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Accurate Estimates In Less Than a Minute

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Accurate estimates can be created in less than a minute by applying powerful techniques and algorithms to create an Excel-based parametric cost model. In five easy steps you will learn how to normalize your company's historical cost data to the new project parameters. This paper provides a complete, easy-to-understand, step by step how-to guide. Such a guide does not seem to currently exist.

Over 2,000 hours of research, data collection, and trial and error, and thousands of lines of Excel Visual Basic Application (VBA) code were invested in developing these methods. While VBA is not required to use this information, it increases the power and aesthetics of the model. Implementing all of the steps described, while not required, will increase the accuracy of the results.

Kennedy Space Center (KSC) is a governmental entity that imparts unique budgetary requirements. Project budgets must be requested years before design has been completed or true requirements are known. To provide project budget information, the Parametric Facilities Cost Model (PFCM) was created. Its operation is simple and fast, and its results are very accurate-the documented average is typically within five percent of the low bidder, which is within the expected accuracy range of a class 1 or detailed estimate. Figure 1 shows the back-checked estimate accuracy of 44 concrete office-type buildings. The total average accuracy of the PFCM estimate is 3.04 percent.

PFCM works by applying algorithms to normalize historical project information that has been entered into an Excel spreadsheet. KSC's requirements, some of which are unique, drove the model design concept. Therefore, other companies may need to adjust the techniques described, especially the economies-of-scale algorithm.

The only requirements for applying these techniques are a basic knowledge of Excel and some historical data of a project type that is comparable enough to enable interpolation.

Knowledge of VBA and statistics would be extremely helpful, but is not a prerequisite for success. The formulas are presented in an Excel format, where:

- * = multiplication,
- / = division, and
- ^ = exponent.

STEP 1—ADJUST FOR THE NUMBER OF BIDDERS

One critical but frequently overlooked facet of data normalization is the Number of Bidders Concept developed by Dr. Martin Skitmore, who has documented this occurrence statistically in numerous high-level papers. The basic theory is that when times are good and there is plenty of work, fewer contractors are willing to spend the time and money required to prepare bids. Conversely, when times are bad and there are not many projects, contractors will spend a great deal of time preparing bids and cut their margins in an effort to stay in business.

Although the concept is well documented, the author could not locate any published data tables that indicate the specific percentage adjustment that should be applied for bid cost adjustment. However, by applying the Number of Bidders Concept to historical bid abstract data for over 1,000 KSC projects, the author developed the following algorithm: Y = 0.74 * the number of bidders ^0.14, where Y = the percentage adjustment required for that particular project.

It should be noted that in instances of one bid response, the correction required can be substantially higher when that bid is received as a solicitation by a 8(a) Set Aside, or HUBZone project; however, it is the best fit that can be statistically derived. Figure 2 demonstrates the adjustment generated by the algorithm. This concept will be applied twice in our estimate preparation, once to normalize historical cost data and once to adjust the final estimate for anticipated market conditions at the time of bid.

An applied example project with two bidders for a new 30,000-SF new concrete office building bid on April, 2002 with a cost of $126.50 per SF would yield the following formula:

- 0.74 * 2^0.14 = 81.5%, 81.5% * $126.50 = $103.10 per SF.

STEP 2—NORMALIZE THE PROJECT COSTS

Depending upon the methodology employed by the model builder, there are two ways to normalize the project unit costs. The first is to correct for all known variations by application of numerous algorithms to more accurately normalize the price. This would include adjustments for location, number of stories, distance from utilities, degree of finish, etc. However, for our

