Study, 1979 [Ref. 3]. These studies have a common structure in that they review the entire organization. Recommendations to correct problems identified generally take the form of organizational changes.

The problems identified by the commissions give rise to a second body of work that investigates specific aspects of a problem. Assuming a much narrower perspective, the research focuses not on organizational issues but rather on the tactics used during the acquisition process and the conditions that exists that may effect the outcome of the tactics. The general question to be addressed in this thesis was developed from three such studies in the area of weapon system acquisition cost and schedule growth.

B. THESIS QUESTION DEVELOPMENT

The primary objective of this thesis is to investigate if there is a systematic, predictable and significant association of contractor cost and delivery performance during the period of weapon system procurement with prime contractor financial condition. The investigation will attempt to identify relationships for cost and schedule growth during both development and production phases of procurement programs.

An assumption basic to the investigation is that the financial condition of a prime contractor is potentially useful in explaining acquisitions related phenomena. Two

studies which bear on this assumption will be discussed in greater detail in later chapters: "Financial Condition and Contractor Pricing Strategy," McGrath and Moses, 1987 [Ref. 4] and "Estimating and Explaining the Production Cost of High-Technology Systems: The Case of Military Aircraft," Moses, 1989 [Ref. 5]. These studies develop the use of financial ratios to characterize a contractor's financial condition. They then relate financial condition to specific acquisitions phenomena, such as pricing strategy and its effect on DOD weapon procurement programs.

The assumption that financial condition has an association with contractor performance requires that outcome measures that reflect performance be developed. Performance measures, and the data on which they are based, are taken from "Acquiring Major Systems: Cost Schedule and Trends, and Acquisition Initiative Effectiveness," Karen W. Tyson, 1989 [Ref. 6] and will be presented in greater detail in a later chapter.

The general question addressed in this thesis, as stated above, rest on the two premises that financial health has an impact on a contractor's actions and that these actions have an effect on cost and schedule performance during the development and production phases of a weapons system acquisition.

Specific strategies of the firms will not be directly addressed. The effects of strategies employed, as reflected

in any change in financial position, will be used in the analysis. Financial ratios will be used to construct summary indexes to represent financial condition.

C. OUTLINE OF REMAINING CHAPTERS

1. Chapter II

Chapter II will present the hypotheses relating financial health to the cost and schedule performance of prime contractors during weapon systems procurement. It will include a discussion of the use of financial ratios to characterize the financial health of a firm and the use of a summary index developed from these ratios. It will conclude with a justification for selecting the index models used in this work.

2. Chapter III

Chapter III will begin with a discussion of the Tyson study [Ref. 6] that includes the data base and outcome measures developed. Next will be a review of the procedures followed to collect the financial data from which the summary indexes were computed.

3. Chapter IV

Chapter IV will present computation of specific independent variables, statistical test of the main hypothesis, and findings.

4. Chapter V

Chapter V will present conclusions drawn from the analysis and make recommendations based on these conclusions.

II. HYPOTHESIS DEVELOPMENT

This chapter will develop the hypothesis of a systematic association between a prime contractor's financial health and its ability to meet cost and schedule targets during the development and production phases of major weapons systems procurement.

A. BASIC HYPOTHESIS

The hypothesis tested in this study is that a firm's financial health, both before and during a specific phase of procurement, has an impact on the firm's cost and schedule performance during that phase of procurement. The measurement of financial health will be discussed later in this chapter. Measurement of cost and schedule performance will be discussed in Chapter III.

How can a contractor's performance, with respect to cost or schedule, be assessed? Any assessment involves a comparison of two items: 1) on original estimate of cost or schedule with, 2) the actual cost incurred or schedule achieved. Cost (or schedule) growth can be "caused" by one or both of two mechanisms. First, the original estimate may be too low relative to a fair estimate of cost. Hence actual costs will be higher and cost growth will be indicated. Second, the original estimate may be fair, but cost control

may be poor due to inefficiencies, raising actual cost relative to the fair estimate. It is not typically possible to isolate these two effects. But any conditions that may lead to either low initial estimates or high actual cost will result in cost growth.

The hypothesis tested in this study rests on the ideas that: 1) a contractor's financial condition at the time original estimates of cost or schedule are made (i.e., at the time a contract is initiated) may influence those estimates and hence have an impact on cost and schedule growth, and 2) a contractor's financial condition during the period of performance on a contract may influence actual cost incurred or schedules achieved and hence also have an impact on cost or schedule growth. Why might these links exist?

First consider original estimates. It can be reasoned that a firm's financial health has an impact on the validity of the original estimates. A firm in a weak financial condition may underestimate a project's cost and completion schedule to secure a contract, thus leading to larger differences between the estimates and actual performance during the project. Conversely, a firm that is relatively strong may not have as great a need to acquire new business, so its estimates may be more realistic and thus more in line with the actual performance.

Financial health, viewed at the time of contract initiation, may be seen as an indicator of a firm's past

performance. A weak financial position could indicate an inability to control cost on past projects. Cost growth might then be expected from firms in a weak financial position. Again the opposite may also be indicated; a firm that has a strong financial position may reflect the ability to control cost of previous projects and cost control on new projects could be expected.

