RISK ANALYSIS

IN

MAJOR TRAINER ACQUISITION

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RISK: The possibility of suffering harm or loss.

VENTURE: An undertaking that is of doubtful outcome.

RISK is a "Buzz word." What is risk and how and why does the Naval Training Equipment Center engage in Risk Analysis???

Risk is used to refer to making decisions when probabilities have been assigned to the outcomes affecting the results of the decision. "Uncertainty" is used to refer to making decisions when these probabilities are neither assigned nor known. An example of a decision under risk is betting on the outcome of a roll of the dice. One does not know the specific outcome in advance, but the probabilities of each possible outcome are well known and may affect one's decision, i.e. bet, in advance of the roll. An example of a decision under uncertainty would be for someone in the United States to make a bet on a local European soccer match. Most people in the United States would have no idea of the probabilities of one team beating the other!

Major decisons in trainer acquisition are made under both risk and uncertainty. These decisons include, but are not limited to the following:

Choice of contract type: fixed price, incentive fee, etc.,

Selection of source from proposals submitted, and

Evaluation of contractor progress during trainer construction.

Risk Analysis techniques are presently being used at the Naval Training Equipment Center to aid in these decisions. Two Risk Analysis projects will be described in this paper:

Evaluation of proposals for contract award and

Monitoring of contractor progress during construction.

Methods of Risk Analysis

The methods of risk analysis are coordinated applications of probability theory and other mathematical tools to decision making. Methods with different levels of mathematical sophistication, from simple to complex, and requiring different amounts of analytical expertise and computing resources, are available for use. Traditionally the more realistic, sophisticated, and complex techniques have required the most analytical expertise and computing resources, available only to upper level management of large programs. The advent of the desktop personal computer has allowed more computationally intensive risk analysis techniques to be available to more levels of program management. Even so, analytical expertise, i.e. the people resource, is still required.

Two of the most useful groups of risk analysis techniques are network methods and decision tree methods. While they are the most resource intensive methods, the insight gained into the workings of the complete system of a trainer and its acquisition provide a worthwhile return for the resources invested in using either, or both, analytical technique.

Network methods for decision/risk/system analysis have a hallowed tradition. They came into the spotlight with the use of PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) in the Polaris submarine program. Networks of sequential activities were used. The arcs of the network represented the amount of time needed to complete various activities. The system of network nodes represented the dependency relationships between activites, where one activity could not start until its predecessor activities, or activity, had been completed. The critical path was the longest (time) path through the network, i.e. the minimum time needed to complete the project. Activities on the critical path were the primary candidates for extra resources to shorten the time for their, and thus the project's, completion.[1] Figure 1 shows a typical project PERT network labelled with times per arc and with the critical path identified

Network techniques evolved from these beginnings to include such features as the following:

Use of Cost and Performance, as well as

Time, as activity/arc properties,

Generation of Time, Cost and Performance

values for each arc by functional relationships and/or stochastic simulation,

Sophisticated input and output node logic schemes to allow simulation of precedence relations, multiple arc completion requirements, backup schemes for activity failure, and/or performance preference choice criteria, and

Preparation of probability density and cumulative distribution functions of network cost, time and/or performance based on the above mentioned simulations.[1,2]

In classical Decision Analysis the complete set of decisions in the system acquisition process is modeled as a tree and its branches. Each node, or branch point, represents either the decision between branches coming into that node, or the union of various sets of outcomes of program events. The "Expected Utility" or the "Expected (Monetary) Value" of each branch, or union of outcomes, entering a decision node is calculated using the estimated, calculated, modified, and/or hypothesized probabilities of each branch's outcome. Calculation of these values starts at the farthest out branch tips and progresses backwards towards the "Root" of the tree model. At any level in the tree, the decision would be made which maximizes the return of these criteria to the decision maker. The resultant "Expected Values" of decisions are carried back to the "Root" as the value of the branch connecting the decision node to the next union of outcomes node closer to the "root."[1] Figure 2. shows a simple decision tree with expected values, decision nodes and probability union nodes.

