Decision Process Simulation Models of Defense Contractor Behavior

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Abstract

The demand for defense systems is determined by a single buyer - the U.S. Department of Defense. In such an environment traditional competitive market mechanisms cannot be expected to operate effectively. Historically, the objective of procurement policies has been to prevent excess profits. This has resulted in bilateral contractual arrangements based on cost reimbursement, with low profits for the contractor and with the government bearing most of the risks. However, studies which have investigated incentive contracts conclude that their effectiveness in achieving DOD costs and performance objectives cannot be generalized.

This paper describes the development of decision process simulation models describing defense contractor motivation, management and performance. The computerized models employ feedback/adaptation/search mechanisms to describe the internal decision making behavior of defense contractors at the project and corporate levels. It is expected that the simulation models will provide the basis for generating and testing various hypothetical incentive schemes.

INTRODUCTION

Procurement of defense systems accounts for over half of the total annual defense budget of the U.S. Unlike the civilian sector of the economy the demand for defense systems and components is determined by a single buyer - the U.S. Government Department of Defense. Furthermore the defense industry is dependent on the development and application of advanced technologies, is subject to rapid obsolesence, is capital intensive and (not surprisingly) is perceived by contractors to involve great risks.

It is generally recognized that in such an environment traditional competitive market mechanisms (such as competitive bidding for contracts) cannot be expected to operate. Indeed most major weapon systems are procured through bilaterally negotiated contracts. Whatever competition does exist seems to be centered on technological and design considerations rather than on minimization of total costs.

The lack of price competition creates the potential for defense contractors to earn monopoly profits. Historically, the objective of procurement policies has been to prevent excess profits. This has resulted in bilateral contractual arrangements based on cost reimbursement, low nominal profits for the contractor, and with the government bearing all or most of the risks.

Cost reimbursement contracts satisfied the contractors' motivation to avoid the uncertainty associated with the development of new systems, but they also resulted in substantial cost overruns. Thus, starting in the 1960's the emphasis of procurement policies shifted to the control of cost overruns; this was done through the incorporation of various incentive schemes in the procurement contracts which were designed to induce contractors to control costs and share the risks of cost overruns and other contract objectives - performance, reliability, maintenance, etc. (Fox (8), Peck and Scherer (15)). The objective of incentive contracts was to: share some of the risk inherent in systems development programs; communicate DOD's objectives; correct for the absence of market mechanisms; and in the case of multi-incentive contracts, allow the contractor to make cost, performance and schedule tradeoffs.

Thus, since the early 1960's the defense contracting problem was viewed as one of developing the right incentive structures which optimize risk sharing between the government and a contractor and which maximize other contract objectives. Much of the academic literature involving defense contracting has focused on the problem of optimal risk sharing and on the relationship between contract incentives and cost control (Berhold (1), Scherer (17), and Williamson (24)). In addition the DOD has devoted substantial resources to develop various types of contracts ranging from fixed price contracts to multi-incentive cost plus fee (or incentive fee) contracts.

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Decision Process Simulation Models (continued)

However, studies which have investigated the effectiveness of various types of incentive contracts conclude that their effectiveness in achieving DOD cost and performance objectives cannot be generalized, and that at best the impact of incentive contracts on contractor motivation and performance cannot be assessed (see, e.g., Runkle and Schmidt (16), Oppendahl (14) and Lynch and Pace (13)). In essence the studies conclude that: "extra-contractual" factors dominate profit or fee objectives; no correlations exist between cost sharing ratios and cost overruns or underruns; incentives have not been effective in countering program cost growth; contractors establish internal limits on profit from government business (large profits or fees are perceived to arouse suspicions of cost padding); contractors will not sacrifice attainment of system performance objectives for profit; and incentives are difficult to transfer to the project level.