Financial health may also have an impact on actual cost incurrence and schedule achievement during the development and production phases of a contract. A weaker firm's access to financing may be limited by reluctant lenders and an inability to attract new capital due to poor financial position. The lack of financing needed to acquire equipment and facilities would lead to the reliance on less productive assets and thus higher cost and schedule slip could result. A firm with a stronger financial position could be more flexible in acquiring and applying the proper and necessary assets to meet the original estimates of cost and schedule.

Based on the above, it is the working hypothesis of this study that: The stronger the financial position of a firm both before and during the execution of development or production contracts, the smaller the cost and schedule growth.

B. FINANCIAL RATIOS

The use of financial ratios to analyze a firm's condition, as a basis for predicting future performance, is widespread. The use of financial ratios in two decision settings is quite common: 1) Financial ratio analysis is used heavily for investment decisions in the stock market. It is one of the prime factors examined to predict future earning on which the current stock price is based. Additionally; financial institutions use financial ratio analysis to make predictions of a firm's future ability to repay loans. Thus financial condition weighs heavily on both the decision to extend a loan and the interest rate at which it may be offered.

There is an almost unlimited number of financial ratios that can be generated from financial statements. The usefulness of any particular ratio is dependent on its intended use. Investors concerned primarily with earning (which could be in the form of capital gains or cash dividends) would select and weight specific ratios for analysis differently than a lender whose primary concern is the ability of the firm to generate cash to meet interest and principle payments.

The two studies that follow are presented as support for the assumption put forth in Chapter I that the financial condition of a contractor, as characterized by financial ratios, has a relationship to program cost.

1. Moses, 1989

This study has the broad objective of estimating and explaining production cost on aircraft production. One chapter, "Explaining Variances--Firm Specific Factors" is of specific interest to this thesis. [Ref. 5:pp. 49-65]

"Stories" explaining possible relationships between financial condition and cost were developed. Empirical tests were then conducted to provide evidence, positive or negative, for each "story."

Working from previous studies that grouped financial ratios into seven dimensions of financial condition, individual ratios were identified to reflect each major financial dimension. The financial ratios selected for each dimension follow;

Dimension	Ratio
Profitability	Income/Sales
Asset Turnover or Capital Intensiveness:	Sales/Assets
Financial Leverage:	Assets/Net Worth
Short Term Liquidity:	Current Assets/ Current Liabilities
Inventory Intensiveness or Inventory Turnover	Sales/Working Capital
Receivables Intensiveness or Receivables Turnover:	Receivables/Sales
Cash Position:	Cash Assets

Multiple regression was conducted by regressing measures of cost overruns (from models developed earlier in

the study) on the selected financial ratios. Three of the dimensions--profitability, liquidity and capital investment--had coefficients that were significant at traditional levels. [Ref. 5:p. 63]

The evidence from the study tends to support the assumption made in this thesis that a contractor's financial condition, as characterized by financial ratios, has an impact on contract performance.

2. McGrath and Moses, 1987

This study is reviewed as a example of the use of financial ratios to indicate aspects of financial health and how such ratios may be used to understand contractor actions. The major objective of the study was to explain contractor pricing strategy using contractor financial condition.

Pricing strategy for the introduction of new products or technology generally follows one of two widely understood paths--skimming or penetration. A skimming strategy with its high initial price will generate high profits in the early stages. Profit can be maximized by limiting price reduction to that necessary to maintain market position. Penetration pricing, on the other hand, lowballs the initial price to capture the market and discourage competition. Once established, profits are derived from price increases or cost reduction. [Ref. 4]

Hypothesizing that financial condition influences pricing strategy, expected associations were summarized: "We

expect firms that skim...to exhibit measures of high profitability, poor liquidity, poor solvency, high-asset utilization and low investment...." [Ref. 4:p. 13]. McGrath and Moses felt that pricing strategy might be explained using financial ratios publicly available before production [Ref. 4.p. 12].

Price reduction curves were constructed for 35 major military aircraft and missile weapon systems to operationalize the concept of pricing strategy. [Ref. 4:p. 14]. To reflect financial condition, 23 financial ratios were computed for the contractors of the weapons systems and divided into five categories--profitability, short term liquidity, solvency, activity and capital investment.

Two procedures were then carried out on the assembled data. First, each financial ratio was correlated with the price reduction slope. Five ratios, one from each category, had relatively strong correlation with the price reduction slope, providing an initial indication that financial condition and pricing strategy were related [Ref. 4:p. 15]. Stepwise regression was then used to build a multivariate model to explain the variance in the price reduction slope. The final model presented in the study was significant overall and explained over half the variation [Ref. 4:p. 16].

The results of this study, like the other study presented in this section, tend to support the assumption that financial condition has a relationship to contractor actions.

A second similarity is that both studies incorporate procedures to identify specific financial ratios that best reflected aspects of financial condition. Two studies specifically addressing the use of sets of ratios to collectively summarize financial condition will be addressed in the next section.

