Pragmatic Expert System for Construction Owners Linking Between Contractor's Past Performance and Future Bid Evaluations

by
George S. Birrell
Professor
School of Building Construction
University of Florida
Gainesville, Florida 32611 U.S.A.
(904) 392-5965
and
Sarah Hatch
Civil Engineer
Badger Engineers
Cambridge, Massachusetts 02142 U.S.A.

Key Words

Expert System, Contractor Performance Evaluation, Bid Evaluation, Bid Modification, Construction Work, Project Owner.

Summary

Many construction project owners accept bids from contractors only to find that during the actual construction process their performance incurs delays and costs due to a poorer than expected performance.

Some large, repetitive construction project owners in the United States are beginning to develop pragmatic expert systems as vehicles by which project owners' engineers may capture contractors' performance experience from past projects, organize such experiences to form a qualitative but in some cases a quantitative basis to enhance their contractor evaluation decision making. Some of the quantitative processes are also being used to modify bids received from such contractors as a constituent of selecting the lowest bidder.

This paper will describe these existing pragmatic expert systems and their principles and processes which are beginning to be used in this crucial decision making aspect of selecting contractors for future construction work.

Pragmatic Expert System for Construction Owners Linking Between Contractor's Past Performance and Future Bid Evaluations

by
George S. Birrell
Professor
School of Building Construction
University of Florida
Gainesville, Florida 32611 U.S.A.
(904) 392-5965
and
Sarah Hatch
Civil Engineer
Badger Engineers
Cambridge, Massachusetts 02142 U.S.A.

Mots-cles

Expert System, Contractor Performance Evaluation, Bid Evaluation, Bid Modification, Construction Work, Project Owner.

Sommaire

Les evaluations d' un grand projet qui sont souvent accepte par les contracteur, sont parfois change a cause du changement de l'horaire de travail, souvent aussi a cause que les prix ne sont pas acceptables. Tout cela, le resultat du travail inferieure.

Dan les Etats Unis les Proprietaires des grandes maisons commencent a developper un systeme d'expert pragmatique pour juger proprement des projets deja conclus, et c'est ainsi que dans plusieurs cas, on trouve une base d'evaluation. Cette methode a ete employe pour la modification des estimations, recu par les contracteurs et aussi pour choisir le prix le plus bas.

Cette lecture va montrer ce systeme d'experts pragmatique ces principes et ces procedees, qui sont use en ce moment pour la selection des contracteurs, et pour le travail de construction dans l'avenir.

INTRODUCTION

The objective of the study which underlies this paper was to synthesize from an array of twenty project owners' contractor performance evaluation forms a suggested format and optimal process of evaluating contractors performance.

The contractor evaluation forms which form the foundation or input data for this study are those used by project owners from various power and industrial companies to evaluate and store the performance of the construction contractors. The power companies are: American Electric Power Co., Baltimore Gas and Electric Co., Brooklyn Union Gas Co., Cleveland Electric & Illuminating Co., Commonwealth Edison Co., Consumers Power Co., Detroit Edison Co., Florida Light and Power Co., Pennsylvania Power Co., Southern California Edison and the Virginia Electric Power Co. The industrial companies are: Dow Corning Co., Esso Resources Co., General Motors Co., Monsanto Co., Owens Corning and Fiberglass Co., Shell Oil Co., Southern New England Telephone Co., T.R.W. and the Union Carbide Co. All of these evaluation forms were provided to the researcher by the Detroit Edison Co.

Each evaluation form contains a set of criteria on which the contractor is evaluated by the project owner staff on each construction process. Each project owner considered certain criteria to be of importance in the evaluation process, thus the sets of criteria as well as the number of criteria used by each project owner vary from form to form. At one extreme, one owner felt that contractor's quality of safety was worthy of about fifteen evaluation criteria and about half a dozen other criteria for all other aspects of performance. Whereas other owners had anywhere from zero to five evaluation criteria allocated to safety from among many criteria. Some of the evaluation forms also contain a scoring system to be used by the owner's staff to establish an overall performance evaluation for the contractor on a single project. Some forms have a weighting system across the criteria listed to account for different degrees of importance they see between criteria when computing the overall performance evaluation. Some have both scoring systems and weighting systems and some have potential for open opinions to support the above more structured responses.

THE HIERARCHY BY WHICH PROJECT OWNERS EVALUATE CONTRACTORS

The results of the analytical part of this research process are best considered in an hierarchical form which has four main levels.

Level Four: At the bottom of the hierarchy, Level Four, are the common expressions of all criteria from all twenty of the project owners' evaluation forms studied.
Level Three: Seventeen categories constitute Level Three of the hierarchy. The construction performance names of these categories represent and were derived from the meanings of subsets of the underlying criteria which had such common meanings.
Level Two: This is composed of five groups of common categories from Level Three which are representative of the main aspects of the contractor's performance from the meaning of the categories in Level Three.
Level One: This is the essence of the whole topic - management of construction by contractors as viewed by project owners.

