Putting a Price on the Head of Non-Dollar Variables

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ABSTRACT

This paper discusses the availability and application of user-friendly software that helps the user understand the imponderables of his project. The discussion deals with construction issues and poses examples of cost estimating as seen from an evolved, higher cost estimating perspective. This perspective can be obtained through the use of new, easy to use Monte Carlo simulation techniques, which should find usefulness in the VE arena as a tool for learning more about cost exposure and probable limits. Further, applications of these software tools are not limited to cost estimating. Most of the packages are suitable for applications on a broad range of subjects, totally unrelated to costing construction.

INTRODUCTION

It is the routine practice in cost estimating to see the estimate as a static document. The goal of the estimator is to go through his processes and finally draw a box around the bottom line figure and declare the bottom line represents his professional opinion of the project cost. Owners typically cast this dollar figure in bronze and await the outcome to see how good the estimator is at his profession. The owner may well be burned by the actualities in the marketplace.

Also, routinely, the only thing that stands between the estimator and a great deal of pain is the validity of the contingency percentage he has tacked on to the estimate. It is this contingency that addresses the imponderables which might affect the cost outcome. After all, it is sometimes not as important what happens when the bids are opened, as what happens along the course to project delivery.

This article illustrates one approach to addressing these unknowns.

THE UNKNOWNS

The unknowns are those non-cost variables that drive project managers and owners to distraction. They include:

- Changes in tax laws
- Crisis in energy availability and costs
- War
- Peace
- Labor shortages which can occur due to:
  - Strikes
  - High work volumes in select trades
  - Shortage of trades in specific geographic areas
  - Inability to pay local labor rates
- Material shortages and delivery delays
- Changing environmental regulations
- Weather
- Design problems

These unknowns beg the following questions:

How can one realistically expect to cover such variables with a contingency percentage?

How much contingency is enough?

How do we appear when we take an overly cautious position—requiring clients to commit unnecessary funds to cover a guess?

Is there not a better way?

There is a better approach.

BACK TO THE ESTIMATING PROCESS

One of the few things in a construction estimate that is fairly reliable, if done with reasonable care, is the quantity take-off. The most apparent source of error in estimates is the unit cost applied to each line item. The unit cost must represent the cost picture at some time in the future. Yet, unit costs are typically derived from an historic database. The estimator hopes that two things will work to his advantage:

1. Compensating variations (errors) in unit costs over a large number of line items
2. The previously mentioned catch-all contingency factor—used in this instance to fill the void between what has happened on jobs in the past and what will happen in the future on this specific project.

SOMETHING IS MISSING

When the typical estimate is being prepared, a debate usually ensues over the selection of unit costs for the "critical" elements. The critical elements vary from job to job, depending on the project components most dominant in the cost estimate. In the example of reinforced concrete, cast-in-place, one estimator might venture that the cost will be based on $225 per cubic yard. His associate might state that it will be $275 per cubic yard. The choice between these two unit costs can be very important to the owner if there are 100,000 cubic yards necessary on the job. The choice usually comes down to a compromise between the candidate unit costs. In this example, the range of possibilities is seen as being somewhere between $225 and $275 per cubic yard. This very important decision may be based more on person's seniority than on adequate knowledge of events likely to occur in the near future construction marketplace.

To ameliorate concern over this limited approach, a recent cost risk analysis was performed by the author during a VE study on a wastewater treatment plant. This was done on an informal basis, to expand the cost information available to the project design engineer. It was also done in accord with a viable VE goal, which is to help avoid future costs, where VE provides the insight to do so. In this case, cost risk analysis was used as a supplemental tool.

The estimator on this wastewater treatment plant design had estimated the construction cost to be $38.7 million. The cast-in-place concrete on this project totaled over $13 million, or nearly 34% of the total construction cost. As one can see, failure to get the right unit cost on this item could severely skew the results of the estimate and bring the construction cost into question.