C. MEASURES OF FINANCIAL STRENGTH

Financial ratios, representing a firm's financial health, have been used successfully in explaining varying aspects of cost, as illustrated in the above studies. In empirical studies a problem arises due to the very large number of ratios available to reflect financial condition. A relatively small set of ratios is desirable. What ratios are most relevant? A second problem results when trying to use individual ratios to track changes in a firm's condition over time. What if different ratios provide contrary signals? A solution to these problems is to aggregate the explanatory ability of several ratios into a single summary index of financial condition. There have been many of these indexes developed that fall generally into the categories of "financial distress models" or "bankruptcy models" that combine various financial ratios to represent a firm's financial health [Refs. 7,8,9].

The following studies developed indexes that will be used in this thesis as summary indicators of financial health.

Selection was based on the similarity of the data base used in developing the index (i.e., both from DOD contractors) and the difference in methodology used to select which ratios to be included in the index.

1. Dagel and Pepper 1989

The purpose of Dagel and Peppers' research was to develop "an objective indicator of financial health for DOD hardware contractors." [Ref. 8]. Multivariate discriminant analysis was used to formulate the financial distress model. The resulting linear formula follows:

$$Z = 1.54 - 6.4X_1 + 4.61X_2 - 0.41X_3 + 9.31X_4 - 5.40X_5 + 1.63X_6$$

where:

X_1 = Total Debt/Total Assets

X_2 = Cash Flow/Total Debt

X_3 = Current Assets/Current Liabilities

X_4 = Quick Assets/Total Assets

X_5 = Working Capital/Total Assets

X_6 = Net Sales/Total Assets.

The model had a predictive accuracy of 97% when tested on their sample. [Ref. 8:p. 9]

Though broad application financial distress models such as the Altman Z-Score [Ref. 7] have been developed, "the fact remains that the significance of accounting ratios

vary substantially from industry to industry...." [Ref. 8:p. 3] The intent of Dagel and Pepper was to target a specific category of firms. Their sample consisted of 29 bankrupt and 29 nonbankrupt firm selected to be representative of DOD hardware contractors.

A total of 18 financial ratios were selected for use as variables and computed for each firm in the sample. Empirical considerations drove the selection of the variable used in the final model presented above. The selection was based on the statistical significance of the t-ratio as opposed to theoretical development, a point acknowledged by Dagel and Pepper. [Ref. 8:p. 3]

2. Moses and Liao, 1986

Departing from previous bankruptcy models that were purely empirical in nature, a theoretical viewpoint was adopted to select financial ratios to be used in a model constructed by Moses and Liao [Ref. 9]. It is this theoretical viewpoint that makes this study a useful contrast to the Dagel and Pepper model, which was empirically based. Both models will be used for analysis conducted in Chapter IV.

First, factor analysis was used to "observe clustering of individual ratios, determine common underlying aspects of financial conditions, and identify ratios which best capture the underlying commonality...." [Ref. 9:p. 5]. From this analysis four dimension accounted for the ratios: Profitability, Leverage, Liquidity and Turnover.

Multivariate analysis was then used to determine a discriminant model. To produce a theoretically valid model the following variable selection criteria listed below were used.

(1) No significant correlation between the predictors;

(2) Meaningfulness of predictors, i.e., predictors must have intuitive casual effect on business failure;

(3) Meaningfulness of coefficients, i.e., predictors must have "correct" coefficient signs.

The following discriminant model resulted:

Concept	Ratio	Coefficient
Liquidity	WC/A	1.6995
Turnover	S/A	.1919
Profitability	EBIT/L	.2867
Constant		-.7688

Tests were conducted to determine the classification and predictive power of the model. They were 73.1% and 71.2% respectively. [Ref. 9:pp. 9-10]

D. INDEX MODEL SELECTION CONSIDERATION

As discussed above, the Dagel and Pepper model is an empirical construct with ratio selection based primarily on the statistical significance demonstrated during stepwise regression analysis. This method has been successful and widely used [Ref. 8:p. 3]. This method does accept conditions at variance with strict theoretical application. The primary example is the lack of independence of variables as

demonstrated by the high correlations between ratios in the model [Ref. 9:p. 11]. The theoretical base for selection of financial ratios used in the Moses and Liao model addresses the problems evident in the empirical based model [Ref. 9].

This study will use the two alternative indexes to represent financial health. This is done so that comparisons can be made when identical procedures are conducted with each. This is also done in an attempt to determine if results of the analysis are sensitive to the index used to represent financial health. For this reason alone models with different criteria for financial ratio selection were used. The correctness of the different approaches will not be addressed.

This chapter has described the indexes to be used to represent contractor financial health. These indexes represent the basis for measuring the independent variables in this study. The next chapter will address issues related to constructing measures of the dependent variables, cost and schedule growth.

III. MEASURES AND DATA BASE

The original data base to be used in this thesis was taken from Tyson et al. [Ref. 6]. Consisting of 89 major DOD acquisition programs with nine different categories of equipment represented, both new introductions and modification of existing systems are included. The selected systems cover over 30 years with nearly all of the programs still in production and in service. This represents a very substantial sample on which to test hypotheses concerning cost and schedule growth. In addition to the cost and schedule data from Tyson, financial statement data for the 21 prime contractors represented by the 89 projects was collected and compiled.