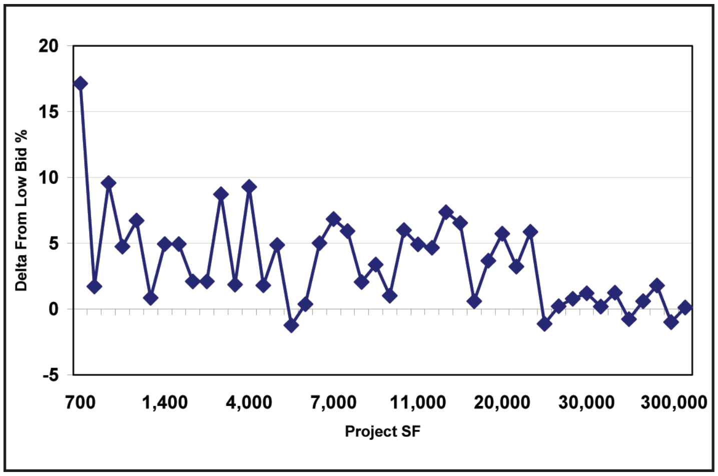

Figure 1—Back-Checked Accuracy of PFCM for 44 Concrete Office Buildings

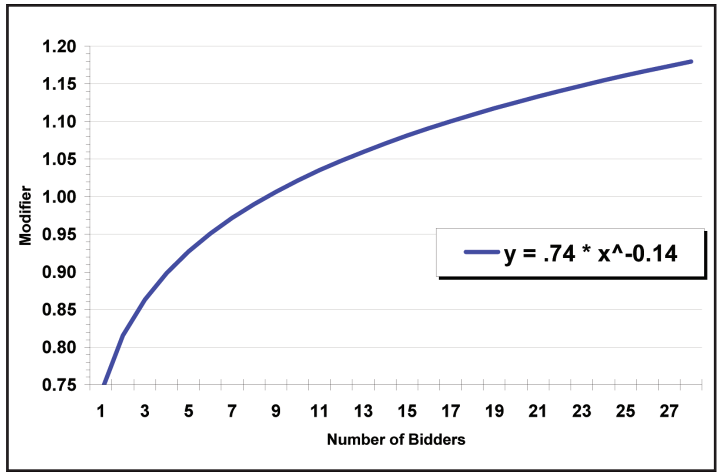

Figure 2—Number of Actual Bidders Algorithm

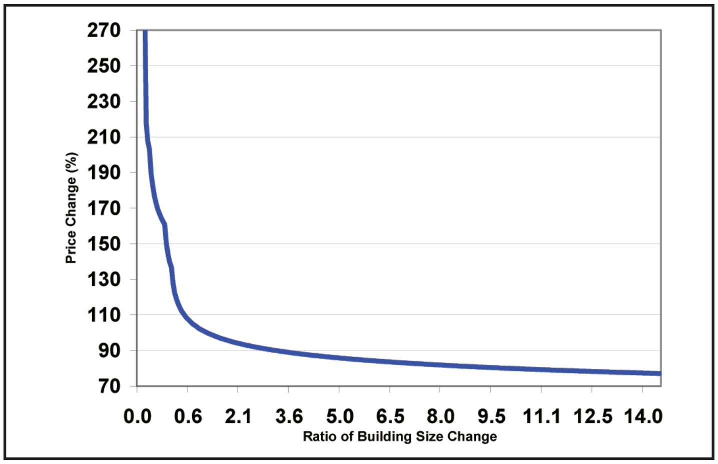

Figure 3—Glenn Butts Economies of Scale

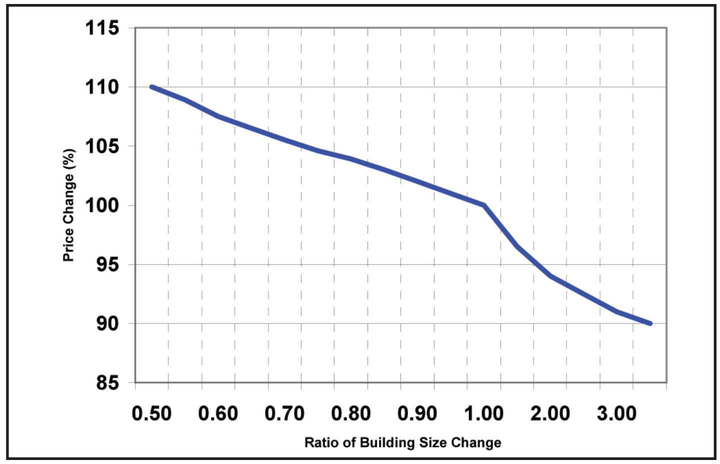

Figure 4—RS Means Economies of Scale

application, this step is omitted since during our budgeting process only sparse project information is available. If the data was fully normalized, we could not accurately assess the probability of not exceeding the proposed budget. Therefore, PFCM step 2 is limited to an economies-of-scale adjustment. This is widely acknowledged in the construction industry as a substantial cost factor but is difficult to quantify. Common methods for this adjustment include capacity factors, which are easier to develop but suffer some limitations since project capacity factors are not typical across all project sizes, as project capacities increase, the exponent also tends to increase.

Capacity factors determine the cost of a new proposed project based on the historical cost from similar project of a known capacity. This is done by creating an estimating algorithm that relies on the nonlinear relationship between capacity and costs. This is accomplished with the following formula:

- $ = Known Project Costs * (Known Project Size / New Project Size)^Exponent.

This reflects the typical economy-of-scale cost relationship that we expect from a change in capacity (or size) of a project. With an exponent of .6, doubling the size of a project increases the project costs by 50 percent, and tripling the size increased costs by 100 percent.

