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# What To Look for in Auditing Cost-Benefit Studies

*Because of increased emphasis on program evaluation and requirement analyses in GAO audits, the likelihood of an auditor having to review and evaluate a cost-effectiveness or cost-benefit study is greater. This article describes the important aspects of such studies and shows by examples the key attributes that mark a good study.*

A cost-benefit study examines one or more alternative ways (or systems) for performing a certain function and compares the cost and benefits (effectiveness) of the various alternatives. Such a study is required by the military as part of the justification for developing or procuring major weapons systems. Increasingly, it is also being made in the civil sector for examining or evaluating various actual or proposed programs.

If an auditor is involved in a program review in which it is necessary to evaluate the adequacy of the program's justification, very likely he will have to examine a cost-benefit study. In reviewing such a study, he should examine several basic features. These are discussed below, using for illustration a cost-benefit study I supervised while I was with a private company.

The study[1] examined Army systems for bulk delivery of fuel to the field army in the 1970 to 1985 time frame. It was a 2 year, 40-man-year effort finished in 1969. It examined the many different components, such as pipe, pump engines, storage tanks, filters, and valves, as well as various systems using different combinations of components.

## Key Items

Eight key items to look for in eval-

[1] "Bulk Petroleum Facilities & Systems (BPFS), 1970-1985," CORG-M-355, Combat Operations Research Group, Technical Operations, Inc., November 1969.

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uating cost-effectiveness studies follow.

1. *Objectives*: Are the objectives clearly stated and appropriate to the problem? Are there quantifiable measures identified which will adequately show the degree to which the various alternatives meet the objectives?

2. *Alternatives*: Are all the major, viable alternatives treated or are the alternatives to the recommended system merely straw men?

3. *Assumptions*: Are the major assumptions explicitly identified? Are they assuming away an important part of the problem?

4. *Future environment*: Is only one threat, scenario, or future environment specified and used, or are several alternative situations treated to address the uncertainty of the future?

5. *Key factors*: Are all the key factors identified and treated, or are some held fixed or ignored?

6. *Appropriate model*: Does the model used in the analysis treat all the key factors, handle the environment and alternatives adequately, and employ the proper measures of effectiveness and cost?

7. *Sensitivity analysis*: Are values of key factors varied to identify the sensitivity of the system choice to variables whose future values are particularly uncertain?

8. *Comparisons*: Are alternatives compared either holding cost constant and measuring effectiveness or holding effectiveness constant and measuring cost?

### Objectives

Matching the objectives of the effort with the real problem at hand is often very difficult because the problem is large and the study must be kept in reasonable bounds. This requires suboptimization, which we can hardly ever avoid, but carefully choosing and defining the study are necessary so that the objectives of the analyzed portions are compatible with the total objectives. Too often the problem is divided by jurisdictional considerations, which often causes poor system definition.

The petroleum study encountered a jurisdictional problem which affected the choice of objectives. The Army engineers are responsible for the bulk petroleum system (pipelines and storage tanks) and the supply corps is responsible for delivering the fuel from the pipehead to the ultimate consumer. The engineers and the supply corps were planning to study their distribution systems. It was suggested that the two studies be combined, because the advent of new materials (and consequently costs) showed a need for determining the best place to end the pipeline and switch to trucks. Efforts to combine the studies failed, however, and the engineer study proceeded with the fixed assumption that pipelines would end at the rear of the corps areas.

Objectives must also be stated clearly so that quantitative measures can be chosen that directly measure the ability of the alternatives to meet the objectives. The petroleum study was to design a system that could carry and store the required fuel quantity and quality and be constructed in a certain time with mini-



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mum cost. Selecting adequately sized components in sufficient numbers would meet the fuel goals; the use of enough men and equipment would meet the construction time requirement. Minimizing the cost is thus the principal objective. But how is it to be measured? We used a broad definition of cost as the use of scarce resources. In peacetime, dollars are a scarce resource to the Army, but in wartime trained manpower and shipping space are apt to be the scarce resources. Therefore, in comparing the systems, we measured the investment cost (dollars), the number of construction and operating personnel required, the weighted average training time, and the volume (for shipping).