This chapter will begin with a review the portions of the Tyson study that are applicable to this thesis. Then the data base and outcome measure to be used in the Chapter IV analysis will be specified.

A. TYSON, ET AL., 1989

The purpose of the Tyson study was to determine the effectiveness of management initiatives in improving the outcome of major system acquisitions in terms of cost and schedule growth. The initiatives examined were: Multi-year procurement, Competition, Prototyping, Design-to-Cost, Total

package procurement and fixed-price development, and Contract incentives. The approach was to categorize acquisition strategy initiatives then quantitatively assess the effectiveness of the initiatives in terms of cost and schedule performance. The intent was to identify the most effective initiatives.

This thesis uses the data base, outcome measures, and explanatory variables found to be significant in the Tyson study. They are discussed in the following sections.

1. Tyson Data Base

The discussion of the data base will be handled in two parts; sample selection and cost and schedule data. The sample includes 89 acquisition programs managed by the Army, Navy and Air Force and represents nine categories of equipment: Tactical aircraft, Electronic aircraft, Helicopters, Other Aircraft, Air-launched tactical munitions, Surface-launched tactical munitions, Electronics/avionics, Strategic missiles, and Satellites. Programs considered successful as well as those that encountered problems were included. [Ref. 6:p. III-1]

The primary source for cost and schedule information was Selected Acquisition Reports (SAR). The SAR is a government document with a prescribed format common to all the services and allows for comparison of cost, schedule and quantity changes during a programs life. The December SAR is designated the comprehensive annual SAR, compiled with great

care because it coincides with the submission of the President's budget to the Congress [Ref. 6:p. III-3]. The cut-off date for inclusion of program data in the data base was December 1987. Several secondary sources of information including Janes's Weapon Systems and Defence Marketing Service were used for clarification and to fill in data missing from the summary SAR. [Ref. 6:p. III-3]

2. Outcome Measures

Several outcome measures were developed in the study. The measures for cost and schedule growth during development and production phases plus cost growth for the total program are of specific interest. These measures are presented in Table 3-1. The terms "current" and "original" used in Table 3-1 have specific meaning. "Current" is defined as the most recent estimate (actual) cost or schedule figures available, with the period cut-off being the completion of contract phase(development or production) or December 1987. "Original" is the estimate of cost or schedule made at the approval for Full Scale Development (FSD) or Production phases of the contract. Time is measured in months. To isolate cost growth from the effects of quantity changes, when necessary, the current cost estimate was restated to reflect the cost of the original planned quantity by applying a learning curve approach. [Ref. 6:pp. III-5, III-9]

TABLE 3-1

OUTCOME MEASURES

Development cost growth (DCG) and Production cost growth (PCG) computed as the:

$$\frac{\text{Current cost estimate(actual) from SAR}}{\text{Original estimate from SAR}}$$

Total program cost growth (TPCG) computed as the:

$$\frac{\text{Current Development Cost + Current Production Cost}}{\text{Original Development Cost + Original Production Cost}}$$

Development schedule growth (DSG) computed as the:

$$\frac{\text{Actual Time from FSD to Production Start}}{\text{Estimated time from FSD to Production Start}}$$

Production schedule growth (PSG) computed as the:

$$\frac{\text{Actual Time from Production Start to Production End}}{\text{Estimated time from Production Start to Production End}}$$

3. Results

Three of the initiative tested by Tyson had statistically significant relationships with cost growth. These were: 1) contract incentives which were associated with lower cost growth, 2) total package procurement which was related to increased production and total program cost growth, and 3) fixed-price development which was associated with higher development cost growth. In addition to the contract initiatives, program stretch (defined as program schedule growth divided by program quantity growth) proved to be a significant explanatory variable for cost growth. The use of

the outcome measures and explanatory variable described above with be explained in Chapter IV.

B. COLLECTION OF FINANCIAL DATA

All financial statement data was drawn from Moody's Industrial Survey. Information was collected for each prime contractor for the period from two years before the full scale development date until 1987. A total of 19 items were drawn from the balance sheet and income statements of the prime contractors for each year. The data were recorded as presented. When restatements of prior years' financial statements were presented the choice between the original presentation and the restatement was made on a case by case basis. Consistency of reporting over the period of interest was the prime consideration in the selection of original financial statements or the restatements. The unavailability of financial data for privately held corporations was the primary reason for deleting projects from the original data base, with Hughes Aircraft causing seven such deletions. Financial data was available in usable form for 73 of the original 89 projects; these are listed in Table 3-2. The financial ratios required by the Dagel and Pepper and Moses and Liao index models were computed from the collected financial statement information. These financial ratios were then used to compute the indexes. From the indexes the explanatory variables to be used in the analysis were

constructed. The explanatory variables will be discussed in Chapter IV.