Preliminary findings of existing research seem to suggest that the goal hierarchy of contractors consists of survival, profit, growth, market share and prestige (Oppendahl (14)). Survival is perceived to depend on attaining the project performance objectives which affect future company image and the ability to obtain future business. Similarly contractors are strongly motivated to retain technical and supervisory staffs even in the face of declining business activity. Maintaining these staffs is perceived to be critical to maintaining competitive positions for securing future business. Contractors pursue growth as a means to maintain internal capabilities and as a means to spread fixed costs over a larger base or as a strategy for achieving barrier to entry by a competitor. It also appears that in the short run contractor management is willing to sacrifice current profits on defense business in order to secure new business, benefit from the spinoffs to the commercial business, improve opportunity for follow-on business, acquire personnel in scarce disciplines and/or gain competitive advantage by engaging in developmental efforts instrumental to gaining future business (IR&D).

It is clear that few (if any) of the many considerations mentioned above are affected by existing incentive strategies. It is also recognized that contractors differ in their internal considerations and internal decision making strategies with regards to the attainment of their basic goals.

Perhaps the most fundamental failure of past research has been a lack of a clear cut understanding of the difference between doing business in the traditional market environment and the defense industry. A firm in the market environment affects its revenues by its control of such variables as price, output, production, inventory, etc. The defense contractor has little control over setting prices since those are negotiated. His revenue is based on cost recovery, specifically on the recovery of direct and indirect costs. His survival depends on successful completion of projects by incurring minimum financial risks. This is achieved via cost recovery type contracts (regardless of incentive structure) as long as their criterion is performance. Similarly future business and the ability to exploit opportunities is related to the IR&D effort and to the maintenance of excess technical and managerial staffs, the costs of which must be recovered from overhead spread across all projects.

The ability of a contractor to continuously behave as if short run profits do not matter depends on satisfying or exceeding the cash flow constraint in each period. In other words, from period to period a contractor will concentrate on achieving his survival, growth and prestige goals subject to not violating cash flow constraints (cost recoveries over all projects in a period that equal or exceed all cash outflows). Furthermore the aspiration for profit is low (6-8% is considered reasonable), and although the contracts nominally guarantee the earning of a profit or fee, in actuality it is discounted because of such practices as hold backs and delays in certification of project completion. Also frequent specification changes in ongoing programs result in renegotiation of the contract price and other provisions. This attitude may be further reinforced by the perception of contractors that the government is unwilling or unable to enforce contract provisions.

MOTIVATION OF THIS RESEARCH

A major premise of incentive contracts has been that defense contractors are primarily motivated to maximize profits. However, if (as seems likely) contractors in managing their enterprises are motivated to satisfy a complex goal structure, then efforts at developing optimal incentive structures will need to be cognizant of the defense contractor diverse goal structure. Stated differently: "If profit is not the primary motivation influencing a defense contractor, then incentives based on the profit motive will not be effective"; in the vernacular the question is "What makes Johnny contractor run?"

It is the overall objective of this research to develop a decision process theory of defense contractor motivation and management which will facilitate a comparative analysis of existing incentive schemes. A potential outcome of this research could be the development of a new mix of DOD incentive based procurement policies. The specific objective of the project described in this paper is to develop decision process simulation models and to demonstrate their theoretical and empirical validity in describing defense contractor motivation and performance when engaged in the development of systems for the DOD.

RESEARCH APPROACH

In order to proceed from the current state of partial and intuitive research on contractor motivation it is necessary to develop insights into the structure of internal resourse allocation decision making of defense contractor firms. This approach has been advocated by (Simon (18)(19)(20)(21)) and has been applied by (Cyert and March (6)).

The objective is to study the procedural aspects of decision making within firms so as to develop information processing descriptions of their economic behavior.

Information processing models have been successfully utilized in studying person perception (Smith and Greenlaw (22), Lewin and Zwany (12), and Lewin and Layman (10)), behavior of bank trust investment officer (Clarkson (3), industrial budgeting (Weber (23)), municipal budgeting decisions (Crecine (5), school board budgeting and salary decisions (Gerwin (9)) municipal zoning decisions (Davis and Reuter (7)) and simulation of the firm's information and decision making system (Bonini (2)).