Network and Decision Analysis methods tend to be complementary, with each supplying monetary/utility and probability values that the other can use. In the best of all possible worlds, one would like to use both network and decision analysis models together. If, as ususally is the case, one must restrict one's efforts to one model, the network techniques are generally used as the development of a network model from a bidder's proposal for a trainer development process is much more straightforward than the development of a decision tree model.

Risk Analysis Prototype Projects

The Naval Training Equipment center risk analysis applications described in this paper used a network analysis model,[2] the Venture Evaluation and Review Technique (VERT).

VERT possesses the characteristics of modern network analysis models described earlier, including:

Generation of Time, Cost and Performance measures for each arc,

Sophisticated input and output logic for nodes, and

Generation of cumulative probability distributions for terminal and other specified nodes in the network.

VERT specifically allows for functional relationships to be defined, i.e., the cost of one activity may be a function of the time-or manpower-loading of that activity, or of other related activities. This provides a refined measure of the associated risk costs. After several hundred, or thousand, iterations of the VERT network, a representative description of the cumulative distribution functions of cost, time and performance of the total process, as well as internal nodes, may be examined.[2]

Figure 3. shows a typical high level VERT network. Details will vary from project to project. The arcs represent activities to be performed or signals of activity completion. The nodes represent initiation and termination of these activities. The nodes can also represent tests for satisfactory completion of activities. Nodes can direct the network to consider "fall-back" activities in the case of failure of an arc, and can send a "signal" to another node to initiate an arc's activities upon successful completion of a preceeding arc. These capabilities are based upon the following input and output logics for nodes.

Node Logics[2]

Input:
- INIT Initial Node, Start of network
- AND All incoming arcs must be successful for output arcs to be initiated
- OR Only one incoming arc must be successful for output arcs to be initiated

Output:
- ALL All output arcs are initiated
- MC Monte Carlo - One arc is randomly chosen to be initiated
- TERM Terminal node for statistics calculation

Two Risk Analysis examples will be described. The first, a proposal evaluation, is complete. The second, a contractor progress evaluation, is underway at this time.

Risk Analysis for Proposal Evaluation

The industry proposal describes the process for transforming government requirements into contract deliverables. Thus there is a conversion of known requirements into known deliverables via a process which has not yet occurred, and must therefore considered to be unknown. The industry proposal can not admit to unknowns. This builds risk and uncertainty into the proposal: uncertainty of the problem solving process, uncertainty of technology applications, uncertainty of ability to manage.

The industry proposal is an optimistic treatment of these risks and uncertainties. Only the possibility of success is presented. Performance, cost, schedule, and resource requirements always constrain planning, however not all foreseeable events or activities are planned, and not all potentialities are foreseen. Thus all program plans are optimisticically free of risk and uncertainty.

Competition multiplies this optimism. The competitive effort to produce a winning proposal invariably drives planning from merely optimistic to overly optimistic. Thus the successful bidder's program may contain planning that is measurably unreal.

Measurement of these risks and uncertainties is a primary objective of the Naval Training Equipment Center risk analysis. It quantifies risks in performance, cost, and schedule. A critical payoff of risk analysis is during proposal evaluation. Risk analysis uses a work breakdown structure (WBS) to determine a probability function for the time and cost of each element of the WBS to be performed. These probability functions were based upon the time and cost schedules in the proposal, as modified by Naval Training Equipment Center (NAVTRAEQUIPCEN) Subject Matter Experts (SME) during the Proposal Evaluation Process (PEP).

A Risk Analysis team was formed which used the Systems Engineering Management Plan (SEMP) submitted by each bidder in response to the Technical Proposal Requirements (TPR) to develop a symbolic network model of each bidder's proposed effort.

These network models were then used as input to the VERT model and probabilistically excercised for many hundred iterations, dynamically testing program activities and their interfaces.

Two separate networks were run for each bidder, a "Final Cost" and a "Should Cost" network. Both used the same schedule estimates and varied only in costs.

The "Final Cost" network represented the bidders final estimate of the proposed trainer's cost. The "Should Cost" network represented NAVTRAEQUIPCEN's estimate of what the proposed trainer should cost to build, after technical deficiencies, if any, are removed and the proposed approach brought to a level of acceptability.