To alleviate the problem of changing exponents when project size changes substantially the author developed the following algorithm:

- Y = 1.010001*(new project size / historical project size)^-0.101,

which simplifies this adjustment substantially. Figure 3 shows the adjustment generated by this calculation. The RS Means economies-of-scale are shown for comparison in figure 4.

To continue with our example project, we need to know the size of the proposed new project; we have determined this to be:

- 50,000 SF: 1.010001 * (50,000 / 30,000)^-0.101 = .959 * $103.1 per SF = $98.87 per SF.

This algorithm works very well with the exception of adjustments for new projects smaller than 3,000 SF, where costs tend to increase substantially. If the historical project costs must be adjusted for a new project that will be smaller than 3,000 SF, the author-

Table 1—Overtime Factors

Work Schedule	% Increase Project Costs
40	0
41–48	10
49–50	15
51–54	20
55–59	25
60–65	30
66–72	40

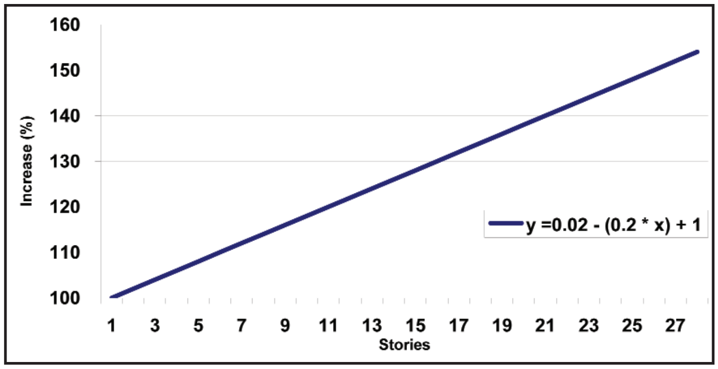

Figure 5—Adjustment for Number of Stories

Table 2—Site Development Factors

Site Development	% Change
Minor	–10
Average	0
Moderate	10
Extensive	20
New Site	40

developed algorithm is applied in addition to the previous one. Small Building Multiplier = (1.11 * (3,000 / Size of New Project))^0.31.

An example is:

- 1.010001 * (1,000 / 30,000)^-0.101 = 1.424 * $103.63 per SF = $147.57 per SF
- (1.11 * (3,000 / 1,000))^0.31 = 1.45 * $147.57 = $211.36 per SF.

Although VBA is used as the PFCM engine that applies the algorithm, it can be easily employed by a "IF" statement in an Excel formula: =IF("Test", Formula if test is True, Formula if test is False).

STEP 3—ESCALATE THE NORMALIZED COST TO CURRENT-DAY DOLLARS

This is accomplished by a VLookup formula from a table that contains applicable cost indexes. PFCM uses a straight average of three cost indexes: the Engineering News Record (ENR) Construction Cost Index (CCI), the Building Cost Index (BCI), and the KSC-produced TR-1511.

BCI—Primarily geared toward new construction the BCI contains 66.38 hours of skilled labor at the 20-city average of bricklayers', carpenters', and structural ironworkers' rates, plus 25 cwt of standard structural-steel shapes at the mill price prior to 1996, and the fabricated 20-city price from 1996, plus 1.128 tons of portland cement at the 20-city price, plus 1,088 board-ft of 2 by 4 lumber at the 20-city price.

CCI—Primarily geared toward renovations and remodeling, the CCI contains 200 hours of common labor at the 20-city average of common labor rates, plus 25 cwt of standard structural-steel shapes at the mill price prior to 1996, and the fabricated 20-city price from 1996, plus 1.128 tons of portland cement at the 20-city price, plus 1,088 board-ft of 2 by 4 lumber at the 20-city price.

TR-1511—This is a quarterly publication that contains a KSC-specific cost index that tracks local Davis Bacon labor and material pricing changes. Price changes are related to a base index of January 1974 and compare to the latest index available. Crew rates for 19 divisions are calculated for the labor cost index with January 1974 as 1,000 for 100 hours of work. Material costs for 26 basic materials are used with an adjusted base of 1,000 in January 1974. These material unit costs are detailed estimates for the most commonly used materials.

For our example project, we will limit escalation calculation to the BCI to avoid needless complexity.

- BCI November 2005 = 4352
- BCI April 2002 = 3583
- 4352 / 3583 = 121%
- $98.87 * 121% = $119.63 per SF

STEP 4—FINAL ADJUSTMENTS

PFCM applies the first three steps automatically by using formulas and VBA macros and then filters out any noncomparable projects so that only representative projects remain. By using the VBA Filter Copy function, but this can also be accomplished by using the Excel AutoFilter function. Those that most closely match the new project are then analyzed with the Excel Subtotal function to determine the following:

- Average Cost =Subtotal(1,Range),
- Standard Deviation =Subtotal(8,Range),
- High Cost =Subtotal(4,Range),
- Low Cost =Subtotal(5,Range).