The seventeen categories of Level Three are the parameters of evaluation suggested and used as the most appropriate distillation of contractors' performance later in this paper. All the common expressions of the owner's criteria on Level Four appear too numerous and ideosyncratic and the groupings of categories on Level Two are too general as the most appropriate distillations of the essence of the subject for use as elements of evaluation and forecasting of managerial performance.

Each category of Level Three within its grouping of Level Two of the hierarchy, which constitute the analytical distillation of the underlying criteria used by these project owners is now listed and defined and its percentage value in its level is stated.(see later for calculation process)

1.OVERVIEW OF THE CONTRACTOR - the capabilities brought to the project and his total performance on the project.(18.0%)
(A) Contractor Capability - the reliability and financial capabilities to complete the project according to the owners requirements. (3.0%)
(B) Overall Performance - the management skills, ability to anticipate problems, and efficiency in handling paperwork. (7.5%)
2.ON SITE MANAGEMENT - The management coordination and control on site of all site staff of all contractors, the craft supervision, as well as coordination with his home office management, and provision of safety on the site. (22%)
(A) Site Staff Management - the field supervision, management of work, decision making and technical ability of the contractor. (9.5%)
(B) Craft Supervision - the efficiency of crew sizes, and their motivation programs along with interfacing with minority regulations. (2.5%)
(C) Interface With Home Office - the supervision of home office staff working on the project as well as the frequency and effect of their site visits on management of construction. (6.0%)
(D) Quality Of Safety - the forming of a project safety plan and the response to safety requests and reporting of accidents, fire security issues, the number of injuries on the job and if the contractor has good site housekeeping practices. (9.0%)
3.RESOURCE FLOWS AND PRODUCTIVITY - the efficiency of use of manpower, the availability and condition of equipment and tools, as well as appropriate material quality and delivery schedules. (29.0%)
(A) Labor and Its Use - the technical ability,workmanship and productivity of labor, the turnover ratio, absenteeism rate, etc. (10.0%)
(B) Equipment and Its Use - the availability and use of appropriate equipment and its working condition as well as the quality of its maintenance. (8.0%)
(C) Materials and Their Flow - the appropriate quality of the materials used, the efficiency of the material procurement and delivery processes as well as the ability to expedite materials flow. (9.0%)
4.MANAGEMENT OF COSTS AND TIME - the quality of his cost control system, and the ability to finish the work within the budget/contract amount. How well scheduling is used and his skills in preconstruction planning and organization as well as the amount of claims filed during the course of the project. (21.0%)
(A) Cost Management - the quality of the cost control system used and his efficiency in modifying construction from it as well as his handling of billings and payments from the contractor. (4.5%)

(B) Time Management - his organization and time planning skills, work expediting and the ability to finish the project on schedule. (12.0%)
(C) Claims By and Against Constructor - the reasonableness in filing for extras and changes and being reasonable and realistic in handling claims, liens, damages, etc., and their settlement. (3.0%)
5.INTERFACE OF CONTRACTOR WITH OTHERS - the interfaces between the contractor and owners, agents, other contractors, with the local construction industry, including labor relations, and with third parties. (10.0%)
(A) Interface With Owners and Agents - the quality of his responses to owners requests, the quality and quantity of that written and verbal communication, and the cooperation with owners and architects. ((6.5%)
(B) Interface With Other Contractors - the effectiveness of his management of the subcontractors and interacting with other primes on site and the quality of the relationship with these other contractors. (6.0%)
(C) Interface With Local Construction Industry - the relations with local trades and contractors organizations and resource suppliers. (0.5%)
(D) Labor Relations - the relations with sources of labor and their (union or nonunion) organizations as well as labor practices on site. (1.0%)
(E) Interface With Third Parties - how the contractor complies with all government agencies, proper handling of permits, and their relation with the general public around the site. (2.0%)

The common expressions of all the criteria culled from all twenty project owners forms and which constitute Level Four of the hierarchy are not listed due to space constraints.

The Importance Weighting of Each Element on Levels Two and Three of the Hierarchy

This hierarchical analysis of the twenty owners' sets of evaluation criteria was also used to provide a sense of the relative importance of each element of Levels Three and Two of the hierarchy. To create this weighting, a scoring system was devised in which a numerical value was calculated first for each category in Level Three of the hierarchy and then for each group of categories in Level Two of the hierarchy.

The numerical value calculated for each category on Level Three was derived from the number of contractor evaluation forms which contained criteria related to that particular category. Thus the numerical value assigned to each Level Three category may range from 1 to 20 (there being twenty owners' forms in the input data base). Thus the higher the numerical value for a Level Three category, the higher is its degree of importance relative to the other categories in Level Three and in evaluating contractors by project owners.