The "Triangular Distribution" was used for all cost and time probability distribution functions. Figure 4 illustrates the distribution. Most Likely "Should" and "Final" cost values for each activity in the network were based on independent Government cost estimates and upon SMEs' assessment of the bid value respectively. Maximum and minimum values were then estimated by the SME's, and the VERT model was run for each bidder's "Should" and "Final" cost networks.

Figure 5 and 6 show the resulting cumulative distribution functions (CDF) for cost and time for a bidder. The 50% point on the distribution represents the median cost estimate. The final cost is equally likely to be above or below that value. The "Risk Costs" for each bidder were calculated as the difference between the median "Should" or "Final" costs from VERT and the Government's should cost estimate or the bid price respectively. Tables 1 and 2 list the resultant Risk Cost analyses for each bidder's "Should" and "Final" cost estimates. The bidders were ranked in order of median "Should" and "Final" costs from the VERT output as indicated in Tables 1 and 2. The numbers are not real, but serve to illustrate the process.

TABLE 1. Risk Cost Analyses - "Final Cost" ($ x 10**6)

Bidder	Median Cost	"Final" Cost	Risk Cost	Ranking
A	34	24	10	2
B	39	37	2	3
C	29	24	5	1
D	43	15	28	4

TABLE 2. Risk Cost Analyses - "Should Cost" ($ x 10**6)

Bidder	Median Cost	"Should" Cost	Risk Cost	Ranking
A	37	26	11	3
B	39	39	0	4
C	29	27	2	1
D	32	21	11	2

Contract Progress Evaluation

The use of risk analysis, begun in the proposal evaluation process, is being continued for contract progress evaluation. This project is still active. Consequently, the information presented here is in the nature of a progress report, and further reports will follow.

The Work Breakdown Structure (WBS) and the System Engineering Management plan (SEMP) required in the Technical Proposal Requirements (TPR) were used as the basis for developing the schedule for the trainer construction.

VERT uses this information in the form of a symbolic network, more detailed than that of the proposal evaluation phase, which models the WBS activities and their interdependencies. For example, an individual circuit board test is dependent on (1) hardware components installed on a (2) printed circuit board with (3) established engineering criteria. This network model of the WBS is critical to meaningful Risk Analysis.

After doing a risk analysis on an abbreviated network during the proposal evaluation stage of this trainer acquisition process, a comprehensive network was developed after contract award. The network was developed at the contractor's plant with his support. This network comprises approximately 300 arcs and 295 nodes. (It is unavailable at the time this paper is being written.) Arcs are for level 5 on the WBS. The critical success factor on the network for this trainer is software. A critical success factor is what must go right for this trainer to succeed.

Initial values for the most likely time and cost for each activity were drawn from the contract WBS. During the early stages of this contract, we are using the triangular distribution. NAVTRAEQUIPCEN SME's were contacted for determining each arcs distribution parameters, i.e maximum and minimum values. As data are collected from completion of individual arcs we should be able to ascertain whether triangular distributions are appropriate or other distributions, more consistent with the contractors performance, should be used.

This symbolic network is then probablisticaly exercised for a large number of iterations, usually 500, dynamically testing program WBS arcs and their interdependencies. Comparison of VERT and actual *results will allow* the definitions used for functional relationships to be refined. For example, the cost of one activity may be found to be better defined as a function of the time and/or the manpower loading of that activity or of other related activities such as Integrated Logistics Support. This allows a more realistic modelling to be conducted of this contractor' work, thereby providing a refined measure of the associated risk costs.

It will then be the responsibility of NAVTRAEQUIPCEN project management to keep the network up to date with Cost Schedule Control System inputs, progress meeting results and such VERT output data as the contractor may provide (histogram data on cost and time of subnetworks, or the entire network). Thus the management *function of decision making is aided by this* powerful decision support tool.

One output from the VERT monitoring of the contract progress is expected to be an evolution of the predicted cost and schedule probability distributions and cumulative distributions to a vertical line, or spike, at the true delivery cost/time on the day before delivery. This is illustrated in figure 7.