The known aspects for proposed project that will impact project costs are selected by the user from pulldown menus enabled by Excel's Data Validation feature. If desired, this adjustment can be implemented as part of step 2 to fully normalize the historical data, depending upon the goal of the model. Items adjusted include:

Table 3—Degree of Finish

Finish	% Change
Sparse	–10
Below Average	–5
Average	0
Above Average	5
Opulent	10

- **Work hours per week**—In theory this factor is applied only to the labor portion of the project; however, in practice, this is very difficult to do since productivity losses are not a constant and tend to increase with time up to a point (see Table 1). Also second- and third-shift operations may be necessary. This requires a shift differential, additional lighting, etc. The root cause of a schedule over 40 hour per week is often a firm completion deadline, which will often require additional cost impacts such as increased shipping costs, acceleration of change orders, etc.
- **Number of stories**—It is well accepted in the construction industry that taller buildings cost more per SF to construct since additional site work may be required, elevator and equipment costs are higher, and productivity losses are encountered by workers during construction. Theoretically, two-story buildings are slightly less expensive to build than one-story buildings, and six-story buildings are substantially more expensive than five-story buildings as a result of code requirement. Except for these two aberrations, the increase in cost is relatively constant. MCAA suggests a labor factor of one to two percent per additional 10 feet of building height, but that the factor should be doubled on work above the 20th floor for all mechanical work. NECA recommends a cumulative factor of one to two percent per floor for electrical work. Filley recommended a varied method depending upon the actual number of stories to be constructed; however, his average recommended increase is two percent per floor level added. His research is for buildings from 1 to 28 stories. Based on the aforementioned, the author developed. The following algorithm to adjust costs for multistory work:

  y = 0.02 - (0 .02*number of stories) + 1.

  The effects are indicated in figure 5.
- **Site development required**—Project location and site conditions can impact costs substantially as a result of costs incurred to remove unsuitable soils, install piers, extend utilities long distances, or mitigate environmental concerns such as gopher tortoises, scrub jays, least terns, and wetlands. See table 2. These costs also tend to become a higher percentage of total project costs, as the project size decreases. It is important to note that for projects smaller than 5,000 SF these factors are currently doubled. An algorithm needs to be derived to more accurately perform this function.
- **Degree of finish**—This adjustment is somewhat subjective, and the factors were arbitrarily in nature, but required. This adjustment attempts to account for whether the building will be a plain square box, a fancy structure with opulent architecture and lavish furnishings, or something in between. See table 3.
- **Project location**—Area location factors are a well-known adjustment. There are many excellent sources of these available, so they will not be discussed here other than to mention that they will change over time depending upon the economic situation of the region. Make sure that they are current.
- **LEED level**—Leadership in Energy and Environmental Design (LEED) is a subject complex enough to warrant its own paper and is not easily reduced to a simple calculation since there are many variables. According to LEED advocates "LEED doesn't cost any more." This author strongly disagrees with this statement, at least at KSC, which is in a hurricane prone region and is required to comply with strict wind codes. All exterior glass (a major LEED component) must be Small Missile Impact (SMI)-rated, which is expensive. LEED is a point-based system, and adjustments are calculated automatically in PFCM with numerous calculations that vary with project size and cost. Smaller projects appear to have a higher LEED cost when expressed as a percentage of the total

