# Functional Economic Analysis of Purchasing at MITRE

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## Abstract

Functional economic analysis is a modeling approach that provides a uniform basis for analysis and comparison of alternative investment and management practices. The approach takes into account the costs, benefits, and risks associated with new ways of doing business and managing organizations. The entire purchasing process from initial request to final delivery, payment and accounting is being re engineered at MITRE. A complete resourced process flow chart was developed for both the present and proposed systems. An "i think" system dynamics model of both the present and proposed process was developed. The model projects the seasonal workload over the proposed system lifetime. Dynamic normal, overtime, and temporary staffing requirements were calculated. The new system reduced total requisition delay by a factor of ten. This will greatly reduce expediting actions and costs. Multiple data bases and computer systems along the process were combined into a single system. This greatly reduces data entry and reconciliation effort. The new process groups purchase requisitions by type that provides the opportunity for bulk discounts. All these will result in 37 million dollars of savings over a ten year system life.

# Functional Economic Analysis of Purchasing at MITRE

## Objective

The purchasing system at MITRE spans several departments. Over the years manua processes have been automated independently by different departments. These systems are o different computers and do not directly communicate. Purchasing data must be keyed in on eac system. This greatly increases cost and delay. Finally all the separate data bases must b reconciled to meet Department of Defense auditing requirements. To reduce both purchasing cos and delay, MITRE included purchasing in its financial re-engineering process.

### Functional economic analysis procedure

A functional economic analysis starts with the definition of what is to be included in the systen studied. This should include all sub-systems that are under control of the organization, and have significant impact on performance. Then the workload measure is defined. In our case this wa completed purchase requisitions. A resourced process flow chart is then developed for th existing process, with all costs, times, and delays related to the workload measure. Flow chartin the existing process often reveals potential improvements. Examples include elimination of non value added activities such as redundant activities, storage and transport activities, inspectio activities, and expediting activities. If Activity Based Costing ABC is employed in th organization, determining the baseline and alternative activity costs is considerably simplified The resourced process flow charts form the basis for model development. A model is required t project performance and costs over the system lifetime. Since the alternative process is new, model must be developed to project its cost and performance. In our case we developed a systen dynamics model in "i think". The simulation model is executed over the system lifetime. comparison is made of performance and cost of the baseline and proposed alternatives. There i considerable uncertainty in making future cost and performance projections. There is als uncertainty in estimates of the proposed alternative process, since in most cases it is not i existence and available for field measurement. Given limited study resources, even the baselin process parameters are calculated from limited sample data and thus are uncertain. In functiona economic analysis the component uncertainties are all documented and the resulting uncertaint in final measure of effectiveness is calculated. We used the analytic uncertainty modelin technique documented in another conference paper to do this. In our case the DEMOS packag was used to perform sensitivity and uncertainty analysis on the purchasing model. The analyti uncertainty analysis calculations were included in DEMOS library subroutines. Our measure o effectiveness was the discounted present value distribution of savings. Management decides if th uncertainty in the final distribution of savings is acceptable for a decision. If there is too muc uncertainty, then more detailed parametric data is required. For greater accuracy the proces might be dis-aggregated to a finer level of detail and a new model developed. Of course both thes actions take time and money and must thus be evaluated relative to the lower uncertainty in fin measure of effectiveness that they may provide.