## Alternatives

Too often the preferred new system and the current system will be the only alternatives presented in a study, and the current system may be quickly discarded because it cannot meet the requirements. More often alternatives are excluded because they belong to another organization. Army air defense studies often ignore the contribution of Air Force interceptors: The Strategic Air Command ignores Polaris in its bomber analyses. If this jurisdictional problem sounds familiar, it is. In GAO, an audit may examine only part of the problem and suggest certain improvements (alternatives) and may ignore other aspects of the problem and other alternatives because they fall in other divisions' jurisdictions.

The task force concept examines a problem from all aspects and treats all the viable alternatives. It has often been said that a good systems analysis/cost-benefit study will not only examine all the proper alternatives but may also develop a new best alternative.

BPFS tended to follow that course. The old World War II system using steel pipe was inadequate in meeting the fuel quality (cleanliness) standards demanded by the Air Force and was very expensive. On the other hand, there were so many new pipe materials, joining methods, types of pump engines, storage tanks, etc., that our problem was to sort through these to define some likely candidate systems.

## Assumptions

Any large study requires a multitude of assumptions. The most important ones apply to the other key areas discussed, such as the alternatives that are assumed. The threat characteristics, the details built into the model, and the system requirements all contain important assumptions. In the BPFS study, the Army required that pipe sections be capable of being handled by four men, two at each end. There was some difference of opinion about how much a man can lift in construction operations; we assumed 70 pounds per man.

## Future Environment

Any future environment is an as-



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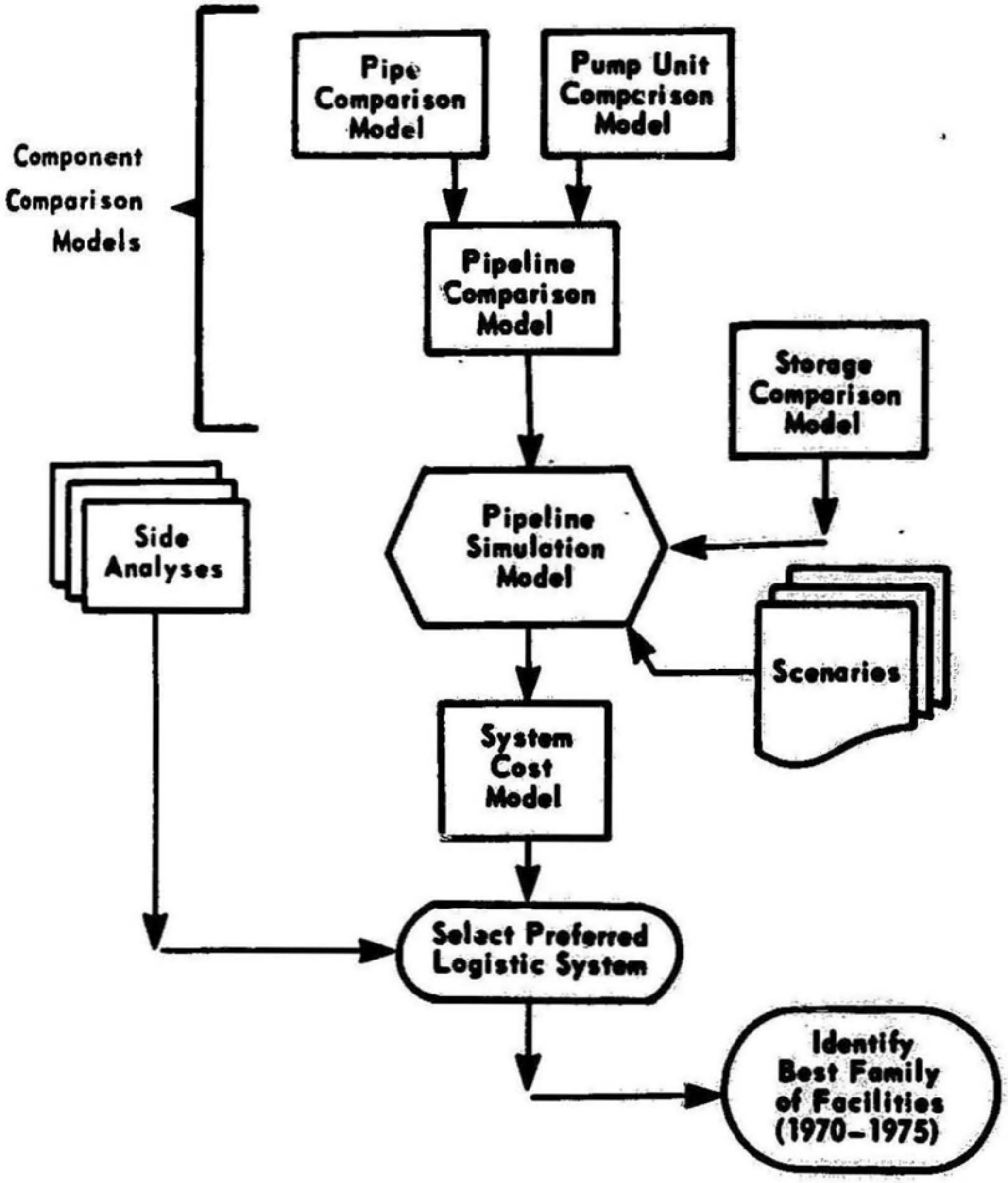
Figure 1