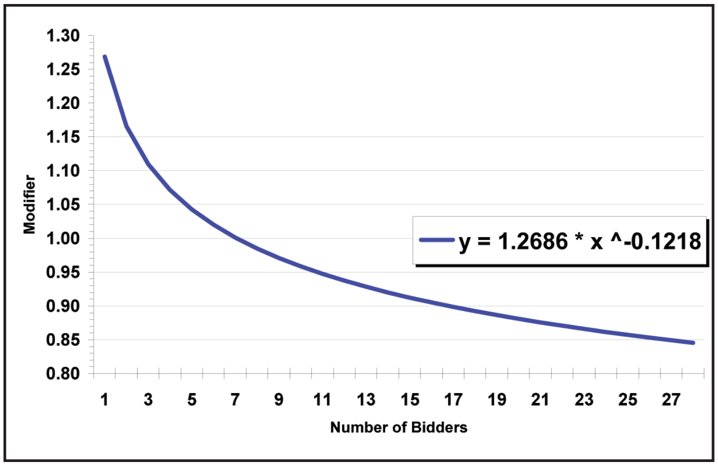

Figure 6—Number of Anticipated Bidders

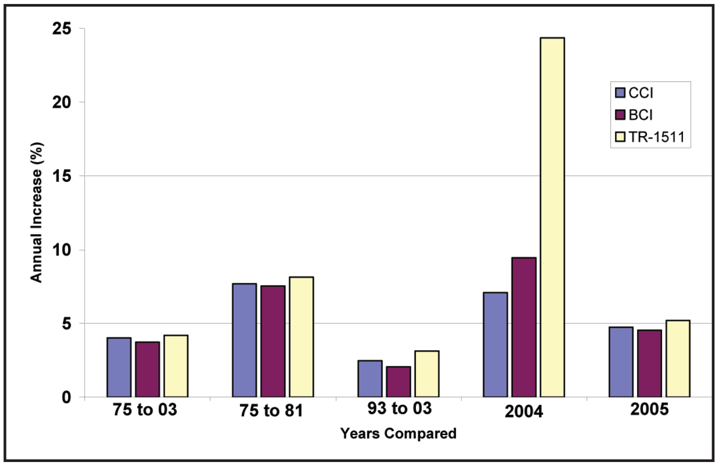

Figure 7—Annual Escalation Averages

Table 4—Difficulty Factors

Difficulty	Factor
Easy	0.90
Normal	1.00
Moderate	1.10
Difficult	1.15
Extreme	1.20
Pad Work	1.25
Secure Area	1.21

project. KSC has not constructed any LEED projects to date but has quite a few in the design phase. Be cognizant of the four choices: none, silver, gold, and platinum, with platinum being the most expensive.

- **Difficulty**—This is primarily a catchall for project factors not previously quantified and not widely used (see Table 4). However, there is one item that is critical to define. It is for work in secure areas that require an FBI background check or an escort for access. Work in secure areas slows down material delivery, site access, and job productivity, and frequently requires numerous escorts.
- **Anticipated number of bidders**—Using the Number of Bidders concept and historical bid abstract data the author developed the following algorithm:

  Y = 1.2686x^-0.1218,

  where Y = the percentage of adjustment required, and x = the number of bidders anticipated for that particular project. **Figure 6** demonstrates the adjustment generated by the algorithm.
- **Escalation to the midpoint of construction**—During step 3, we escalated the construction costs to the present time, so an escalation percentage must be applied to the project. The difficult part is determining how much escalation to apply. Escalation tends to change over time, as figure 7 demonstrates. There are many choices for handling this escalation, again the subject for another paper and of great debate. PFCM uses estimated future cost index values to accomplish escalation so that the same formulas can be applied when back-checking the program.

Returning to our example project, we have now selected our other project factors and will apply them to our example project. Conditional formatting is applied so that cells that have any values other than the average are color-coded red. This helps to avoid the inadvertent application of incorrect factors.
It is important that the factors be calculated correctly or an incorrect answer will be derived. The method must be:

- (Factor 1 + 1) * (Factor 2 + 1) * (Factor 3 + 1) = markup percentage.

This method is employed to avoid compounding markups and is illustrated in figure 8.

% of Total Project	100%	114.1%	Anticipated Number of Bidders	4	7.2%
Hrs Week	40	0.0%	Project Date	Jun-07	12.4%
# of Stories	3	4.0%	Project Location	KSC	0.0%
Site Development	Average	0.0%	Leed Level	Silver	2.3%
Finish	Average	0.0%	Difficulty	Normal	0.0%