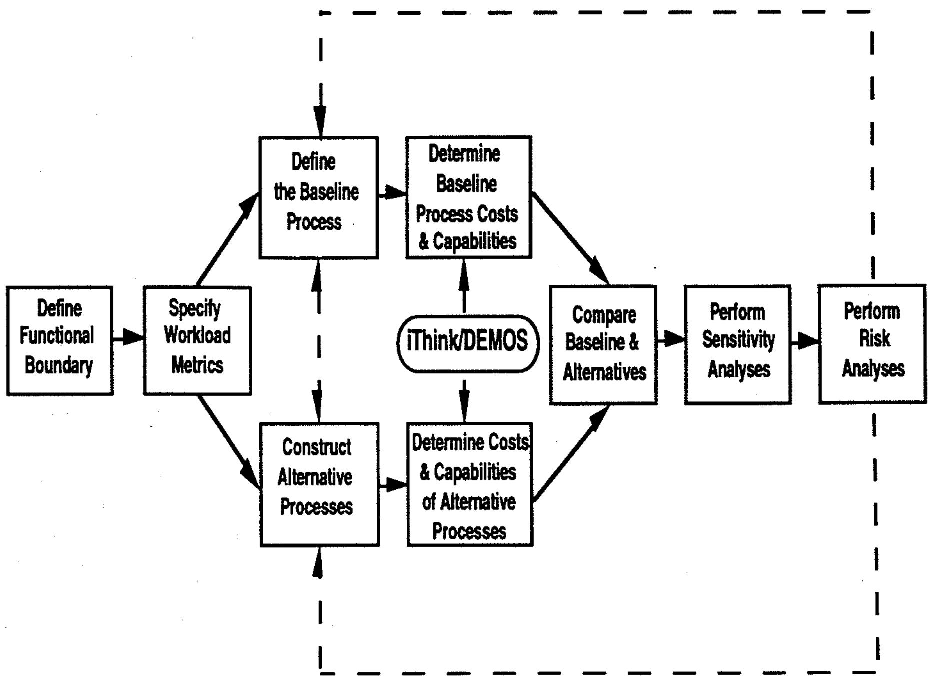


Figure 1. Functional Economic Analysis Procedure

**Present and proposed purchasing procedure**

Figure 2 gives the staff time required per purchase requisition activity and activity delay. Data was obtained from time-stamped purchase requisition forms and interviews of purchasing personnel. Estimates were calibrated based on past staffing and actual numbers of purchase requisitions processed or rejected. Note delay is far longer than activity staff minutes and includes mail time, time to contact people for approvals, wait time for typing. Both delay and staff time are modeled for both the present baseline and proposed alternative system. The purchase requisition (PR) originates at the department level. It is typed up based on a purchasers submitted form. In the new system the purchaser directly enters the information from his desktop computer connected to the company local area network. The input program does considerable checking as the form is being filled out to insure each entry is valid. In the old system this checking was done later as the process proceeded. This greatly increased delay because many questions required contact with the purchaser for an answer (telephone tag, at meetings etc.). The old system had many rejected and reworked PRs. This rework was included in the table staff minutes and delay numbers. Given that the requisition is on line from the start and all approval authorities in department and division also are on the local area network, a new approval procedure can be implemented. The department and division approval authorities are sequentially notified as soon as the PR is input. If no action is taken in a specified time period the PR is routed to a designated alternate. This considerably reduces approval delays. In the old system PR data was typed in to several independent computer systems in division, configuration management, property, purchasing, budgeting, accounting and receiving. These many data bases required considerable staff time for redundant data input. In addition because of normal human input errors, effort was required to reconcile the data base differences and prepare files for potential DOD audits. Multiple purchase orders can be combined into a single purchase order to a vendor. Similarly a single purchase requisition can have associated purchase orders to multiple vendors. Manually keeping track of the purchase requisition number to purchase order number led to considerable reconciliation effort. In the new system with its single common on line data base this linking is automatic. With an on line data base the purchaser can find the status of his order at any time without disturbing personnel performing purchasing activities. Given the large variable delay of the baseline system, considerable purchasing staff time was taken in finding and reporting status to frustrated purchasers. Configuration management is required for computer and peripheral purchases. These make up 40% of purchase requisitions. The new system has a menu of configured systems the purchaser can select. If one of these configurations is selected no configuration management activity is required. In the new system only 5% of purchase requisitions should be non-standard. A property number is automatically assigned in the new system so this step was deleted. In the baseline system a separate budget approval was required by accounting. Given the PR delays encountered, a call back to the division administrator was made to see if there was still money in the budget. With the greater speed of the new system this was not deemed necessary. In the old system there was no official direct link between accounting and purchasing. Accounting could be withholding vendor payment while purchasing was issuing new purchase orders to that vendor. Similarly vendor performance records were not kept. The new common data base system links all parties and keeps vendor performance data. Purchases can now be guided to vendors with superior performance. With a more limited set of preferred vendors, standard agreements and forms become a possibility. Electronic data interchange and FAX links can be used rather than the mail. This considerably reduces the effort and delay in obtaining and evaluating bids. With a preferred group of graded vendors, and a lower delay time, the effort required for vendor expediting should also be reduced. In the process of gathering baseline process data the purchasing manager mentioned that she could get significant discounts if bulk orders were made. The new system supports this with a draft PR. Purchasers project their next year needs with this device. The projected unapproved PRs are entered with a draft categorization. These are categorized and summed and used as the basis for bulk purchase agreements. The 15 to 20% savings from this feature alone more than compensates for all the new system cost. A side benefit is the future cost visibility given to budgeting personnel. Different incentives are being considered to encourage use of draft PRs.