COST – EFFECTIVENESS ANALYTICAL PROCEDURES




sumption, but hopefully it is based on current data and a rational way to extrapolate into the future. The prime point to remember is that the future is uncertain; the postulated environment has very little chance of occurring. Thus it is important to consider a variety of possible threats. Beware the study that treats only one threat (environment); it may be chosen to show off the preferred system to the best advantage. It is better to design a sys-



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tem that will act reasonably well in most situations than to optimize the design for one situation and have it flounder or fail in other likely, but not examined, situations.

The BPFS study avoided most of the problem, since the Army supplied four scenarios. Two scenarios were dropped, however, for logical reasons: one was in an area with an indigenous oil supply and the other required a simple system with modest fuel requirements which were very similar to part of the system of the third scenario.

The third scenario required an extensive pipeline network with wide variations in fuel flow and storage requirements in various locations. This scenario was used to evaluate the candidate systems. The fourth scenario was used, as a check, to compare the best system from the third scenario against the current system to determine the cost advantage.

In domestic studies, the principle of examining a spectrum of future situations still holds. Will consumer acceptance of certain types of housing change and in what way? What if traffic forecasts, inflation rates, life styles, and distribution methods are different from those postulated? The more likely they are to change, the more important it is to evaluate the alternatives in several different environments.

## Key Factors

A key factor is any parameter of a system or the environment that has an important effect on one of the measures of cost or effectiveness. It is difficult to know in advance what the key factors are, but the study should identify them, after determining their effect by treating them either in the main model or in a side analysis.

The BPFS has a large number of key factors—the pipe's material, length, weight, operating pressure, and friction coefficient. When the key factors of pumping stations and storage tanks are considered, the number of combinations becomes astronomical. All the key factors were covered at least to some degree. The methods used are discussed below.

## Appropriate Model

Seldom does a single model handle all the key factors, alternatives, and measures of cost and benefit or effectiveness. Usually there is at least a cost model that is separate from the benefit or effectiveness model. The large number of parameters in BPFS forced us to use a whole family of models and analyses, as shown in figure 1.

Even this chart is over simplified, because it deals only with the "logistic" system and the "permanent" pipeline system. We also had to examine components of an "assault" system, a temporary "over the beach" system designed for rapid installation and operation until the logistic system was constructed.