(Crecine (5)) developed a decision process simulation model for the budgets of Cleveland, Pittsburgh, and Detroit. The program modeled the sequential processes of departmental requests, followed by the mayor's formulation, and city council's approval, of a budget. It predicted budget decisions over 10 years for Cleveland, 6 years for Pittsburgh, and 7 years for Detroit with rank correlations (r^2) exceeding .977. Similarly, (Davis and Reuter (7)) constructed an information processing simulation model for municipal zoning decisions made by both the Planning Commission and the City Council of Pittsburgh during 1963, 1964, and 1965.

(Weber (23)) conducted a field study of the budgeting process in the electronic data processing department of a firm. He developed five process model programs to predict actual budget decisions, relying primarily upon interviews and questionnaires. Using data from one year, he "predicted" the decisions made in the preceding two years. Of the predictions made, approximately 90% were correct.

(Bonini (2)) developed an information processing simulation model of a hypothetical business firm. His purpose was to study the effects of certain informational, organizational, and environmental factors upon the decisions of a business firm. Thus, for example, Bonini, studied the effects of changes in inventory valuation, the organization's sensitivity to pressure, variability of the external environment, and market trends.

In summary this research involves the development of a computer simulation of the behavior of defense contractors. This simulation will consist of detailed decision process models which describe the internal decision making structures of defense contractors at the project and corporate levels. The general approach to building the simulation will, in general, be analagous to (Bonini (2)) and to the general computer simulation of price and output developed by Cohen, Cyert, March and Soelberg [See (Cyert and March (6), ch. 8)].

BASIC ELEMENTS OF ANALYSIS

A major objective of this research effort is to develop a capability to model the potential impact of various incentive schemes on the performance of DOD contractors. It therefore will be necessary to incorporate in the simulation such basic elements as: i) DOD project goals; ii) contractor goals; iii) DOD incentive mechanisms; and iv) contractor strategic and organizational response mechanisms.

The DOD project goals involve such factors as attainment of reasonable cost (minimizing cost overruns), timely delivery, performance to specifications, quality assurance of delivered products, etc. The role of the various DOD contracting incentive schemes is to facilitate the accomplishment of project goals by the DOD contractor.

The key goals of the contractor as mentioned earlier include, among others, survival, profit, growth, market share and prestige. It is clear that in general the DOD project goals and the contractor goals are not congruent, and that the ability of the DOD to accomplish improvements in DOD project goals depends on modifying the contractors behavior in pursuing their own goals.

The DOD mix of incentive mechanisms represents the DOD decision variables which can affect contractor performance. In the simulation this element could include the use of various types of award contracts (designed to affect the contractor profit goal); progress payment policies (designed to affect the cash flow goal); hold back provisions on fixed price contracts (affecting both the profit and cash flow goals); use of preferred bidding lists or sole source negotiations (affecting the contractor's survival and market share goals); IR&D allowances (affecting the contractor's survival, and barrier to entry goals); and more traditional incentives such as higher profit margins and overhead rates.

The contractor firm's behavioral responses and organizational actions utilized in its attempt to achieve its own goals comprise the fourth basic element of the modelling effort. It is important to recognize that the contractor internal actions have a direct impact on the DOD set of project goals. Thus, for example, the use of the IR&D account when the backlog is thin can help smooth out the workload and improve cash flow. But this action also impacts on the contractor's total costs. Similarly DOD project goals are affected when contractors attempt to affect their backlog by reducing profit margins or increasing cost sharing on new proposals; renegotiate overhead when cash flow is inadequate; increase subcontracting when backlog is too high; transfer critical individuals off projects to help write proposals; add individuals who contribute little to projects to increase cash flow and lower overhead rates; and renegotiate contract terms regarding schedules, costs and overhead rates.

In summary, the total process governing the contractor actions consists of a system of feedback, adaptation and search efforts with the contractor's goals as a starting point and with outputs indicative of the degree to which both the contractor goals (at project and corporate levels) and DOD project goals are met.

DESIGNING THE DECISION PROCESS SIMULATION MODEL

The computer simulation models that we are developing describe the internal decision making behavior of defense contractors.