Figure 8—Adjustment Section of PFCM Model

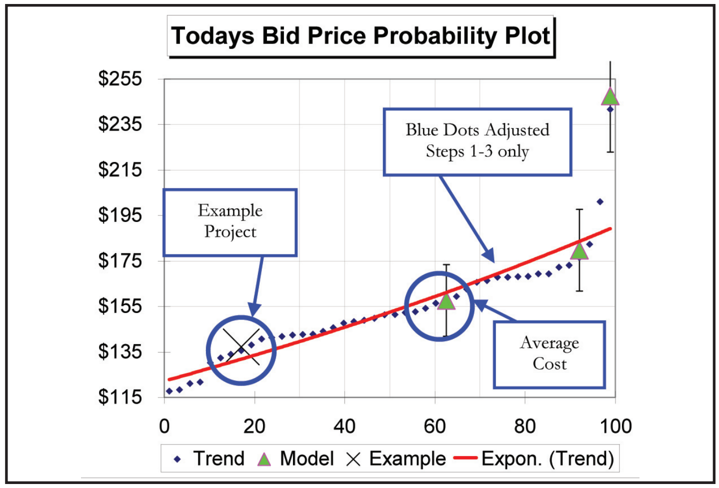

Figure 9—PFCM Bid Probability Chart

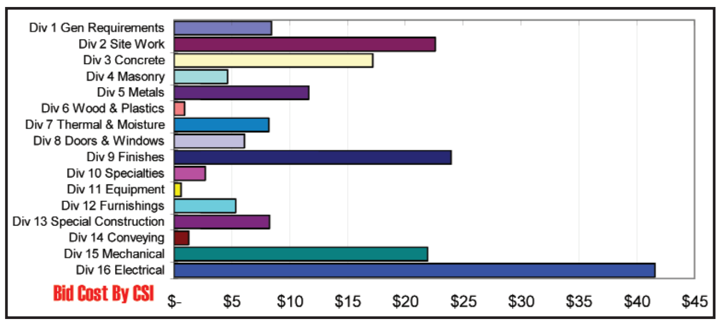

Figure 10—PFCM Bid Cost by CSI

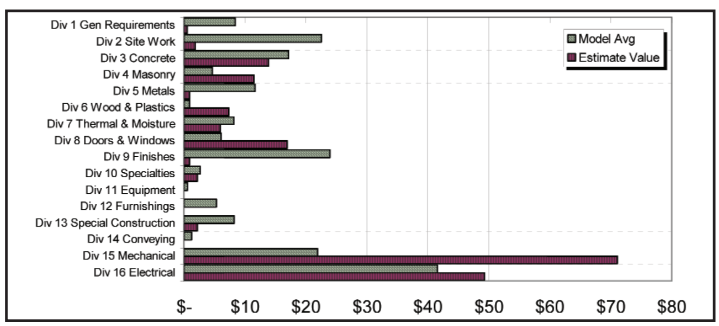

Figure 11—PFCM Comparison to Detailed Estimate

114.4% * $119.63 = $136.86 (Today's Bid Cost)
$136.86 * 112.4% = $153.83 (Future Bid Price)

We have now calculated our unit price for our example project. However, our example is an analogy estimate, which means that it is based on one actual project, which may not be representative of our proposed new project. When the final adjustments are applied, the average cost typically gives us a 60 to 70 percent probability that the low bid will not exceed the estimated one. Approximately 95 percent of the time, the average cost is the correct cost. For budgeting purposes the average cost + 1 standard deviation is frequently used on smaller projects to provide some contingency as a result of scope creep.

So, it is apparent that the project we selected for our example was below our average cost, but by how much? A good way to see the corrected prices in relation to each other is to graph them as shown in figure 9.

From figure 9 we can tell that we are low compared to the Average Cost and 14 percent low when compared to the model costs. There is a simple explanation for this. Our example historical project was a one-story building requiring minimal site work. It was constructed near all required facilities, used existing parking, and required no piers or removal of unsuitable soil. If the 10-percent factor for site development is added to our example, then our estimate is within 4 percent of the adjusted average project-not too bad for a estimate that took less than a minute to complete. Consequently, the highest-cost project ($242 per SF) depicted in Figure 10 is for a remote, 868-SF building that required a pier foundation.

STEP 5 CSI COST BY DIVISION (OPTIONAL)

Other valuable information can be calculated automatically by applying historical information included in our database. Figure 10 is automatically generated by PFCM. This is accomplished by entering the detailed estimates into a database and then converting the cost per CSI division into a percentage of the total project. When the database is filtered, the relevant project division percentages are averaged and then multiplied by the Average unit costs by CSI division. This is simple to do and shows where the project budget is most likely to be expended. As depicted in figure 10, KSC has unusually high division 16 costs as a result of its requirements for redundant power systems, facility monitoring, paging systems, etc.

As shown in figure 11, this information is also helpful for comparison to a detailed engineering estimate to ensure that items are not omitted. This project is for a specialty-type facility that is not contained in the model database; however, using information known about the facility-it requires additional HVAC and electrical systems-we can determine that this facility estimate looks reasonable, with the exception of site work, which may be low.

TESTING THE MODEL

It is important to test any cost model extensively before it is used, back-checking the assumptions and algorithms. This can be automated with a VBA procedure if desired. To be statistically valid, the project being tested should be removed from the database; however, frequently the historical project database does not contain enough data points to allow this exclusion. Figure 12 indi-