The initial phase of the analysis consisted of analyzing alternative pipe and joining methods by using the pipe comparison model. Various grades of steel, aluminum, and plastic were considered, and from these the best candidates were identified. A similar analysis was made for pumps driven by gasoline, diesel, and turbine engines. The best candidates were identified by using the pump comparison model. The results of these separate analyses were used as inputs to the pipeline comparison model. Using this model, each pipe candidate was examined for a range of pressures, diameters, and throughput requirements using the least-cost pump required. From this model, a set of cost and performance curves (fig. 2) was developed for each of the primary material categories.

The installation of a number of storage tanks in a tank-farm complex was considered by using the storage tank comparison model. The number of each type of storage tank needed to satisfy the storage requirements was determined by considering the capacity of each tank. The top tank candidates were further considered in the simulation, along with the best pipeline candidates.

The selected pipeline and storage tank candidates, the scenario requirements, and ancillary data on system installation provided the inputs to the pipeline simulation model. On the basis of the scenario requirements for pipeline construction and the layout of the pipeline system for various ports of origins and delivery point destinations, the simulation model was run to determine the length of time required to construct each candidate system. Other runs were made in which the manpower and equipment levels were adjusted to achieve the scenario construction-time goals (i.e., obtain equally effective systems). The system cost model was then used to calculate the significance of these differences and to show which system was economically preferable.

Analyses of the system cost model outputs and the assault system provided the basis for selecting the best family of facilities for the engineers to construct and maintain.

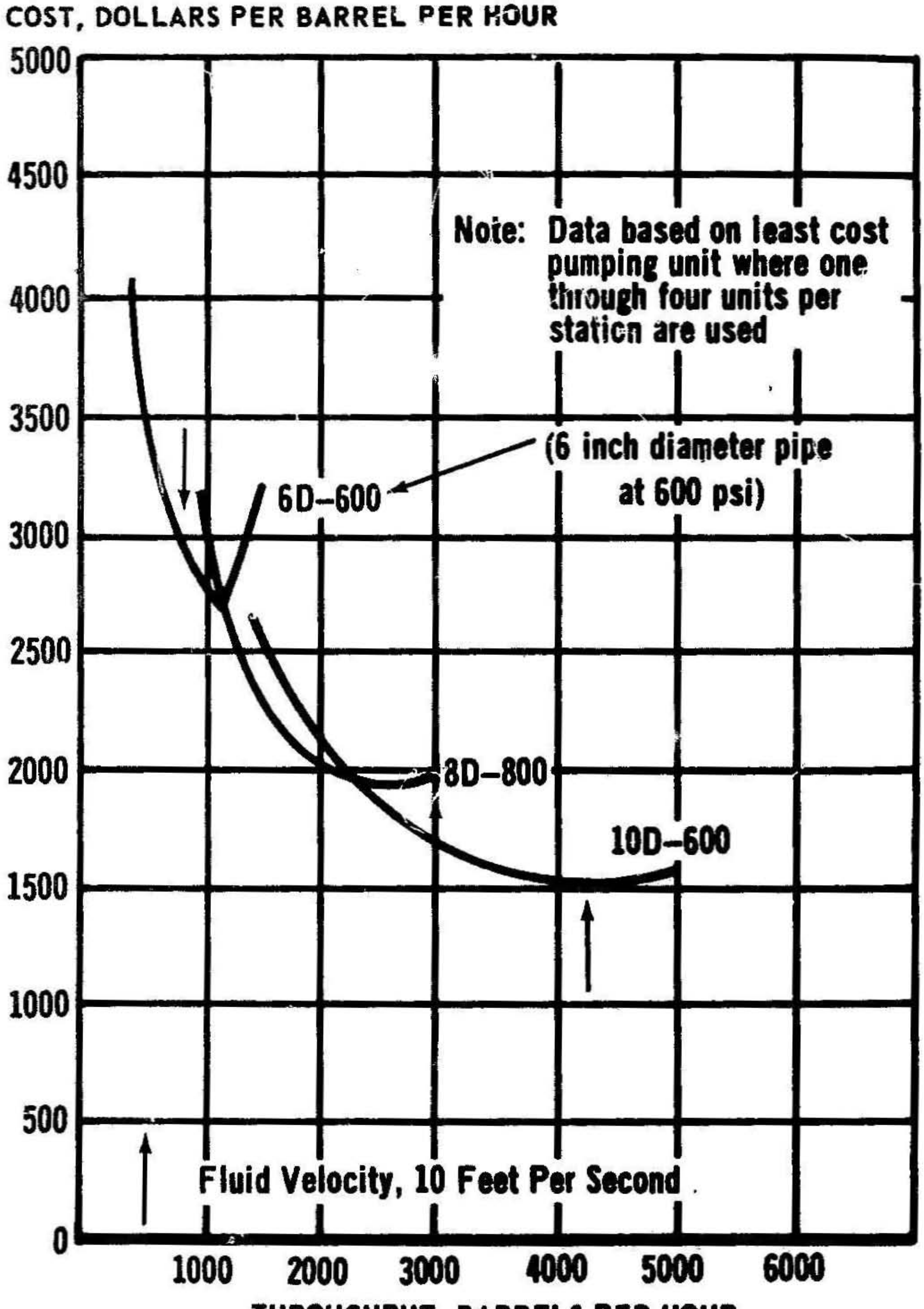
Along with the main study effort, a number of side analyses were made on pipe section weight and length, fluid velocities, reliability and maintainability, automated trunkline pumping stations, fuel quality, operating hours, and vulnerability. The results were used as constraints or operating criteria in the pipeline system analysis. For instance, automating the pumping stations was found to be too expensive. Only manned stations were used in the alternative systems.