The numerical value for each group of categories in Level Two was calculated by summing the numerical values assigned to each category in Level Three belonging to that particular group of categories and then dividing the result by the number of categories in that group. Thus, the numerical value for each group of categories in Level Two of the hierarchy also may range from 1 to 20 and the higher the numerical value for such a group means a greater relative importance that group of categories has in evaluating contractors by owners. Each relative value from 1 to 20 on both levels were then expressed as percentages (see Table 1 and Table 2).

OVERVIEW OF CONTRACTOR PERFORMANCE CAPTURE, SCORING, STORING, FORECASTING AND FUTURE BID MODIFICATION

From all the analysis of the many features of the twenty forms in the above research it is suggested that the following distilled format of use of contractors performance evaluations contains virtually all the strengths of all the forms but expresses them in a simple, useable, balanced, user friendly format and beneficially creative manner. The (a) performance capture format also carefully and simply interfaces with the subsequent (b) performance scoring system which in turn interfaces with (c) future bid modification for management performance and bid selection process. These three sub processes are set up for separation of functions by roles in the organization as well as the above user friendliness. The performance capture format is completed by the owners representative responsible for overseeing the contractor's activities on a project. That person has no need to be concerned with the processes and values used in the subsequent calculations and vice versa and, therefore, each format is derived from that separation of organizational function. Once the project owner has set the values used in the performance scoring system the process can be carried out clerically or by computer. The setting up of sub sets of past performance records for future bid modification depends on the nature of the future project and should be decided for each project by either the owners adminstrator of that project or the chief estimator.

Suggested Performance Capture Format

The Performance Capture Format (see Figure 1) comprises a set of parameters each of which comes from one category on Level Three of the above hierarchy and expressed as rows of the matrix. The quality of contractor performance for each category/parameter on any one project is established against the given performance levels of Excellent, Good, Satisfactory, Poor and Terrible and expressed as columns of the matrix. A normal performance is rated as Satisfactory. The evaluator simply states the quality level of performance against a category by placing a mark in that matrix core element against that category and performance level. The information about each contractor and the project can be filled in before or after the performance evaluation.
The choice of five given levels of performance is appropriate because more or fewer categories appear to be either too many or too few for user friendliness and accuracy of evaluation. Also, these five levels of performance can easily mesh with the suggested scoring system and bid modification system described below.

Because the performance form is a distillation from the input data of so many expert forms and it will be the input into a calculation process it was considered that there should be no option for open ended opinions by the evaluator. In some situations open opinions may be desirable but usually these are sought to allow covering any factor that is not on the prearranged criteria. However, with the benefit of a set of criteria distilled from such a large and expert data base the potential and need for open opinions to augment the specific evaluation against criteria is greatly reduced and hence not considered needed on this format.

Because some of the categories on Level Two have comparatively small percentage weightings the range of categories could be reduced by combining some or eliminating some of an overall character, depending on the preferences of the

user. For presenting the results of this piece of research it was felt that all the categories should be presented with their percentages.

Suggested Performance Scoring System

The Performance Scoring System (see Figure 2) carries the evaluation from a subjective opinion of a performance level against each of seventeen parameter categories to a single numerical value for a contractor's performance on any one project. Also, that output single value is in a format that it can easily and quickly be used in the modification of a future bid from that contractor. This scoring system came mostly from the form used by Cleveland Electric and Illuminating Co.

The scoring system gives the values of 0.8, 0.9, 1.0, 1.1 and 1.2 respectively to the performance levels of Excellent, Good, Satisfactory, Poor and Terrible for each of the performance categories.

Furthermore, each category is weighted relative to the other categories by its percentage value within the whole performance of managing construction from the value of each category on Level Three of the hierarchy presented above. That validity was derived from the degree of use of the criteria found in the twenty project owners forms. The weighted value of the contractors performance against each performance category is reached by multiplying the performance score by the importance weighting of the category. Then, to arrive at a total performance rating across all categories, the weighted value for all categories are added up.

Because the scoring system is normalized to Satisfactory being 1.0 and the relative weightings of all categories are percentages, it follows that a "satisfactory" performance on all performance categories would create a whole performance value of 100, a "excellent" performance on all criteria would be 80 and a "terrible" performance would result in a whole value of 120. A mixture of performances per category would result in a value between 80 and 120. All of these should be expressed as a ratio against the datum of 100 for a satisfactory performance. Thus values of 80 and 120 would be considered as 0.80 and 1.20.

Suggested Process of Future Bid Modification by the Results of Contractors Performance Scoring

Available after a period of time will be a set of performance evaluations and scores for all contractors who have worked for a particular project owner over a duration of time. These can be sorted per each contractor, type of project, project location, dollar value of contract, and calendar dates of construction and any other feature considered useful such as contract type, e.g., lump sum or cost plus, etc. Subsets of these past records could be retrieved by any of these traits by sorting on a computer or manually.