Conclusions

Risk Analysis, using VERT, has been demonstrated to be a useful tool for the Proposal Evaluation Process. Several lessons have been learned for use in future studies. These are *explained in the following paragraphs.*

A VERT network, as part of the Systems Engineering Management Plan (SEMP), will be required of bidders in the Technical Proposal Requirements (TPR). The TPR should then contain a reference to where VERT documentation and codes may be obtained, as well as a discussion of alternate risk analysis computer codes. Other computer codes should be allowed, after coordination with NAVTRAEQUIPCEN. The primary requirement is that they produce a cumulative distribution output similar to that of VERT.

The VERT network required of bidders can only require that the bidder provide a point estimate of time and cost for each arc in the network. These are ostensibly the cost and time from the proposal *itself. To require the bidder to provide* distribution parameters would be to ask him to modify his bid as part of the proposal!

NAVTRAEQUIPCEN would then generate distribution parameters and functional relationships for use with the bidders' point estimates of time and cost. These parameters would be based upon such factors as the maturity of the proposed technology, the bidder's experience with that technology, the bidder's management plan and proposed level of effort, the bidder's past performance on other NAVTRAEQUIPCEN contracts, and other factors used by NAVTRAEQUIPCEN SME's in proposal evaluations.

NAVTRAEQUIPCEN will write guidelines for its personnel to use in these parameter estimations. These guidelines would then be made available to bidders as part of the technical proposal requirements.

It is too early to evaluate the full effectiveness of risk analysis techniques in contract progress monitoring. Based upon other commands' use of VERT for this task, it is anticipated that it will be successful. Results will be communicated as they are available.

It is concluded that risk analysis, with the use of VERT as the example used in this paper, is a useful tool when applied properly. It is only a tool, is not a decision maker. Decisions must still be made by management, who can and will use all the information available. Risk Analyses and VERT are providers of that information.

References

1. Defense Systems Management College, Risk Assessment Techniques, Fort Belvoir, Virginia, July, 1983.

2. Moeller, Gerald L., Venture Evaluation and Review Technique (VERT), Decision Models Directorate, U.S. Army Armament Material Readiness Command, Rock Island, Illinois, October, 1979. (Available from Defense Technical Information Center, Cameron Station, Alexandria, VA 22314, ADA 076600)