The general framework assumes that there are several goals that the firm is seeking to satisfy. Examples of these goals for a defense contractor would include survival, market share, prestige, backlog, cash flow, profit, and growth. Whenever it appears that one of these goals cannot be satisfied, i.e., when anticipated performance falls short of goals, search activity is triggered. This causes the firm to search for new ways of behaving, and it also may lead to downward revisions of goals. When it appears that the goals are being achieved, standard operating rules are then invoked without any search activity. On the basis of feedback from past results, the firm may modify its goals and operating procedures. This feedback, adaptation, and search process is illustrated in Figure 1, below.

EXAMPLE

As one specific example of a component of the simulation model, let us consider the submodel relating to the backlog goal. This is depicted in flow chart form in Figure 2, on the next page. First assuming that the cash flow goal is being met, the contractor will compare the backlog to upper and lower acceptable bounds. If the backlog is within these limits, then normal effort for proposal writing and normal amounts of IR&D will be undertaken, and the backlog constraints will be slightly relaxed.

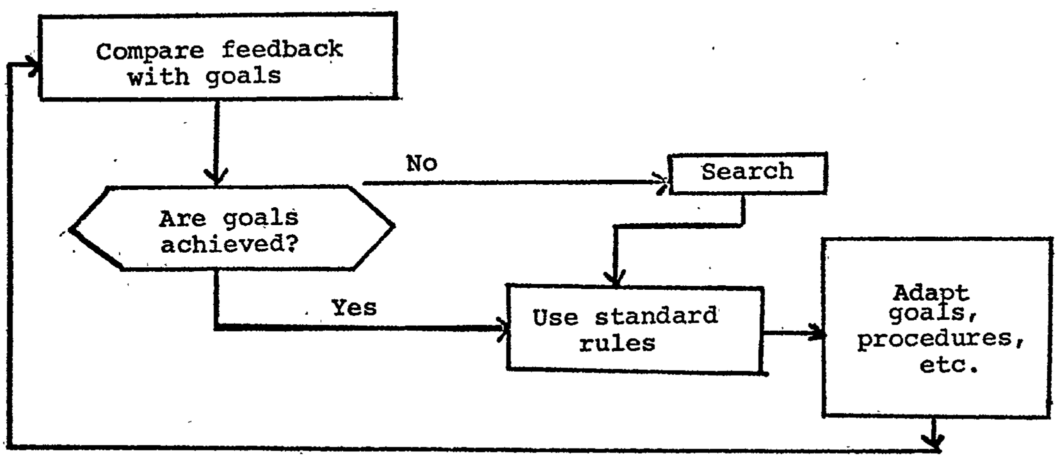
If the backlog exceeds the upper limit, this will reduce submission of new proposals, less IR&D will be done, more resources will be put into the direct labor aspects of the project, there will be pressures put on project managers to complete projects sooner, there may be more hiring of project personnel, or more subcontracting of portions of the project outside the firm.

If the backlog is less than the lower limit, this implies that, ceteris paribus, lower levels of cash flow are expected in the future. This is undesirable, and it will trigger more intensive proposal writing efforts, more people will be shifted into IR&D and out of direct labor catagories, people may be laid off, and contracts may be renegotiated to increase the recovery of costs. Note that there are important contextual differences (that will lead to different types of behavior) between the situation when backlog is declining but the firm is viable and the situation when backlog is declining but the firm may not be able to survive. The illustrative example that we present in Figure 2 assumes the former situation, i.e., that the firm is viable even though backlog is declining.

The preceding discussion of what happens when backlog exceeds its upper or lower limit assumes that the cash flow goal is being satisfactorily met. However, if not enough cash flow is being generated, and backlog is within its upper and lower acceptable bounds, then search efforts will be triggered to increase cash flow. When cash flow is unsatisfactory and the backlog is low, then there will be a reduced profit target built into new proposals in order to increase the capture rate, cost sharing will be increased, fewer portions of the contract will be subcontracted outside the firm, and the firm's growth goal will be reduced. In the case where the cash flow is unsatisfactory and the