| | Staff Minutes/Activity | | Days Activity Delay | |
|---|---|---|---|---|
| **Component** | **Baseline** | **Alternative** | **Baseline** | **Alternative** |
| **Department** | 18.07 | 18.07 | 14.90 | 0.50 |
| **Division** | 15.31 | 15.31 | 2.93 | 0.50 |
| **Config. Mangt.** | 114.00 | 7.05 | 1.40 | 0.10 |
| **Property** | 14.08 | 0.00 | 1.76 | 0.00 |
| **Assign Buyer** | 15.13 | 1.90 | 0.99 | 0.24 |
| **Budget Approve** | 15.00 | 0.00 | 1.00 | 0.00 |
| **Obtain Bids** | 336.00 | 252.00 | 0.80 | 0.40 |
| **Evaluate Bids** | 145.20 | 72.60 | 4.55 | 2.28 |
| **Purchase Order** | 18.18 | 9.09 | 0.62 | 0.31 |
| **Expedite** | 63.50 | 25.90 | 1.00 | 0.00 |
| **Invoice** | 12.00 | 1.80 | 0.60 | 0.02 |
| **Reconcile** | 15.00 | 0.00 | 0.50 | 0.00 |
| **Audit** | 30.00 | 15.00 | 3.00 | 0.13 |
| **Total** | 811.47 | 418.72 | 34.05 | 4.48 |

Figure 2 Purchasing Activity Staff Minutes and Delay

**The MITRE purchasing model**

Figure 3 is an extract of some of the key sectors in the purchasing model. In the upper lef seasonal workload is projected into the future for both present and alternative systems. Peopl tend to spend their budget as soon as they get it or before they loose it at the end of the fisca year. The activity times also change. For example more checking must be done at the end o the fiscal year to see if there is sufficient budget funds available. To handle the increase workload overtime is authorized and temporary staff are hired. The greater staff pressure an new employees lead to a higher error rate that must be corrected after the peak loading Personnel that normally reconcile and audit completed purchasing paperwork are reallocated t handle the increased workload. Thus backlog in auditing increases. This is captured in the audi backlog sector. Five Years of historical MITRE archive purchase requisition documents were used to initialize the workload projection sector.

The staffing actions sector captures the decision rules used to approve overtime, hire temporary personnel, and hire permanent personnel. It also allocates these personnel to departments based on the data presented in figure 2. Increasing staff lowers staff utilization and reduces process queuing delays at the expense of greater staff cost. This is captured in the delay calculation sector. This sector employs analytic queuing described in another conference paper. Purchasing system performance is measured in terms of overall purchasing delay, delay variation, audit backlog, purchasing error rates, and operations cost. The model provides for staffing cost versus purchase requisition delay trade-offs for both the present and alternative systems. Note that there are separate staffing, delay calculation, audit backlog, requisition and vendor expediting sectors for baseline and alternative processes. Only the baseline process is shown in figure 3. The requisition and vendor expediting sector calculates effort required as a function of process delay.