TABLE 3-2

SAMPLE PROGRAMS

PROGID	PROGRAM	COMPANY	PROGID	PROGRAM	COMPANY
1	V-22	BELL	38	SDWNDR_M	FORD
2	T45TS	McDD	39	JSTARS	GRUMMAN
3	B-1A	ROCKWELL	40	SINCGARS	ITT
4	C-5B	LOCKHEED	41	ASPJ	ITT
5	C-17A	McDD	42	LANTIRN	MARMAR
6	C-5A	LOCKHEED	43	OTH_B	GD
7	B-1B	ROCKWELL	44	DMSP	RCA
8	FB-111A	GENDYN	45	NVST_GPS	ROCKWELL
9	AV-8A	McDD	46	DSP	TRW
10	F-5E	NORTHROP	47	DSCS3	GE
11	F-15	McDD	48	ROLAND	BOEING
12	F-16	GENDYN	49	IMPWAWK	RAYTHEON
13	F-14D	GRUMMAN	50	MLRS	LTV
14	F-14A	GRUMMAN	51	MK-50	HONEYWELL
15	AV-8B	McDD	52	STNGER_P	GD
16	A-10	FAIRCHILD	53	MK-48	GOULD
17	F/A-18	McDD	54	STNGR_BA	GD
18	E-6A	BOEING	55	COPPRHD	MARMAR
19	E-3A	BOEING	56	DIVAD	FORD
20	EF-111A	GRUMMAN	57	FIVEINCH	MARMAR
21	E-2C	GRUMMAN	58	STNGR_R	GD
22	EA-6B	GRUMMAN	59	DRAGON	McDD
23	P-3C	LOCKHEED	60	PERSHNG2	MARMAR
24	LAMPSMK3	SIKORSKY	61	PATRIOT	RAYTHEON
25	E-4	BOEING	62	STD-MSL2	GD
26	S-3A	LOCKHEED	63	LANCE	LTV
27	CH-47D	BOEING	64	PEACEKPR	MARMAR
28	OH-58D	BELL	65	GLCM	GD
29	UH-60A	SIKORSKY	66	TOMAHAWK	GD
30	CHEYENNE	SIKORSKY	67	SRAM_II	BOEING
31	HELLFIRE	ROCKWELL	68	MINUTEM2	BOEING
32	HARM	TEXINST	69	TRIDENT2	LOCKHEED
33	SPARRO-F	GD	70	ICBM	MARMAR
34	SDWNDER_L	FORD	71	ALCM	BOEING
35	HARPOON	McDD	72	SRAM	BOEING
36	SPARRO_E	GD	73	MINUTEM3	BOEING
37	SPARRO_M	GD			

IV. ANALYSIS

The relationship between a prime contractor's financial health and project outcomes will be analyzed using simple and multivariate linear regression. The project outcome measures developed by Tyson [Ref. 6] and reviewed in Chapter III will be used as the dependant variables. Tests will be conducted individually to analyze each of the five outcome measures. The independent variables, also called the explanatory variables, were constructed from the indexes calculated from the financial distress models of Dagel and Pepper [Ref. 8] and Moses and Liao [Ref. 9], reviewed in Chapter II. Tests will be conducted, separately, using measures constructed from each of the two models. The chapter will proceed along the following steps:

(1) Construction of the independent variables.

(2) Discussion of method used in analysis.

(3) Results obtained from the analysis for each of the combinations of dependent and independent variables.

(4) A discussion of the results in relation to expectations.

A. INDEPENDENT VARIABLES

Several explanatory variables were developed in an attempt to quantify two general aspects of financial health: a) financial condition at the start of each phase (development

or production), and b) financial condition during the conduct of each phase.

Financial ratios were computed for each year under consideration. The ratios were then used to compute indexes using the financial distress models. The methods used for computing the explanatory variables were identical for both index models.

Three project phases (periods) were defined: The development phase of a project was considered to be from the start year of Full Scale Development (FSD) to the year prior to the beginning of production. The production phase ran from the first year of production until its completion (or 1987 if still active). Total program was defined as the period that encompassed the development and production phases. These periods were selected to match the periods selected in the Tyson study for the construction of outcome measures.

Recall that the hypotheses developed in Chapter II argued for a relationship between program outcomes and financial condition, measured both at the start of a program phase (development or production) and during execution of the phase. It is necessary to construct measures to reflect both these points in time. Two variables were computed to represent financial condition at the start of a given phase: A point estimate (the index for the year prior to the start of each phase) and the change in the index during the two years prior to the start of the phase. The first measure is an

indicator of financial condition per se; the second is an indicator of the trend in financial condition--prior to the start of a program phase. Two additional independent variables were constructed to represent financial condition during a given program phase: One being the average index during the entire phase. The second being the change in the index between the starting and ending year of the phase. Again the first measure is an indicator of (average) financial condition; the second is an indicator of the trend in financial condition--during a program phase. The independent variables are listed by index model in Tables 4-1 and 4-2.

B. DEPENDENT AND INDEPENDENT VARIABLE RELATIONSHIPS

The four independent variables discussed above, two to indicate financial condition and change in financial condition before a phase, and two to indicate financial condition and the change in financial condition during a phase, were developed to encompass the entire time period of a particular phase. For example, the independent variables associated with the development phase are: DDEVIT-1, DDICHST, DDIAVPER, and DDICHPER. This collection of variables allows the relationship between DCG and a starting condition (DDEVIT-1), a trend before starting (DDICHST), an average condition during (DDIAVPER), and a trend during (DDICHPER) the development phase.