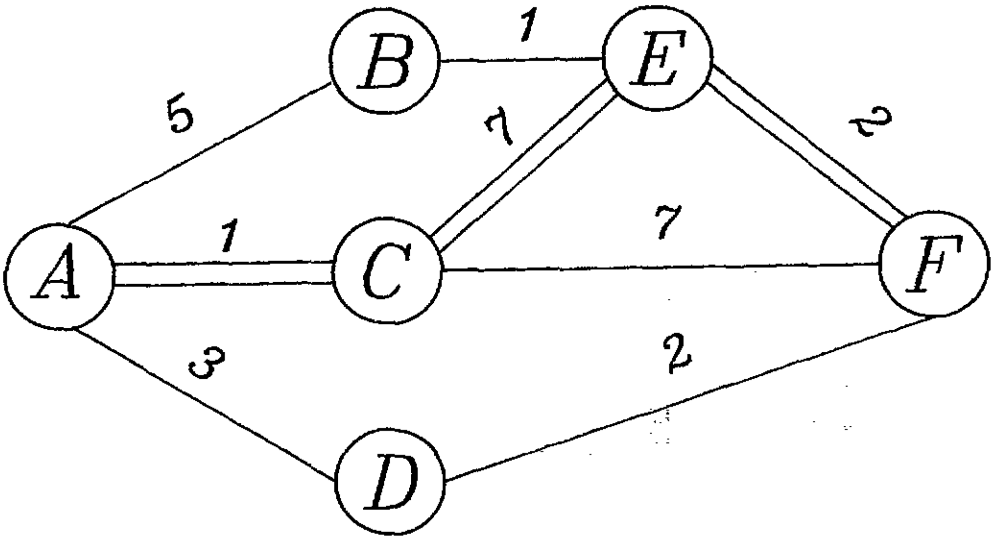

FIGURE 1. TYPICAL PROJECT NETWORK

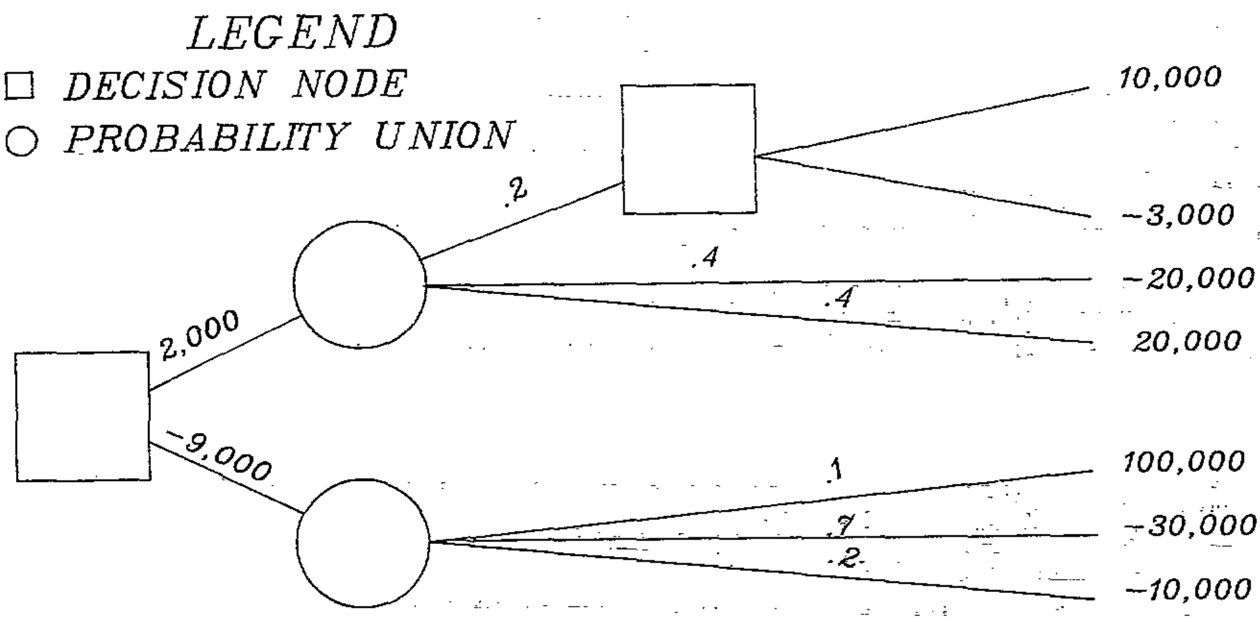

FIGURE 2. TYPICAL DECISION TREE