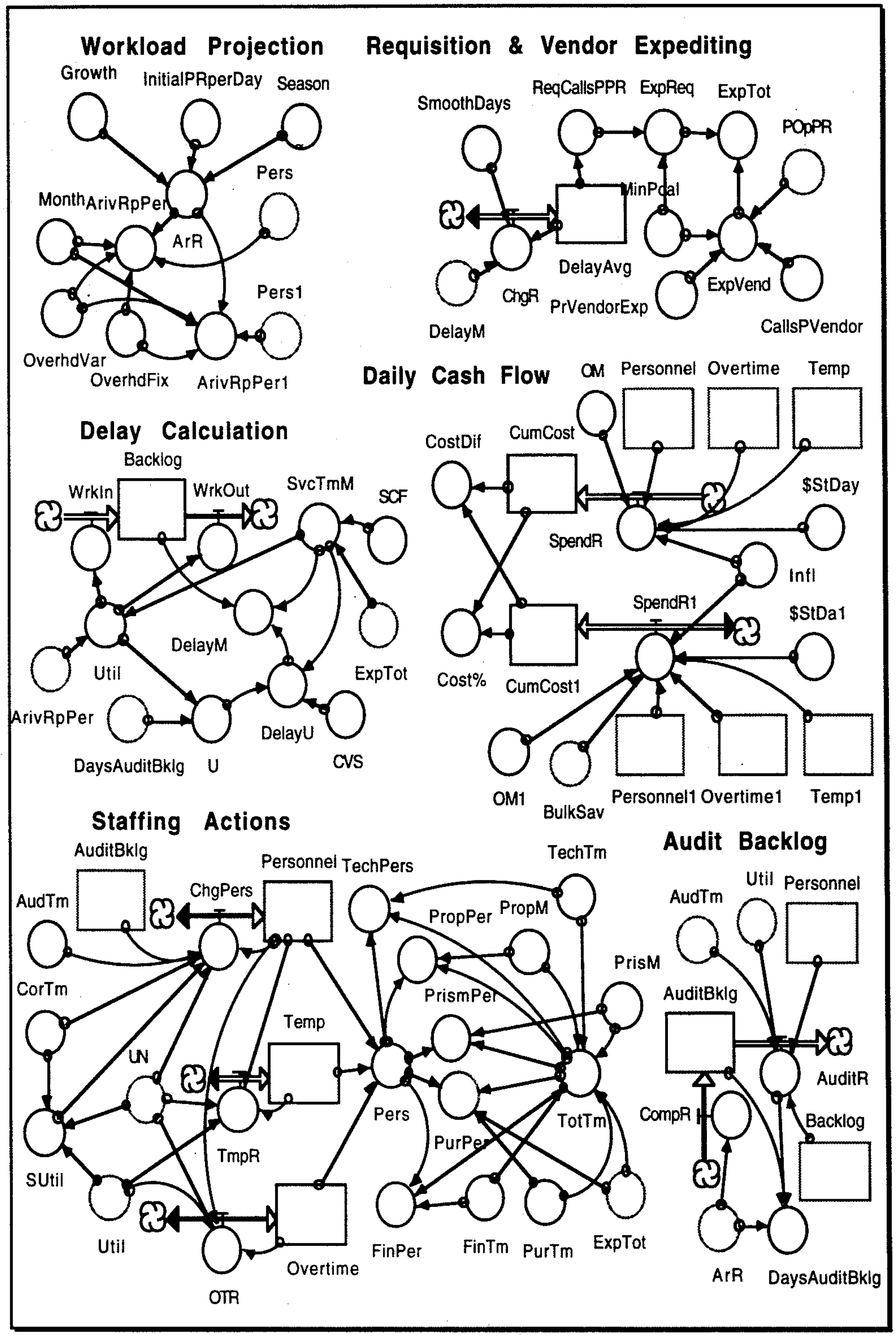


Figure 3. Key Purchasing Model Sectors

Note that the there is considerable interaction between purchasing activities. For example, hiring staff reduces purchasing delay which reduces the staff required for requisition expediting.