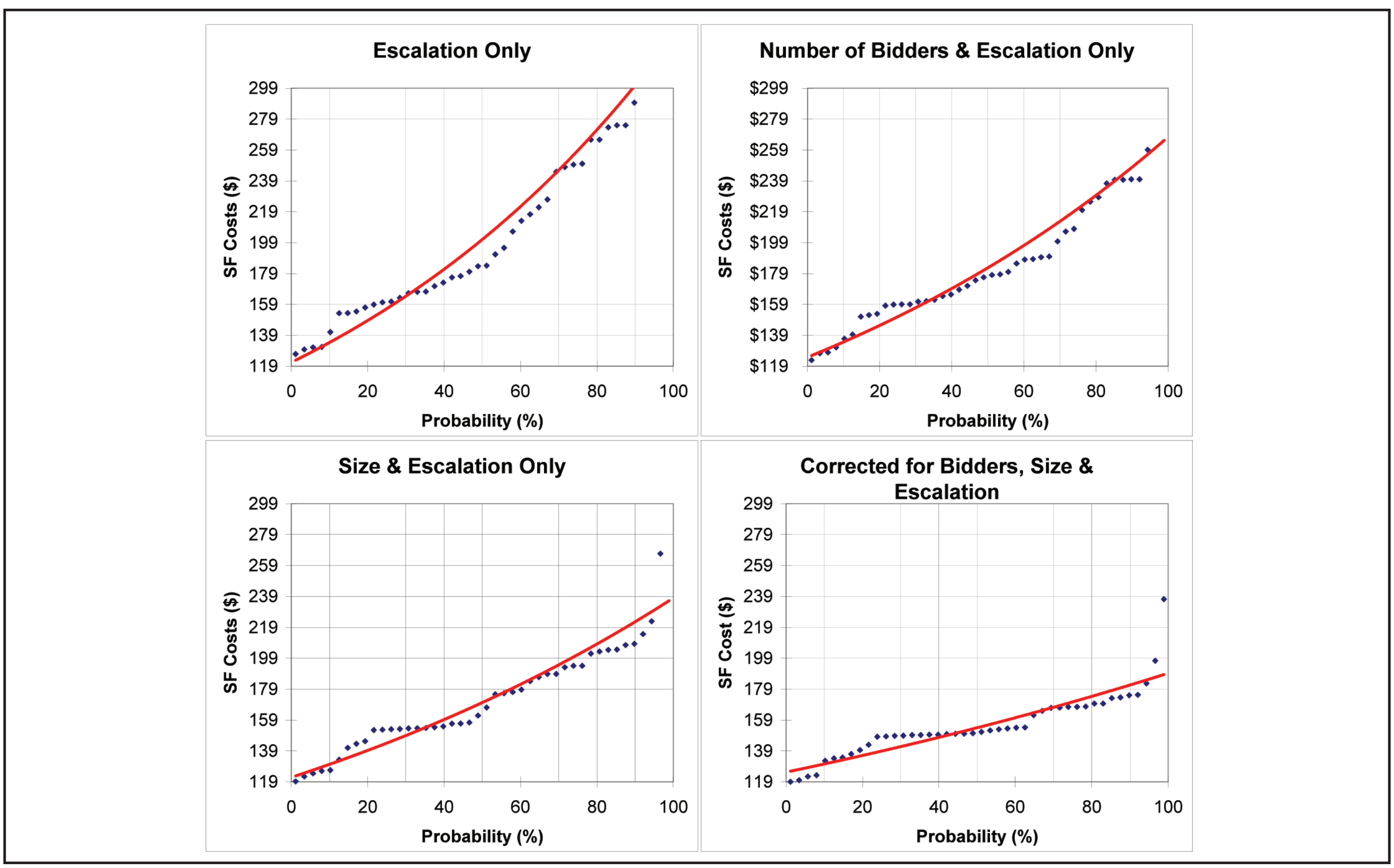

Figure 12—Effects of Various Adjustments on Estimate

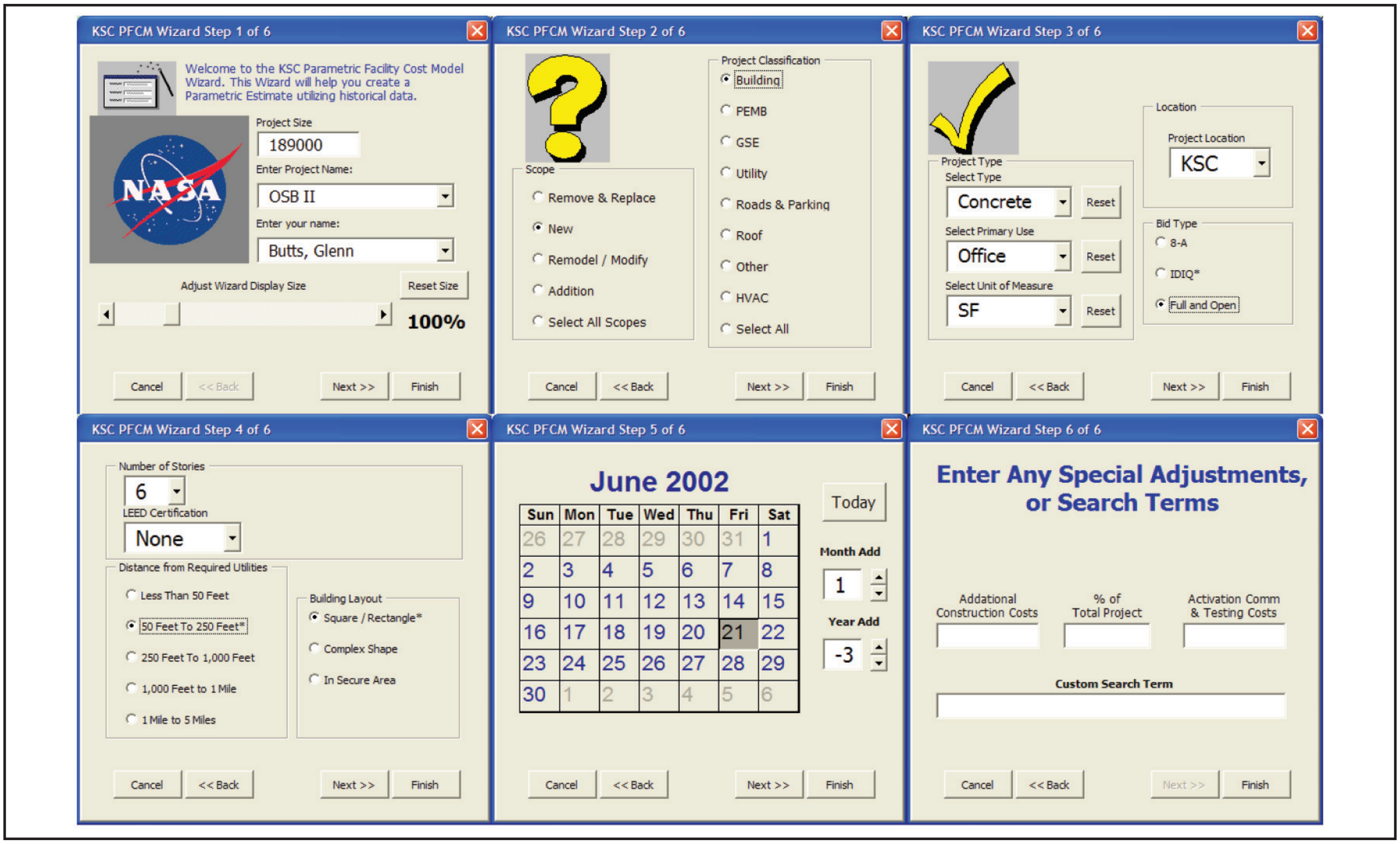

Figure 13—PFCM Wizard

cates the effect of each adjustment on a randomly selected project and displays the probability of not exceeding SF project costs. This method is a good way to assess the effectiveness of various adjustments.

PFCM WIZARD

PFCM offers two choices for data inputs. The first is manual and requires some knowledge of the program and its capabilities. The second, shown in figure 13, is a wizard or graphical user interface (GUI) that steps the estimator through the process and provides additional information about the possible selections.

Parametric modeling can be a powerful tool to quickly create ROM estimates with limited scope definition or to validate detailed estimates. PFCM is currently being used to prepare estimates for all types of facility projects, including concrete and steel buildings, pre-engineered metal buildings, and roofing projects, as well as various repair and remodeling projects, with very good results. It must be kept in mind that a model is not a substitute for professional judgment. There are exceptions to every rule, and outliers, typos, or inaccurate data can skew the results for your model.

Meticulous, time-consuming recordkeeping is required to effectively execute this type of estimate. Relevant historical project cost data is required create accurate estimates. A monumental effort is required to gather, sort, and analyze historical project data. Both cost and design scope information must be identified and collected. It is best to collect the information at as low a level of detail as possible since it can always be summarized later if required.

Excel appears to be the best medium for creating of a parametric cost model. Upgrading to Excel 2003 is advised for performing any statistical calculations because the earlier versions are substantially flawed in their analysis capabilities. Even proficient Excel users will improve their parametric modeling abilities with some additional study of Excel and its easy-to-learn VBA component. Some excellent sources are listed as references.

Creating a complete parametric model is not a painless task, but the rewards can be substantial. Its utility is well worth the time and effort required to develop the model and build the historical project database. Fortunately model creation is not an all-or-nothing task. A model can be developed and used a step by step, with each step increasing functionality and accuracy. Remember, "a journey of 10,000 miles begins with a single step" (Lao Tzu). The author welcomes comments, suggestions, or criticism regarding this subject.

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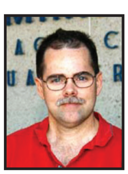

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