The VE team decided to use the Monte Carlo technique to point out the level of confidence which one could have in the range of potential cost results that were to be attributed to non-cost variables. The VE team, in effect, became a participant in the debate over what the unit cost for cast-in-place concrete should be. The team chose to factor in their knowledge of the effects of tightening air emissions standards on cement factories. This, in the opinion of the team, could result in the cost of cast-in-place concrete increasing by as much as ten (10) percent by the mid-point of construction.

When the Monte Carlo simulation was run on this project it was allowed to work on the four major cast-in-place concrete line items in the estimate. What the Monte Carlo simulation does is insert random numbers, chosen from directed ranges of probable numbers, for each of as many "runs" as the program is directed to carry out. If 1,000 runs are selected, the bottom-line outcomes are analyzed for each of 1,000 random numbers injected into the model—in this case, numbers chosen between $225 and $275. This permits the analysts to quickly gain the experience of working through the job 1,000 times.

The team chose to work with a triangular probability distribution for each of these line items (judgment might have dictated other probability distributions such as: Normal, Uniform, Lognormal, etc.—any of which can quite easily be implemented, as desired). Each of these line items was predicted to range in cost from 90% of the original estimate as the minimum cost, to an increase of 7.5% over the original cost as the likeliest scenario, and to a cost increase of 21% for the maximum. The assumptions made are identified on the enclosed Table 1,

Assumptions. The results of the simulation are included on Table 2, **Forecast**.

What the frequency chart tells us is that the owner and his engineer can have a 90% confidence level that the construction cost will range from $38.7 million to $40.3 million. Bear in mind that this is an informal attempt to give the owner and the engineer other cost information than just one bottom-line figure. What they make of the fact that $40.3 million might be reasonably expected for the construction cost is up to them to interpret. This simulation approach has been presented by the author on several occasions, particularly to design engineers and architects. If anything, their responses can be generally classified by saying, "This is interesting and well taken, however, I would rather that this be our in-house estimating tool—not something else we have to explain to owners who don't want to delve into technospeak."

Accordingly, this simulation tool is seen as advisory for designers and VE team participants. This technique could, for example, serve to give the designer and the estimator a sense of confidence in the contingency factors they have chosen. More is said about this later in the section entitled, " USING SPREADSHEET ADD-IN MODULES."

Finally, if the results of the simulations yield totally unacceptable projections, the VE team, the designers and the owners may focus on the most sensitive items causing the problems. Part of the output, a sensitivity analysis, is enclosed. This sensitivity analysis can identify topics for an added Creative Phase session to help bring costs back into line.

Consideration might be given to substituting alternative materials to avoid the underlying problem, e.g., use steel in lieu of reinforced concrete. Fast tracking design and construction may get the project built in time to avoid the major impact of regulatory changes, etc. One can see how this can provide several headings for the Creative Phase brainstorming effort.

VARIOUS TYPES OF SIMULATORS

The author has identified three available types of Monte Carlo simulator packages:

- Optional modules available with CPM scheduling programs
- Dedicated statistical analysis programs
- Add-in modules, for use with spreadsheet programs

The author chose to use an add-in module for spreadsheets since, in VE, the consistent use of cost spreadsheets and cost models lend itself to this package. And the add-in package made quick implementation possible since the author already had a standard spreadsheet program.

Should potential users of the Monte Carlo technique already have CPM programs, consideration might be given to use of the CPM add-in module as it can usually make ready use of the of the cost- and labor-loaded data base that are developed while fleshing out a construction CPM.

The statistical packages are best for those desiring to analyze the statistics with which they are working during day-to-day research.

In general, all three approaches use sophisticated mathematical techniques to massage the data—whether dealing with construction costs, labor utilization projections, or, in the case of pure research, projecting results from scientific experiments.