The daily cash flow sector compares baseline and alternative costs over the system lifetime. Discounted present value of the cash flows is done in another sector not shown in figure 3. Note the significant bulk savings obtainable with the alternative system are included in this sector.

**Sensitivity and uncertainty analysis**

Figure 4 presents the DEMOS purchasing sensitivity analysis model. The baseline system is shown on the left and the alternative system is on the right. Delay and audit performance is presented in sub-models accessed through clicking on the lower left and lower right bold buttons. Rounded rectangles contain data inputs or relationship equations. Square rectangles contain lists of parameter values for sensitivity analysis. Key process parameters are monthly operations and maintenance cost (OM), staff utilization (Util), PR process time, overhead proportion (Overhead), dollars per staff month ($Staff), initial PRs per month (PR/mo) and initial monthly PR dollar value (PR$). Other inputs include the new system investment cost (Invest$) and the discount rate (Discount) and the system life (simulation time). Sensitivity analysis parameters include annual growth rate in number of PRs (PR Growth), annual growth rate in PR dollar value (PR$Growth), proportion of purchase requisitions with bulk saving potential (Pr Bulk) and the bulk saving percent discount (Bulk Save). Figure 5 gives a sample of the sensitivity analysis model output of discounted present value of savings when all alternative investment operations and maintenance costs are included. It assumes 15% bulk discount on 40% of the purchase requisitions. Even with no growth in purchase requisitions and a 5% reduction in the number of PRs there are $12.53 million savings over 5 years assuming a 7% annual discount rate. At a 5% annual growth in PR value, and a 15% increase in the number of PRs, $36.85 million savings are achieved over 10 years.