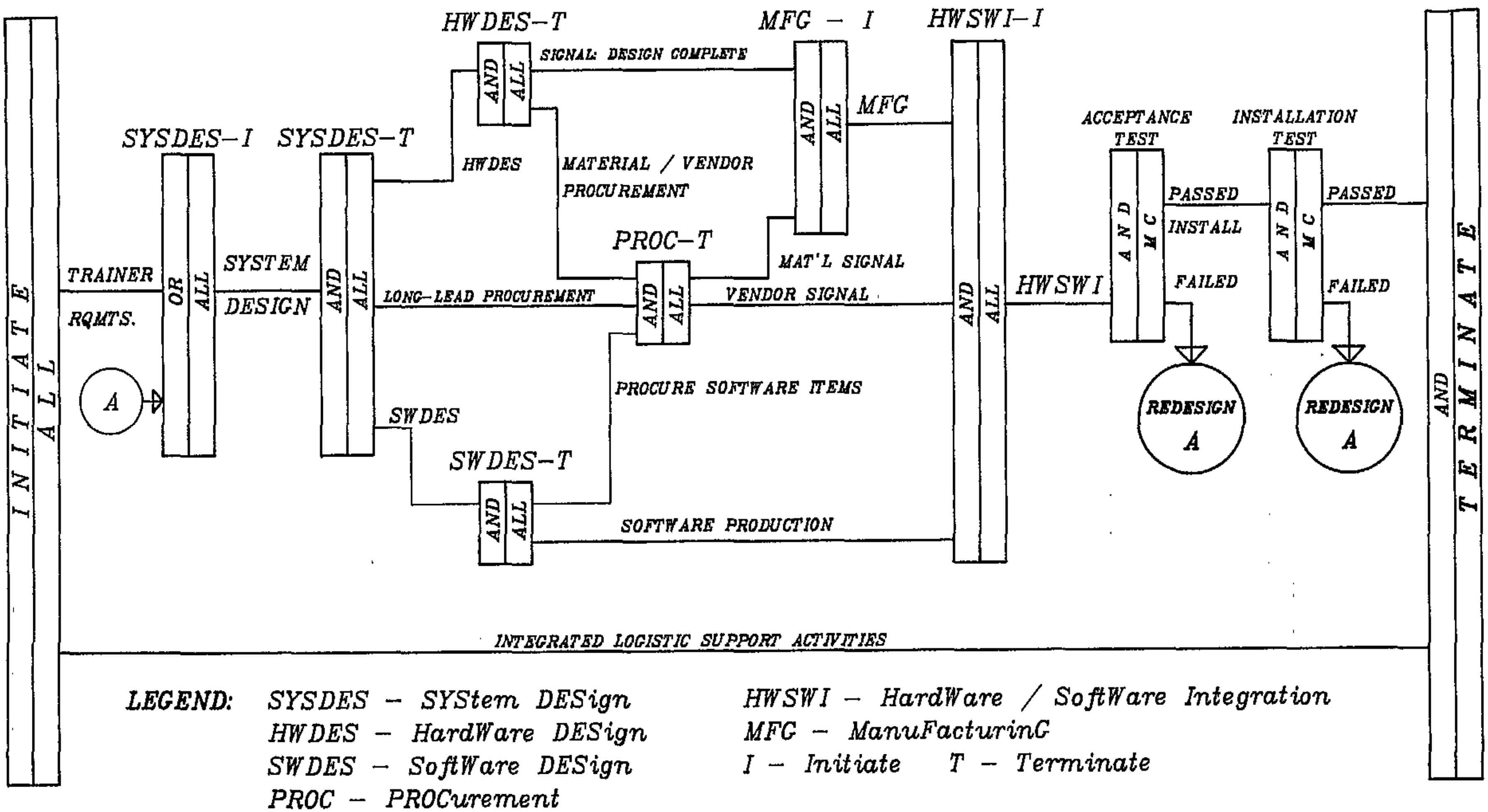

FIGURE 3. HIGH LEVEL VERT NETWORK

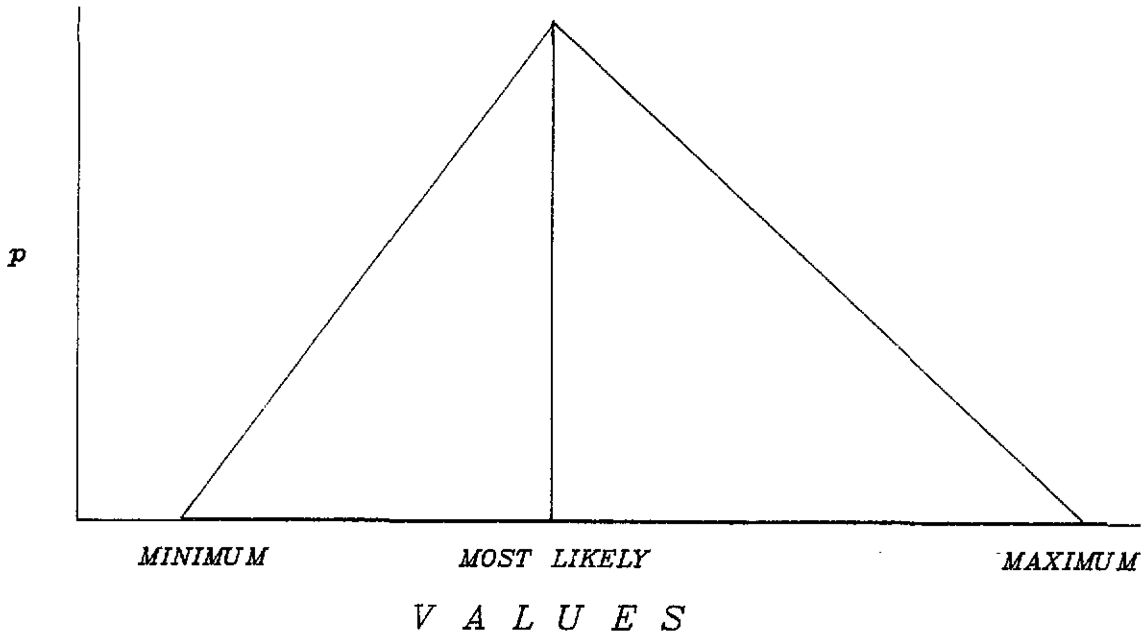