TABLE 4-1

LIST OF INDEPENDENT VARIABLES
CONSTRUCTED FROM DAGEL AND PEPPER MODEL

DDEVIT-1	Index for the year prior to FSD
DDICHST	Difference between the indexes for the two years prior to FSD
DDIAVPER	Average of indexes during years from FSD year through the year prior to production
DDICHPER	Difference between indexes for the FSD year and year prior to production start
DPRDIT-1	Index for the year prior to production
DPICHST	Difference between the indexes for the two years prior to production
DPIAVPER	Average of indexes for the years from first year of production through last year of production (or 1987 if still active)
DPICHPER	Difference between indexes for first year of production and last year of production (or 1987 if still active)
DIAVPROJ	Average of indexes for the years from FSD year through last year of production (or 1987 if still active)
DICHPROJ	Difference between the indexes for the FSD year and last year of production (or 1987 if still active)

Example for understanding labels: DDICHPER would read as, Dagel and Pepper Index Change over the Development Period.

TABLE 4-2

LIST OF INDEPENDENT VARIABLES
CONSTRUCTED FROM MOSES AND LIAO MODEL

MDEVIT-1	Index for the year prior to FSD
MDICHST	Difference between the indexes for the two years prior to FSD
MDIAVPER	Average of indexes during years from FSD year through the year prior to production
MDICHPER	Difference between indexes for the FSD year and year prior to production start
MPRDIT-1	Index for the year prior to production
MPICHST	Difference between the indexes for the two years prior to production
MPIAVPER	Average of indexes for the years from first year of production through last year of production (or 1987 if still active)
MPICHPER	Difference between indexes for first year of production and last year of production (or 1987 if still active)
MIAVPROJ	Average of indexes for the years from FSD year through last year of production (or 1987 if still active)
MICHPROJ	Difference between the indexes for the FSD year and last year of production (or 1987 if still active)

Example for understanding labels: MPIAVPER would read as, Moses and Liao Index Averaged over the Period of Production.

The procedures for both index models are identical. The dependent variables and the associated independent variables follow:

DEPENDENT VARIABLE	RELEVANT INDEPENDENT VARIABLES			
DCG	DDEVIT-1	DDICHST	DDIAVPER	DDICHPER
	MDEVIT-1	MDICHST	MDIAVPER	MDICHPER
PCG	DPRDIT-1	DPICHST	DPIAVPER	DPICHPER
	MPRDIT-1	MPICHST	MPIAVPER	MPICHPER
DSG	DDEVIT-1	DDICHST	DDIAVPER	DDICHPER
	MDEVIT-1	MDICHST	MDIAVPER	MDICHPER
PSG	DPRDIT-1	DPICHST	DPIAVPER	DPICHPER
	MPRDIT-1	MPICHST	MPIAVPER	MPICHPER
TPCG	DDEVIT-1	DDICHST	DIAVPROJ	DICHPROJ
	MDEVIT-1	MDICHST	MIAVPROJ	MICHPROJ

The relationships presented above will be used to construct the models on which the statistical test described in the following section will be conducted.

C. PROCEDURE FOR REGRESSION ANALYSIS

The first procedure run was simple linear regression for all meaningful combinations of dependent and independent variables, as presented above. The intent of this series of regressions was to test for the statistical significance of each individual independent variable.

Multivariate regression was then run on each meaningful set of independent variables to test the amount of variation explained when used in combination. From this set of regressions residual analysis was conducted to test the assumption of linear regression: linearity between dependent

and independent variables, constant variance of residuals, normal distribution, and randomness. Where violation of the above assumptions became apparent during residual analysis applicable procedures and modifications were applied.

D. RESULTS OF REGRESSION

The intent of the simple linear regressions was two-fold --to test for the significance of the independent variables and to provide information for comparing the results obtained from the alternative index models. The coefficients and t-ratios from the simple regressions are presented in Table 4-3. Using a probability level of 10% as the level of significance, three variables --DEVIT-1, DPRDIT-1, and DDIAVPER--were found significant. Variables computed from the Dagel and Pepper Index model generally were more strongly significant than those from the Moses and Liao model. A fuller discussion of the result will follow in the next section.

The results from the multivariate regressions are presented in Table 4-4. Two of the regressions produced models significant at a probability level of 10%: DCG and PCG when regressed on the corresponding Dagel and Pepper index set of explanatory variable. Six of the coefficients were significant--DDEVIT-1 and DDICHST when associated with DCP, DPRDIT-1 and DPICHPER when associated with PCG, and DDEVIT-1 and DICHPROJ when associated with TPCG.