For a future construction contract a project owner will receive an array of bids each from a different but specific contractor. The project owner can retrieve all the past performance scores for each bidding contractor who has worked before for the owner. For each bidder these may be sorted to say three groups (a) those which have occured over a duration thought appropriately recent (b) those projects similar to the one being currently bid and (c) those projects within a dollar range similar to the one being

currently bid. A single figure value of performance for each of (a), (b) and (c) may be calculated by mean, mode, median or time series projection and the three results then combined by a ratio thought to be appropriate among (a), (b) and (c) for the project being bid. The result of the calculations should be a value between 0.80 and 1.20 for each previously experienced bidder for the future contract.

Once the bid figure for the future project from each bidder is known by the project owner he can then multiply the bid amount of each bidder by his performance rating to arrive at a "true" bid figure reflective of his expected managerial performance. It is upon this resulting "management discounted true bid" figure that the project owner should make his choice of contractor for the project and then accept the dollar bid of that contractor.

CONCLUSION

This paper has analyzed the contractor performance rating forms used by twenty major project owners who reasonably frequently construct many projects. From that analysis of experts a distillation was synthesized to produce an hierarchy of the elements of their evaluations along with a sense of the relative importance of the performance categories found.

From this distilled base of expertise a user friendly form of evaluation was created from studying the twenty forms. A scoring system was utilized which had been found from one of the project owners by which that expertise evaluation could be used via simple arithmetic to modify the future bid of each contractor bidding for a future contract by the performance rating of the bidder.
Even if the hypothesized process or ingredients are ignored the paper presents the analysis and essential features of how numerous project owners evaluate the managerial performance of their contractors for the reader to synthesize his own system as he moves toward the future where expertise is used in more of a quantified and systematic manner than as a subjective, mysterious element of judgment as has been in the past. Alternatively, the reader may wish to only modify the values of the weighting system across parameter categories or performance levels or he may wish to test this pragmatic expert system in his own organization for the future or test it on the data he may have as an historical data base.

Furthermore, and of great importance to project owners, as contractors become aware that their current managerial performance on a project will be used to modify their bids for future work, such contractors begin to pay attention to improving their management of construction on all current projects. Clearly, this creates benefits to the contractors, project owners and the construction industry at large. Thus, a pragmatic expert system of performance evaluation as described above can and does play a part in improving the work done by the industry for society at large.

CONTRACTOR PERFORMANCE EVALUATION CATEGORIES		PERFORMANCE LEVELS EXCEL	GOOD	SATIS	POOR	TERRIBLE
Contractor Capability	1A					
Overall Performance	1B					
Quality of Site Staff Management	2A					
Quality of Craft Supervision	2B					
Interaction With Home Office	2C					
Quality of Safety	2D					
Efficiency of Use of Labor	3A					
Efficiency of Use of Equipment	3B					
Efficiency of Flow of Materials	3C					
Effectiveness of Cost Management	4A					
Effectiveness of Time Management	4B					
Claims By and Against Contractor	4C					
Interface With Owners and Agents	5A					
Interface With Other Contractors	5B					
Interface With Local Construction Industry	5C					
Labor Relations	5D					
Interface With Third Parties	5E					
CONTRACTOR NAME		CONTRACT AMOUNT				
CONTRACT START		CONTRACT				
FINISH DATES		PACKAGE				
PROJECT NAME		CONTRACT TYPE				
PROJECT LOCATION						

FIGURE 1 PERFORMANCE CAPTURE FORMAT

		PERFORMANCE LEVELS EXCEL 0.8	GOOD 0.9	SATIS 1.0	POOR 1.1	TERRIBLE 1.2	CATEGORY % WEIGHT	CATEGORY PERFORMANCE VALUE
	1A						x 3.0 =	
	1B						x 7.5 =	
	2A						x 9.5 =	
	2B						x 2.5 =	
	2C						x 6.0 =	
	2D						x 9.0 =	
	3A						x 10.0 =	
	3B						x 8.0 =	
	3C						x 9.0 =	
	4A						x 4.5 =	
	4B						x 12.0 =	
	4C						x 3.0 =	
	5A						x 6.5 =	
	5B						x 6.0 =	
	5C						x 0.5 =	
	5D						x 1.0 =	
	5E						x 2.0 =	
CONTRACTOR NAME							TOTAL VALUE OF PROJECT PERFORMANCE =	
CONTRACT START & FINISH DATES							CONTRACT AMOUNT	
PROJECT NAME							CONTRACT PACKAGE	
PROJECT LOCATION							CONTRACT TYPE	

FIGURE 2 PERFORMANCE SCORING SYSTEM