FIGURE 4. TRIANGULAR PROBABILITY DISTRIBUTION

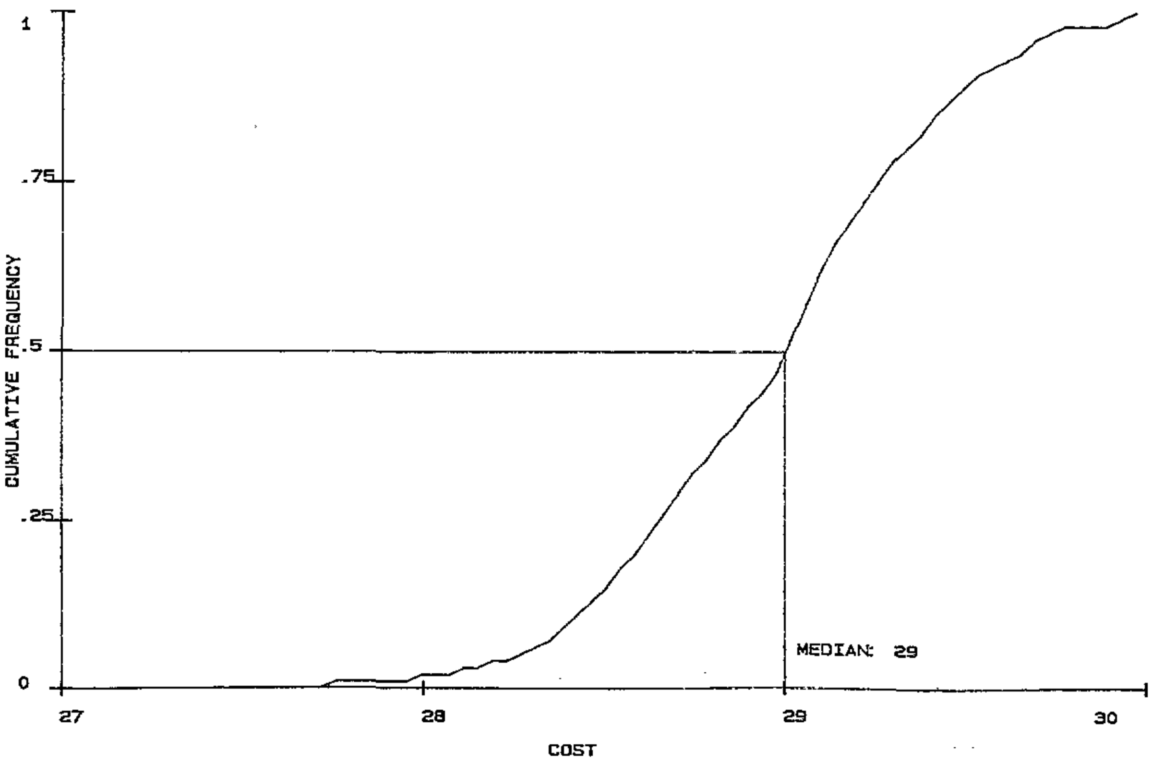

FIGURE 5. VERT COST DISTRIBUTION (DOLLARS x 10^6)