TABLE 4-3

SIMPLE REGRESSIONS

DEPENDENT VARIABLE		INDEPENDENT VARIABLE			
		DDEVIT-1	DDICHST	DDIAVPER	DDICHPER
DCG	COEFFICIENT	0.07597	-0.1030	0.1120	0.0195
	T-RATIO	1.49	-1.27	1.87*	0.04
DSG	COEFFICIENT	0.01514	-.05173	0.0623	0.0493
	T-RATIO	0.44	-0.940	1.55	1.56
		MDEVIT-1	MDICHST	MDIAVPER	MDICHPER
DCG	COEFFICIENT	0.1632	-0.8449	0.3670	-0.2036
	T-RATIO	0.43	-1.21	0.75	-0.43
DSG	COEFFICIENT	0.0605	0.2490	0.1697	0.3030
	T-RATIO	0.24	0.53	0.52	0.98
		DPRDIT-1	DPICHST	DPIAVPER	DPICHPER
PCG	COEFFICIENT	0.15068	-0.0001	0.0519	-0.0831
	T-RATIO	2.47*	-0.19	0.57	-1.59
PSG	COEFFICIENT	-0.07179	0.0004	0.0489	-0.0282
	T-RATIO	-1.27	0.65	0.60	-0.59
		MPRDIT-1	MPICHST	MPIAVPER	MPICHPER
PCG	COEFFICIENT	-0.0719	-1.1861	0.4796	-0.3007
	T-RATIO	-0.13	-1.51	0.69	-0.61
PSG	COEFFICIENT	-0.2344	0.4791	0.9236	0.4757
	T-RATIO	-0.44	0.71	1.35	1.11
		DDEVIT-1	DDICHST	DIAVPROJ	DICHPROJ
TPCG	COEFFICIENT	0.0861	-0.0348	0.0417	-0.0598
	T-RATIO	1.85*	-0.43	0.53	-1.66
		MDEVIT-1	MDICHST	MIAVPROJ	MICHPROJ
TPCG	COEFFICIENT	0.2007	-0.3395	0.2787	-0.3178
	T-RATIO	.33	-0.43	0.55	-1.20

* = Significant at p <= .10

TABLE 4-4

MULTIVARIATE REGRESSIONS

DEPENDENT VARIABLE		INDEPENDENT VARIABLE			
		DDEVIT-1	**DDICHST**	DDIAVPER	DDICHPER
DCG	COEFFICIENT	0.1126	-0.1665	0.1007	0.0463
	T-RATIO	1.73*	-2.01*	1.52	0.79
		R-sq = 14.2%		F ratio =	2.70*
DSG	COEFFICIENT	0.0533	-0.0662	0.0455	0.0636
	T-RATIO	1.20	-1.16	0.99	1.57
		R-sq = 9.6%		F ratio =	1.74
		MDEVIT-1	MDICHST	MDIAVPER	MDICHPER
DCG	COEFFICIENT	0.0552	-0.9346	0.4576	0.1829
	T-RATIO	0.09	-1.26	0.63	0.33
		R-sq = 3.7%		F ratio =	0.61
DSG	COEFFICIENT	0.1545	0.3366	0.0480	0.4495
	T-RATIO	0.39	0.68	0.10	1.22
		R-sq = 2.9%		F ratio =	0.49
		DPRDIT-1	DPICHST	DPIAVPER	**DPICHPER**
PCG	COEFFICIENT	0.2269	0.0007	-0.1193	0.1335
	T-RATIO	3.22*	1.12	-1.25	2.53*
		R-sq = 20.8%		F ratio =	3.34*
PSG	COEFFICIENT	-0.1319	-0.0001	0.1425	-0.0634
	T-RATIO	-1.89	-0.18	1.54	-1.20
		R-sq = 9.3%		F ratio =	1.18
		MPRDIT-1	MPICHST	MPIAVPER	MPICHPER
PCG	COEFFICIENT	-0.6458	-0.8999	0.7164	-0.5704
	T-RATIO	-0.80	-1.07	0.83	-0.92
		R-sq = 5.6%		F ratio =	0.75
PSG	COEFFICIENT	-0.6200	0.5585	1.3044	0.2370
	T-RATIO	-0.75	0.80	1.60	0.41
		R-sq = 8.2%		F ratio =	0.99
		DDEVIT-1	DDICHST	DIAVPROJ	**DICHPROJ**
TPCG	COEFFICIENT	0.0861	-0.0348	-0.0323	0.0732
	T-RATIO	1.85*	-0.43	-0.42	1.81*
		R-sq = 10.8%		F ratio =	1.55
		MDEVIT-1	MDICHST	MIAVPROJ	MICHPROJ
TPCG	COEFFICIENT	0.2007	-0.3395	0.3030	-0.2307
	T-RATIO	0.33	-0.43	0.44	-0.70
		R-sq = 3.3%		F ratio =	0.42

* = Significant at p = .10

E. RESULTS TO EXPECTATIONS

The basic hypothesis of this thesis, as stated previously, is that a firm's financial health, both before and during a specific phase of procurement has an impact on cost and schedule performance. Discussions in Chapter II argued that a firm in a strong (or improving) financial position would exhibit smaller cost and schedule growth. This suggests an inverse relationship between the measures of cost and schedule growth and the measures of financial position. This position would be supported if the signs of the coefficients for variables reflecting financial position before and during a program were negative.

1. Results of Simple Regression

The results for the simple regressions tabulated in Table 4-3 show that the signs for the coefficients are mixed; of the 40 coefficients, 16 had the expected negative sign. The results from the simple regressions indicate that variables computed from the Dagel and Pepper index produced generally stronger results than those from the Moses and Liao index. But in both cases the sets of variables were weak indicators, with only three explanatory variables having an error probability below 10%.