## Sensitivity Analyses

A sensitivity analysis is one wherein a potential key factor, or set of factors, is varied to determine the effect on the measures of cost or effectiveness. It may be done running the main model, submodels, or side analyses. For instance, in BPFS, the pipe diameter, operating pressure, type material, and throughput requirement all interact to affect the cost, particularly since the spacing (and thus cost) of the pumping stations is affected. Figure 2 shows the interrelationship for alumi-

Figure 2

ENVELOPE FOR THE ALUMINUM FAMILY PIPELINE SYSTEM FOR VARIOUS THROUGHPUTS



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num pipe. Only the lowest cost curve for each diameter is shown; the curves of other pressures are higher. This represents a double variable plot in which pipe diameter and pressure are traded off. There is an optimum operating pressure for a given diameter and an optimum diameter for a given flow.

## Comparisons

If both cost and effectiveness vary among alternatives, it is more difficult to make a choice. Is the extra performance worth the extra cost? The analysis should be designed, if at all possible, to hold either cost or effectiveness constant. A one-to-one comparison (e.g., one new ship v. one current ship) is misleading because the new ship is better but also is more costly. A comparison of two equal-cost ship forces (new design v. old) has more meaning. For BPFS, effectiveness was held constant by requiring that each system (considered in the simulation model) carry the required throughput and be constructed in the required amount of time. Thus the lowest cost system is preferred.

The men and equipment required to meet the specified construction time were input to the cost model to determine the cost in dollars, the number of construction personnel and operating personnel, the average training time, and the volume. The plastic pipe system required the fewest men and the least equipment but dollar costs were considerably higher. Aluminum was the recommended material.

## Concluding Remarks

We have identified eight key aspects of cost effectiveness and have illustrated them by discussing a study of a rather complex hardware system. These key aspects, and the principles of application, are of general validity, however, whether the subject is a weapon system, software package, social program, or organization. If all questions asked in the key items section can be answered in a positive sense for a given study, it is a good one. If one or two aspects are negative, it does not necessarily mean the study is poor; it may be only incomplete in a small area or inadequately documented. The importance of the deficiency has to be assessed. A beautifully written and fully documented study may have all the key attributes, except it fails to consider one prime alternative.

One can always find something to object to in a study. The question to ask yourself is "Would corrections to these errors or omissions significantly change the results of the study or the recommendations it supports?"

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