USING SPREADSHEET ADD-IN MODULES

As mentioned, the spreadsheet module was chosen for its ease of use. The author typically prepares for a VE study by developing the cost models for the project which is to be "VE'd." These cost models include a summary of the cost estimate, done on a spreadsheet. This is used as the basis for a Pareto Chart which highlights where the VE team should focus its efforts, i.e., on the high cost items. This spreadsheet becomes a ready tool for applying the Monte Carlo module. The steps for running the simulations are as follows:

1. Create the cost summary spreadsheet
2. Identify the pivotal (high) cost elements about which the assumptions will be made
3. Make the assumptions
4. Identify the item in the estimate that will be the subject of the "forecast." This is typically the bottom-line in the estimate, i.e., how is the project going to be costed?
5. Tell the module how many runs to make
6. Run the modular program
7. Interpret the results

The time-consuming part of the process is setting up the spreadsheet. Accomplishing steps two through six take only a few minutes. With the software, making the assumptions is an automated, user-friendly task. Of course, interpreting the results takes some attention to detail. It is imperative that the user interpret the results accurately so he may offer solutions to the owner and designer.

The add-in type modules each have sophisticated graphical displays available at the touch of a keystroke. These displays make it possible to analyze the results in several ways, including:

- Displaying the assumptions made about the line items involved in the assumptions
- Forecast Chart, and Statistical and Percentile views of the resulting forecasts
- Trend Chart
- Sensitivity Chart
- Distribution and Curve Fitting
- Reverse Cumulative Comparison Chart

One of the advantages of these modules is that the input data, assumptions, charts and various views can be quickly edited and assembled into attractive reports for positive, graphic persuasive use on the job.

OTHER USES FOR SIMULATORS

This paper has dealt with the simulator tool from an estimator's viewpoint. It has indicated the possibilities within the scope of a VE study to employ Monte Carlo simulations. It is also possible to make constructive use of these tools in other works, e.g., in making labor and schedule projections. Recall that Monte Carlo simulations derived from the need to statistically analyze a myriad of scenarios occurring in laboratory and other statistical applications. The further use of this versatile tool is only limited by the creativity of the user.

IN CONCLUSION

Hopefully, this paper has awakened an interest in this useful and powerful tool. VE practitioners have many opportunities ahead of them to add depth to their cost modeling efforts for their clients.

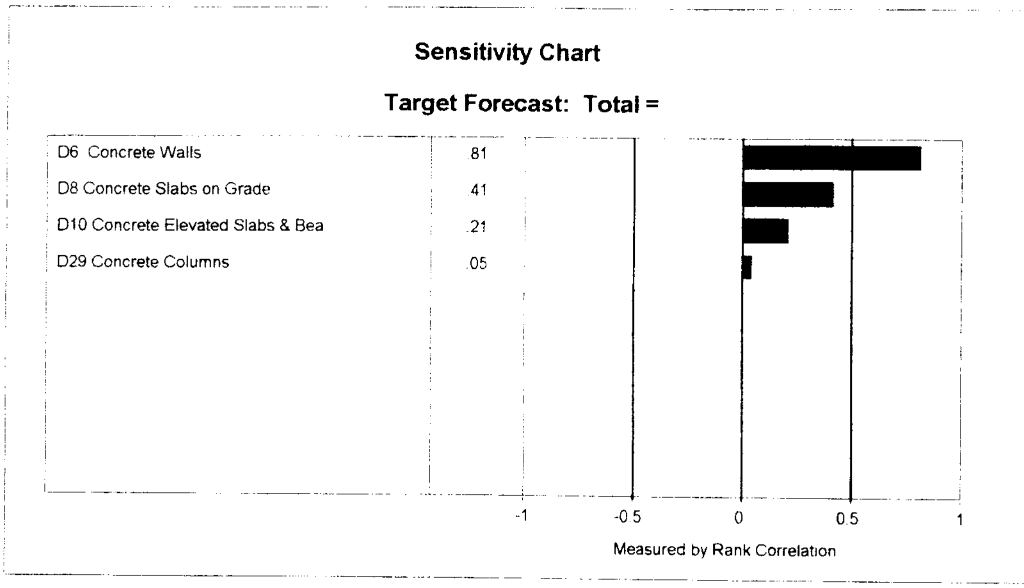
Sheet1

The Big Wastewater Treatment Plant - Pareto Cost Model
Prepared By Lewis & Zimmerman & Associates, Inc.