The three significant variables were all from the Dagel and Pepper index set. Note that each was significant in a model explaining cost growth. One variable was significant in each of the DCG, PCG and TPCG regressions.

There was no evidence of any significant relationship between financial health and schedule growth. Note also that all three significant variables were indicators of financial condition, not of change in financial condition. Lastly, note that in all three cases the sign of the significant coefficient was positive, contrary to the negative sign that was expected. These observations indicate that a weak relationship between financial condition and cost growth does appear to exist, but the nature of the relationship is different than that hypothesized.

2. Multivariate Regression Results

As with the simple regression the results of the multivariate regressions were mixed with respect to coefficient signs; 14 of the 40 coefficients had negative signs. The overall relationships were weak, only the models for DCG and PCG (with the Dagel and Pepper variables) were significant even at 10% probability. Six coefficients for individual variables were significant as indicated in Table 4-4.

The six coefficients were all for variables measured using the Dagel and Pepper index. The regressions for DCG, PCG, and TPCG each contain two significant variables. Like the simple regressions none of the results indicates a significant relationship between financial health and schedule growth. In each case (DCG, PCG, and TPCG), one of the significant variables reflects financial condition and one

reflects change in financial condition. This contrast with the simple regressions, where no variables reflecting change in financial condition were found significant. Five of the six significant variables had positive signs. Though this confirms the results from the simple regressions, it is contrary to the negative signs expected. Overall the results do show a weak relationship between cost growth and financial health but, as in the simple regressions, the difference between the hypothesized signs and the results indicate that the nature of the association is not as argued in Chapter II.

Conclusions from these result will be addressed in Chapter V.

V. SUMMARY

This chapter will address four areas: 1) A summary of the objective and procedures used in this thesis, 2) Conclusions drawn from the results of the research, 3) Limitation of the results due to procedures used, and 4) Recommendations for future research.

A. SUMMARY

The primary objective of this thesis was to investigate if there is a systematic, predictable and significant association of prime contractor financial health with contractor cost and delivery performance during the period of weapon system procurement. To this end, associations between financial health and cost and schedule growth were theorized, then tested by linear regression.

Outcome measures of cost and schedule growth were drawn from a recent study that had constructed the measures in order to investigate the effects of contract initiatives on major DOD acquisition programs. Summary indexes of financial health were constructed using the indexes computed from two financial distress models. The summary indexes were used to measure both financial health and change in financial health, both before and during the development and production phases of programs, as well as for the total program. Simple and

multivariate linear regression was then used to test the strength of the relationships between financial health and cost/schedule growth.

B. CONCLUSIONS

The results of this analysis indicate that, though weak, a relationship does exist between financial condition and cost performance of prime contractors. The original hypotheses theorized that a negative relationship between financial health and cost/schedule growth should exist. The results from both the simple and multivariate regression analysis are consistent in that the coefficient signs for variables found significant were generally positive. Additionally, variables reflecting financial condition prior to program start were the most consistent (evidence from both the simple and multiple regressions) in explaining cost growth.

One argument originally offered was that poor financial condition (prior to program start) would increase a firm's need for new projects, lead to a downward biasing of initial cost estimates to secure the program, and consequently lead to subsequent cost growth.

A contrary argument, consistent with the result, can be offered. Firms in poor financial condition may: 1) have greater need of short run capital, and 2) be less willing to accept projects that only pay off in the long run. Such firms should have incentives to adopt strategies that encourage

rapid recovery of funds and emphasize short run profits. Such firms would be less willing to "buy-in" to a program with a low estimate of initial cost.

A firm in poor financial condition may require early progress payments. Given the link between progress payments and cost, the need for short run progress payments could provide incentives to accept only a realistic cost estimate. A firm in poor condition may be unwilling to "bet" on the future. Such a firm would be less willing to accept a low initial cost estimate in the hope that profits could later be realized by negotiating increases. The next section will address the financial condition measures used in the analysis.

C. LIMITATIONS

In general, the strength of the financial health indicators in explaining cost and schedule growth was less than what might be expected given the results from the studies by McGrath and Moses [Ref. 4] and Moses [Ref. 5] reviewed in Chapter II. Two possible explanations for the poorer results are related to the procedures used for constructing the indicators of financial health. First, the financial statement data collected for computing the indexes was for the parent corporations of the prime contractor. By using information from consolidated balance sheets and income statements the actual condition of the prime contractor may have been masked. Second, the explanatory power of individual

financial ratios, demonstrated in the previous studies, may have been diminished due to aggregation when the summary indexes were constructed. For these reasons the results of the analysis should be view critically before concluding on the value of financial health as a possible predictor of contractor cost and schedule performance.

D. FUTURE RESEARCH

The intuitive relationship between the financial condition of a contractor and contract performance is stronger than the results of this analysis indicate. This difference between what would seem "reasonable" and the current findings demonstrate that further investigation would be warranted. In light of the limitations discussed above an analysis using individual ratios, each representing an individual dimension of financial condition, a procedure more in line with previous studies, may produce a more definitive result.

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