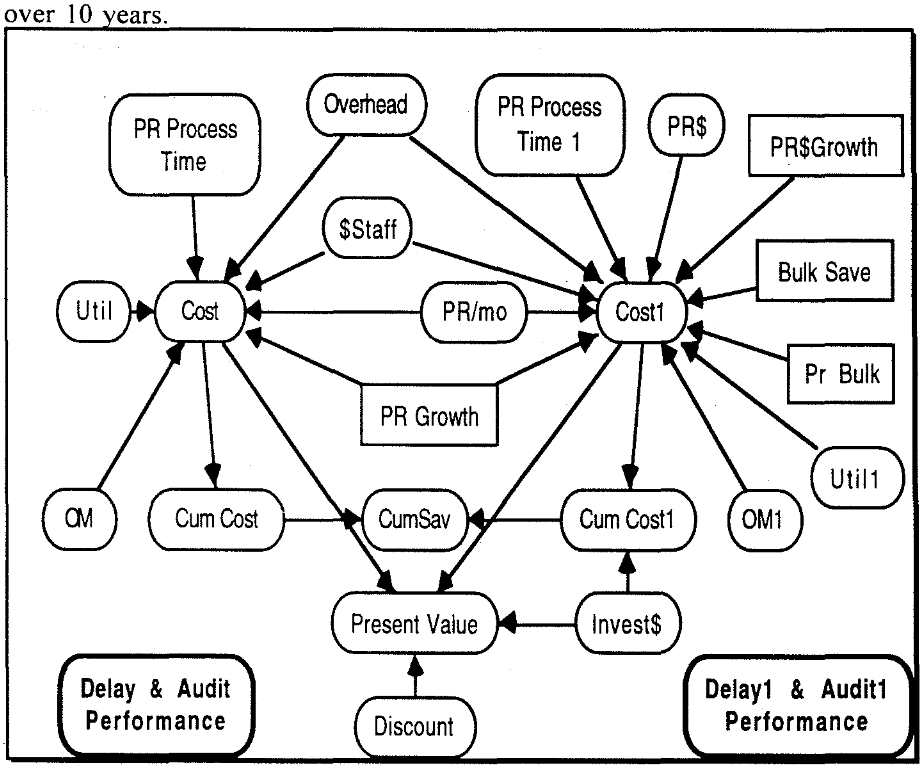


Figure 4. DEMOS Sensitivity Analysis Model

| System Lifetime Years | Annual PR $ Growth | Discount Rate 0% | | | Discount Rate 7% | | |
|---|---|---|---|---|---|---|---|
| | | Annual Growth In Number Of PRs | | | | | |
| | | -5% | 5% | 15% | -5% | 5% | 15% |
| 5 | 0% | 15.70 | 16.59 | 17.83 | 12.53 | 13.24 | 14.21 |
| | 5% | 17.95 | 18.84 | 20.08 | 14.31 | 15.02 | 15.99 |
| 10 | 0% | 35.16 | 38.74 | 45.86 | 24.09 | 26.37 | 30.71 |
| | 5% | 44.91 | 48.49 | 55.61 | 30.23 | 32.50 | 36.85 |

Figure 5. Sample Present Value Of Savings In Million Dollars

Figure 6 shows the impact of bulk savings. It is based on a 5% annual growth rate in PR dollar value and a 15% annual increase in the number of PRs. Even at no bulk savings (0% bulk purchases) there are half a million dollars savings over a 5 year system life and $7.33 million savings over a 10 year system life. The chart shows that percent bulk purchases and the proportion of PRs that have bulk purchase potential are two of the most significant model parameters.

| System Life | % Bulk Savings | Percent Bulk Purchases 0% | 30% | 40% | 50% |
|---|---|---|---|---|---|
| 5 | 10% | 0.50 | 8.25 | 10.83 | 13.40 |
| | 15% | 0.50 | 12.12 | 15.99 | 19.87 |
| | 20% | 0.50 | 15.99 | 21.16 | 26.32 |
| 10 | 10% | 7.33 | 22.09 | 27.01 | 31.93 |
| | 15% | 7.33 | 29.47 | 36.85 | 44.23 |
| | 20% | 7.33 | 36.85 | 46.69 | 56.53 |

Figure 6. Sample Bulk Savings in Million Dollars

A similar DEMOS model to the one shown in figure 4 was developed for uncertainty analysis. Here the input parameters are given beta uncertainty distributions based on minimum, maximum, mean, and standard deviation estimates. The model calculates the discounted present value of savings which is presented in figure 8. In our case the discounted (7% annual rate) present value of savings ranged between $14.59 million and $20.22 million over a five year system life with a mean savings of $16.85 million. This case was for a 5% annual growth in PR dollar value and a 15% annual growth in the number of PRs. It included a 15% bulk purchase discount on 40% of the PRs. The mean discounted value of $16.85 million differs from the mean value without uncertainty analysis of $15.99 due to the skew of the input parameter uncertainty distributions and non-linearity of model factor relationships. The figure lists all of the uncertain parameters in the model. Uncertainty is specified with estimates of minimum, maximum, mean, and standard deviation statistics. A beta distribution is fit to each of the uncertain parameters. It is also fit to the resulting savings measure of effectiveness. The fit beta a and b parameters are given in the figure 7. The analytic uncertainty modeling technique employed is described in another conference paper. The beta density function is given by:

Probability density $= C\ X^{(a-1)}\ (1-X)^{(b-1)}$ where:

X = (value - minimum) / (maximum - minimum)
C = normalizing coefficient so the integral of the density between minimum value and maximum value is one

Figure 8 plots the discounted present value of savings cumulative distribution function. In this case it is easy to decide to go with the alternative system. In general however this might not be the case. Alternative savings distributions can overlap, or there can be a non-zero probability of loss.