Concrete Walls	$ 6,690,000	17.27%
Electrical	$ 6,028,615	15.56%
Concrete Slab on Grade	$ 4,035,250	10.42%
Earthwork	$ 2,785,390	7.19%
Conc. Elevated Slabs & Beams	$ 1,920,000	4.96%
Sluice Gates	$ 1,461,000	3.77%
Yard piping	$ 1,235,300	3.19%
Valves	$ 1,173,050	3.03%
Vertical Mixer	$ 1,087,500	2.81%
DI Fittings	$ 880,325	2.27%
Instrumentation and Control	$ 844,000	2.18%
145' Dia. Clarifier Mechanism	$ 750,000	1.94%
Demo. of Existing Structures	$ 700,000	1.81%
Unit Masonry	$ 694,860	1.79%
Blowers	$ 673,750	1.74%
Yard piping fittings	$ 620,000	1.60%
100 hp horz angleflow pumps	$ 600,000	1.55%
Diffusers	$ 598,785	1.55%
Electrical Equipment	$ 522,585	1.35%
Filter Equipment and Filters	$ 440,625	1.14%
SS Pipe and Fittings	$ 396,204	1.02%
Grit-related equipment	$ 392,625	1.01%
Bar Screens and Parshall Flume	$ 391,250	1.01%
Concrete Columns	$ 357,000	0.92%
Handrails and Railings	$ 246,200	0.64%
60 hp horz angleflow pumps	$ 237,150	0.61%
DAF Basin Equipment	$ 205,000	0.53%
DAF Basin Cover	$ 175,000	0.45%
Expansion Couplings	$ 165,500	0.43%
Modify Existing Filters	$ 160,000	0.41%
Misc. Site Work	$ 159,800	0.41%
Primary Clarifier Equipment	$ 150,000	0.39%
Process Piping, DI	$ 140,426	0.36%
Structural Steel	$ 130,320	0.34%
Silencers	$ 112,500	0.29%
Conc. Structure - intermediate	$ 108,000	0.28%
Bridge Crane	$ 100,000	0.26%
Scum Pumps	$ 100,000	0.26%
HVAC	$ 93,750	0.24%
Metal Stairs	$ 93,165	0.24%
EQ Blower Building	$ 90,000	0.23%
Checker Plate	$ 84,900	0.22%
CS Pipe and Fittings	$ 84,614	0.22%
Sludge Pumps	$ 83,125	0.21%
Steel Joists	$ 79,300	0.20%
FRP Weirs	$ 79,200	0.20%
Slide Gates	$ 73,500	0.19%
Chem Phos. Removal Equip	$ 69,225	0.18%
Concrete Fill	$ 67,800	0.18%
Thickened Sludge Pumps	$ 59,375	0.15%
Recycle Pumps	$ 55,000	0.14%
Thickener Mechanism	$ 50,000	0.13%
Miscellaneous	$ 201,106	0.52%
Total =	**$38,732,090**	100.00%