Figure 1

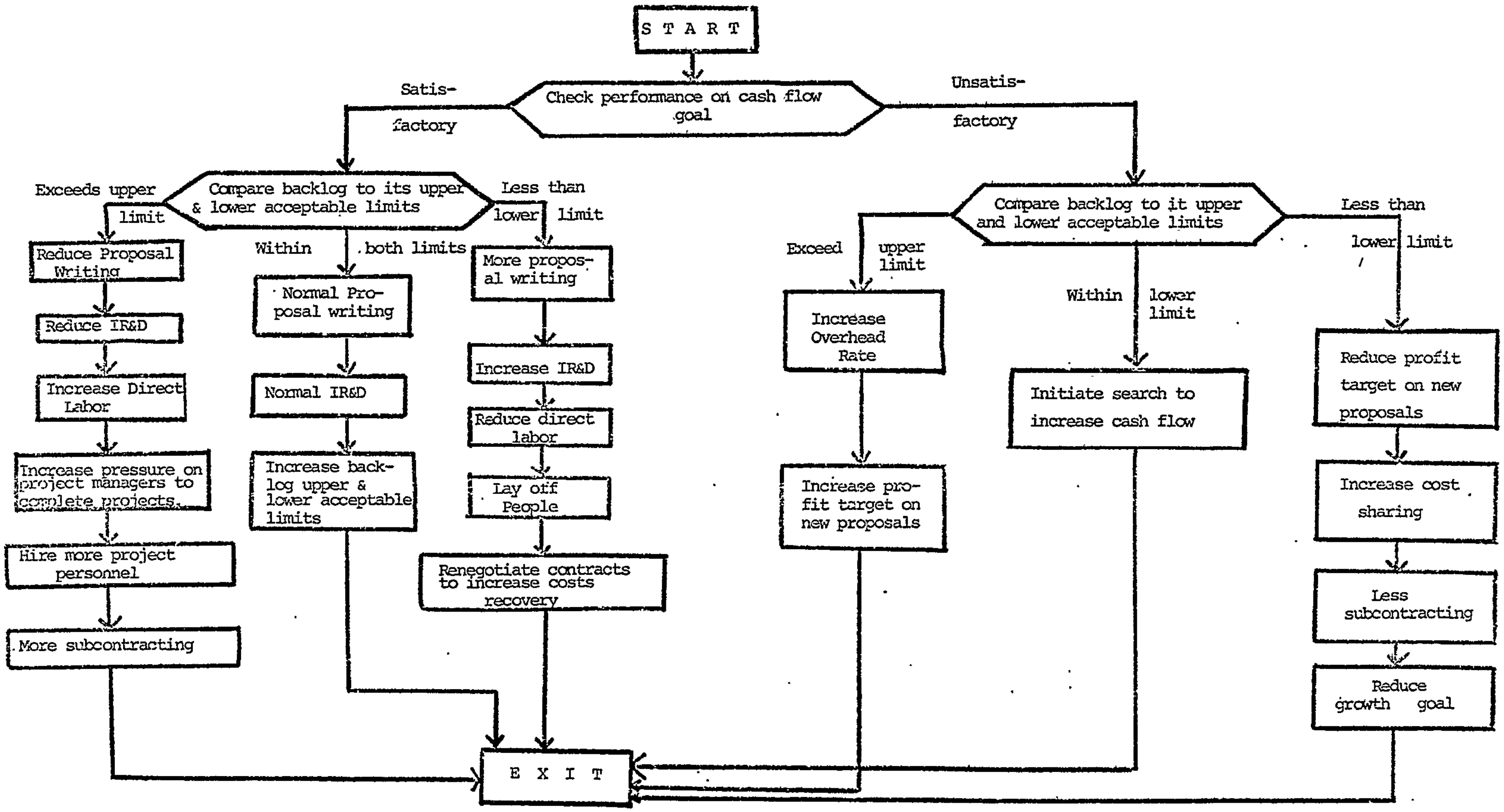
FEEDBACK, ADAPTATION, AND SEARCH*



*Source: Cyert and March (6), p. 151.