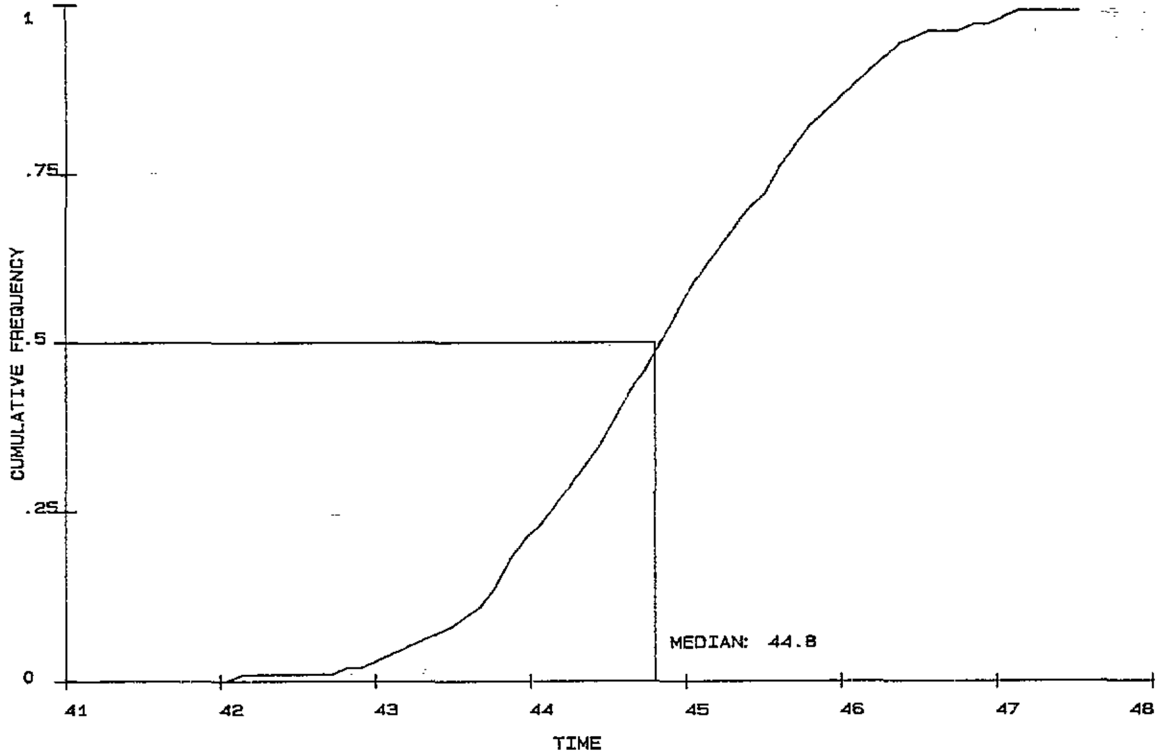

FIGURE 6. VERT TIME DISTRIBUTION (MONTHS)

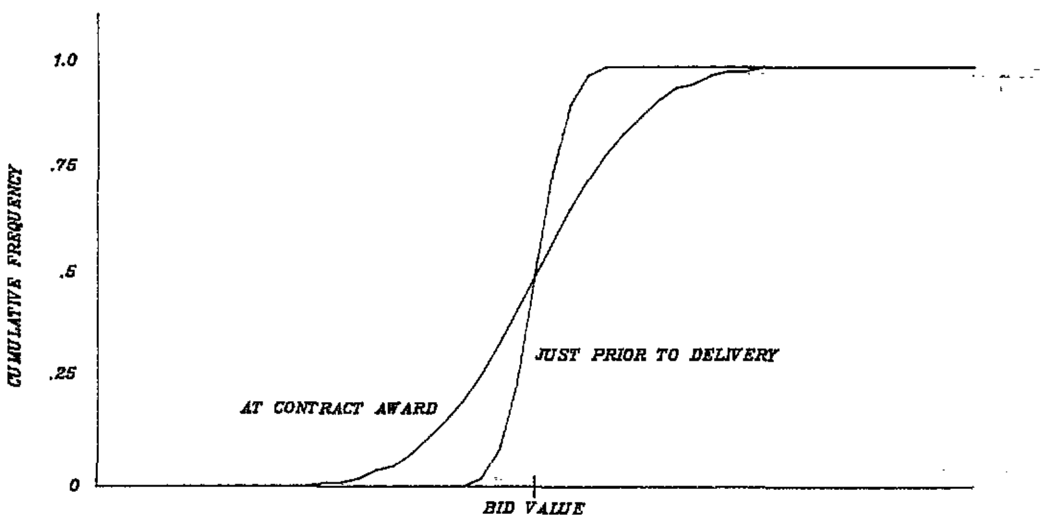

FIGURE 7. COST/TIME DISTRIBUTION CHANGE