Note:
Numbers in boxes represent assumptions for Monte Carlo run

Report1

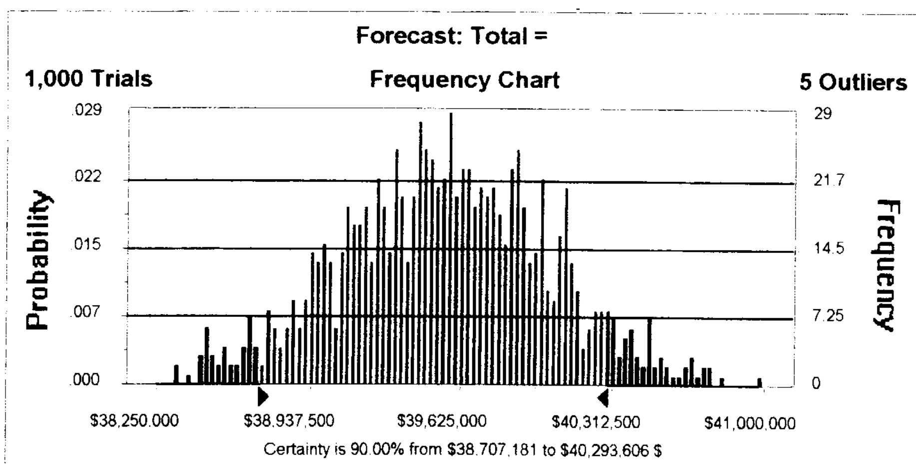

Sensitivity Chart
Target Forecast: Total =
D6 Concrete Walls
81
D8 Concrete Slabs on Grade
41
D10 Concrete Elevated Slabs & Bea
.21
D29 Concrete Columns
.05
-1
-0.5
0
0.5
1
Measured by Rank Correlation

Report1

Forecast: Total = **Cell: D59**

Summary:
Certainty Level is 90.00%
Certainty Range is from $38,707,181 to $40,293,606 $
Display Range is from $38,250,000 to $41,000,000 $
Entire Range is from $38,021,543 to $40,990,650 $
After 1,000 Trials, the Std. Error of the Mean is $15,120

Statistics:	Value
Trials	1000
Mean	$39,553,841
Median	$39,566,105
Mode	---
Standard Deviation	$478,139
Variance	2E+11
Skewness	-0.07
Kurtosis	2.90
Coeff. of Variability	0.01
Range Minimum	$38,021,543
Range Maximum	$40,990,650
Range Width	$2,969,106
Mean Std. Error	$15,120.08



Report1

Forecast: Total = (cont'd) **Cell: D59**

Percentiles:

Percentile	$
0%	$38,021,543
10%	$38,945,148
20%	$39,144,021
30%	$39,304,341
40%	$39,446,499
50%	$39,566,105
60%	$39,677,307
70%	$39,812,667
80%	$39,965,539
90%	$40,138,848
100%	$40,990,650

End of Forecast

Report1

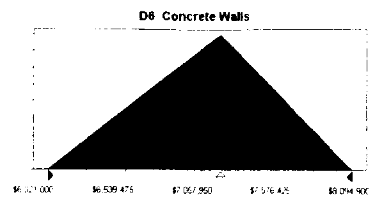
Assumptions

Assumption: D6 Concrete Walls **Cell: D6**

Triangular distribution with parameters:

Minimum	$6,021,000
Likeliest	$7,191,750
Maximum	$8,094,900

Selected range is from $6,021,000 to $8,094,900
Mean value in simulation was $7,122,619

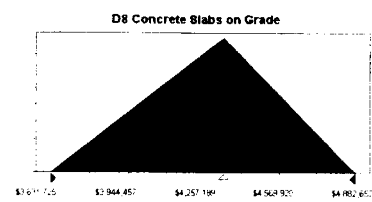


Assumption: D8 Concrete Slabs on Grade **Cell: D8**

Triangular distribution with parameters:

Minimum	$3,631,725
Likeliest	$4,337,894
Maximum	$4,882,652

Selected range is from $3,631,725 to $4,882,652
Mean value in simulation was $4,278,610

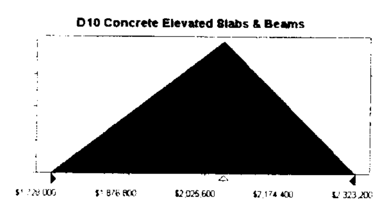


Assumption: D10 Concrete Elevated Slabs & Beams **Cell: D10**

Triangular distribution with parameters:

Minimum	$1,728,000
Likeliest	$2,064,000
Maximum	$2,323,200

Selected range is from $1,728,000 to $2,323,200
Mean value in simulation was $2,044,407



Assumption: D29 Concrete Columns **Cell: D29**

Triangular distribution with parameters:

Minimum	$321,300
Likeliest	$383,775
Maximum	$431,970

Selected range is from $321,300 to $431,970
Mean value in simulation was $378,366