| Variable | Minimum | Mean | Maximum | Std.Dev. | Variance | a | b |
|---|---|---|---|---|---|---|---|
| Base Staff Days/PR | 0.4900 | 0.5490 | 0.6050 | 0.022361 | 5.00E-04 | 2.8722 | 2.7309 |
| Alt.Staff Days/PR | 0.2500 | 0.2830 | 0.3200 | 0.010954 | 1.20E-04 | 4.3254 | 4.8469 |
| Base OM $/Mo | 28,000 | 31,490 | 37,000 | 1,000 | 1.00E+06 | 7.0692 | 11.1610 |
| Alt.OM $/Mo | 16,650 | 18,500 | 22,200 | 707 | 500000 | 4.2300 | 8.4600 |
| PR Growth %/Yr | 5 | 15 | 20 | 0.7746 | 0.6000 | 3.9626 | 1.9814 |
| PR $ Growth %/Yr | 0 | 5 | 10 | 0.4899 | 0.2400 | 3.8403 | 3.8402 |
| % Bulk PRs | 1 | 40 | 60 | 1 | 1 | 4.4946 | 2.3051 |
| % Bulk Savings | 5 | 15 | 25 | 10.95 | 120.00 | 4.5000 | 4.5000 |
| Investment $M | 3.00 | 4.44 | 7.00 | 0.84 | 0.70 | 1.5359 | 2.7304 |
| Cum. Savings $M | 18.95 | 21.15 | 24.49 | 1.18 | 1.39 | 1.6970 | 2.580 |
| Present Value $M | 14.59 | 16.85 | 20.22 | 1.08 | 1.17 | 2.1939 | 3.2816 |

Figure 7. Uncertainty Analysis Inputs And Results

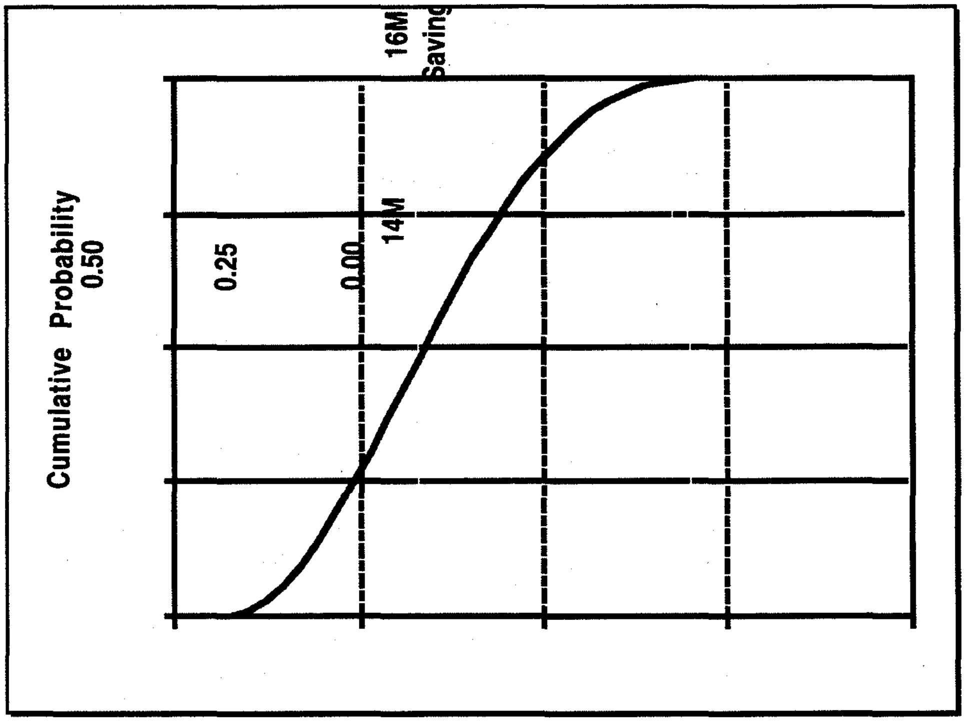


Figure 8. Discounted Present Value Distribution Of Savings In Million Dollars

## Conclusions

We have summarized a full functional economic analysis along with sensitivity and uncertainty analysis. Both analytic queuing and analytic uncertainty analysis techniques described in other conference papers were employed. The alternative system suggested is presently being implemented at MITRE. Staff are looking forward to speedy execution of purchase orders.

## References

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