Figure 2

ILLUSTRATIVE CASH FLOW AND BACKLOG GOALS SUBMODEL



backlog is high, then higher overhead rates and profit targets will be incorporated into new proposals. We thus see that there often is interaction among goals. For example, cash flow, growth, profit, and backlog goals are all interrelated.

The results of search efforts to increase cash flow could include the following types of outcomes: layoffs, using vacation time, reducing fringe benefits, freezing raises, shifting from subcontract to in-house work if possible, renegotiating the contract, and defaulting or violating the contract. These search procedures will generally be pursued sequentially until the need for search is removed. The order of the search will change in response to feedback from experience. If a search procedure is successful (i.e., after it is implemented the firm does not search on the next decision cycle), then that procedure goes to the top of the search order list. If a search procedure is unsuccessful (i.e., after it is implemented the firm must continue to search on the next decision cycle), then that procedure goes to the bottom of the list.

Note that Figure 2 and the above discussion is presented here only as an example of the type of information processing models which are incorporated in our simulation. The actual cash flow goal submodel which we have been developing is substantially more comprehensive and intricate.

EXPLORING THE PROPERTIES OF THE SIMULATION MODEL

A great deal of useful model building and exploration of the properties of the model can be done without having detailed actual data on the performance of defense contractors.

Regression analysis, experimental design and other hypothesis testing type techniques will be used to explore the main effects and their interactions as well as the differing impacts of market response, number of contractors, and size of firms. Also following (Bonini (2)), experimental block designs will be utilized to assess the sensitivity of the simulation to initial conditions.

The computer simulation model of a defense contractor will be used to generate a variety of specific case scenarios. Each scenario will be based upon a particular set of assumptions about the type of firm, nature of DOD contracts and possible civilian business, incentive scheme (if any) built into the contracts, etc. The simulation model will be run for each scenario, to produce detailed print-outs describing exactly what the simulated firm did. This output will be shown to experienced defense contractor project managers and Air Force project managers and contract officers, so that they can assess its reasonableness. This will provide at least a prima facie check on the model's validity.

For example, the response outputs might detail the process by which the firm adapts and responds to a low backlog situation, which in turn affect the achievement of the survival goal. Similarly it would be possible to track the process of adjusting contractor aspirations when the contractor's current goals of growth, cash flow, etc. are being met.

After the extensive validation and sensitivity analyses have been completed it is intended to introduce various hypothetical incentive schemes (hopefully suggested by the DOD) and to exercise the model to determine whether these incentives affect the contractor firm's performance on projects and the attainment of its goals. Thus, for example, it would be interesting to explore how the use of a prefered bidding list (which rewards superior contractors and affects the survival goal) affects the management of projects in terms of shifting attention to the accomplishment of such DOD goals as costs, quality and timeliness. It is hoped that the relative cost-benefits of various incentive schemes could be explored within the simulation and that insights could be gained as to the proper mix of such incentives for different types of contractors.

POTENTIAL BENEFITS OF RESEARCH

The potential of the simulation for the purpose of designing various incentive schemes and assessing their impacts on different types of contractors has already been discussed. However, the nature of the simulation is such that it could be adapted to serve other important DOD purposes.

Such a simulation, for example, could become the basis for the training of DOD project officers. The training designed around a man/machine version of the simulation would give participants insights into the managerial and organizational behaviors of the companies with whom they do business. Such simulations (management games) have been used extensively in the training of MBA students and in corporate management training programs (Cohen, Dill, Kuehn and Winters (4), and Lewin and Seidler (11)).

Another important application would be a comuterized interactive environment in which several (or all) DOD contractors are represented. In this environment each contractor is described as a customized adaptation of the models developed in this research. This would be accomplished through the adjustment of contractor specific parameters describing size, project mix, capitalization and other characteristics. The industry simulation could then be used to trace the impact of various policy scenarios. For example, it would be possible to gain insights into the impact and consequences of possible DOD actions (e.g., terminating the IR&D allowances and changing procurement policies), as well as of changes in external factors (e.g., consolidation of the industry or withdrawal of firms from defense contracting).

In summary, it is important to note that the core of all of the possible future applications are the decision process simulation models of defense contractors currently being developed and which were described in this paper.

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