A Model By Which to Analyze Past and Forecast Future Managerial Performance In A Construction Process

by
George S. Birrell
Professor
School of Building Construction
University of Florida
Gainesville, Florida 32611
(904) 392-5965
and
Seung-Han Paek
Graduate Student, Ph.D. Program
Department of Civil Engineering
University of Missouri
Columbia, Missouri 65201

KEY WORDS

Construction Performance, Construction Team, Expert System, Management Model, Pragmatic Criteria.

SUMMARY

A previous major research project uncovered the factors of managing construction as used by general contractors to evaluate the performance of subcontractors and used by subcontractors to evaluate general contractor's managerial performance during the construction process. In addition, a sense of importance of factors was established from both general and subcontractors.

When both sets of factors are taken together they can be considered as the raw ingredients or parameters by which to measure the performance of the management of any construction process by any management group or agency.

This paper will describe a model of managing the construction process based on these factors and general organization theory. Also discussed will be how it could be used as an expert system to analyze past managerial performance and forecast the quality of future managerial performance.

A Model By Which to Analyze Past and Forecast Future Managerial Performance In A Construction Process
by
George S. Birrell
Professor
School of Building Construction
University of Florida
Gainesville, Florida 32611
(904) 392-5965
and
Seung-Han Paek
Graduate Student, Ph.D. Program
Department of Civil Engineering
University of Missouri
Columbia, Missouri 65201

MOTS-CLES

Construction Performance, Construction Team, Expert System, Management Model, Pragmatic Criteria.

SOMMAIRE

Une etude precedente a produit les elements que l'entrepreneur general d'une guestion de construction utilize dans l'evaluation du rendement des sous-entrepreneurs, et d'autres. Elements utilizes par les sous-entrepreneurs pour evaluer la gestion de l'entrepreneur general durant la construction. En plus, l'importance de tout ces ele- ments a ete etablie du point de vue de l'entrepreneur general et des sousentrepreneurs.

Quand ces deus groupes sont mit ensemble, on obtient des parametres necessaires pour l'evaluation de tout les ontrracteurs par n'importe quel groupe de geation.

Cet article decrit un modele de gestion d'une entreprise de construction base sur ces facteurs et la theurie d' "Organization Generale". On decrit ausse l'utilization de ces idees dans un "system expert" pour l'analyze des rendements des entrepreneurs et pour projettes la qualite du rendement future.

INTRODUCTION

This paper will describe an hierarchical model of managing the construction process derived from the distillation of the results of previous research which gathered a large set of factors/criteria by which expert staff of general contractors evaluated the management performance of subcontractors and by which expert staff of subcontractors evaluated the management performance of general contractors. The relative importance of the elements of the hierarchy and how such importance was established will also be presented.

The approach to using such analyses of past performances as a means of forecasting future performance by participants of roles in the construction process will be discussed.

Underlying the whole paper is the fact that the original research work derived its factors/criteria from well over a hundred staff in general and subcontractor organizations who were considered experts by their peers and contractor organizations. This high quality expertise foundation gives validity to the generalized hierarchical model and to the parameter questions against which past performances are analyzed and a performance rating established and future performances will be forecast.

THE GENERALIZED MODEL OF MANAGEMENT OF CONSTRUCTION

The generalized model of managing a construction process is in the form of an hierarchy, the apex of which is the whole management of the construction process. Each lower element of the hierarchy is presented at a vertical position representing its degree of importance and horizontally by the logic of its meaning in the context of management of organizations in general and managing construction in particular. How the percentage degree of importance of each element was established is explained later and the logic of the grouping of the elements was established from the common meanings of the initial input factors/ criteria.

The whole generalized hierarchical model is shown in Figure 1 and each major and minor element of it is now described.

1 Inherent attributes; Inherent attributes of managers of construction such as earnest attitude to his work, integrity of his behavior, his amount of work experience and knowledge of construction and the local market.

- 1.1 Attitude; The earnest attitude and behavior towards the work requirements and other participants.
- 1.2 Integrity; Honesty, morality, trustworthiness and fairness in dealing and interacting with others.
- 1.3 Knowledge and Experience; Accumulated amount of knowledge and experience in construction and the local market.

2 Financial Capability; Organization's financial capability and status. His methods of handling cash flows and the size and stability of his perceived or inherent or financial reserves.

3 Management Ability; Organization's ability of implementing activities in planning, organizing, leading and controlling to produce the end product effectively and efficiently.

3.1 Planning of Construction; Ability to set up his goals and objectives for the construction process, his insight to create efficiency in the whole construction process, and his ability to achieve these goals.

- 3.1.1 Pre-construction Services; All services and activities which must occur prior to beginning each piece of construction work e.g., shop drawings, etc., and site layout, temporary facilities, etc.
- 3.1.2 Planning and Scheduling; Ability of understanding the end product as a whole construction process and setting up scheduling to carry it out effectively and efficiently with the given resources and constraints.
- 3.1.3 Problem Solving and Decision Making; Ability of quickly identifying construction problems and determining alternative solutions even before they occur. Effective opportunity finding, problem solving and decision making are major features of planning construction.

3.2 Organizing; Arranging and allocating the work among participating trades and work squads so that the construction process can be effectively and efficiently carried out.

- 3.2.1 Arranging Resources Flows; Handling issues to minimize frictions to marshalling and expediting flows of all required resources to and on the site.
- 3.2.2 Coordination; Integrating the objectives and activities of the separate trades and work squads into one wholistic construction process and minimizing friction between them.

3.3 Leading; Directing, Influencing and Motivating the workmen to perform their tasks and even influencing construction process participants outside their entrepreneurial control.

- 3.3.1 Staffing; The quality of knowledge and energy of personnel of the on-site management of the whole construction process, i.e., the general's site super, assistants and trade site foremen.
- 3.3.2 Leadership; Ability, especially in the site super and site foremen, to direct, lead, motivate and creatively influence workmen and others on and off the site.
- 3.3.3 Ability to Expedite; Ability to aggressively push the resources flows through their construction work to ensure completion.

3.4 Control of Construction; Ensuring that actual construction activities conform to planned activities in cost, time and quality.

- 3.4.1 Communication; Good, clear communication within the project organization by acquiring quality information and putting it in the minds of staff who need it to do their work and make their decisions in an integrated manner.
- 3.4.2 Ability to Handle Changes; Ability to handle changes which may arise during the construction process, i.e., the ability of quickly settling change orders with the owner and his agents, keeping changes to a minimum number and prompt action toward handling the changes, etc.
- 3.4.3 Quality of Finished Work; Recognizing and providing the quality of work specified for the end product. Low quality work causes extra expenditure and delay as does demands by the owner or agent for a quality higher than specified.

In conclusion, the contractor's management ability comprises the largest part of the whole entity. Among the elements of management it was concluded that planning and scheduling, communication, arranging resource flows, and ability to expedite are the most important ones.

System Used to Establish Relative Weighting of the Elements

Weighting of the relative importance of each element in the hierarchy, which is represented by its vertical position in Figure 1, is based upon the degree of use of the criteria/factors gathered in the original main study and which are grouped by meaning under each element of the hierarchy.

In the original study each of one hundred experts was asked to state his degree of use of each criterion/factor used by his own type of contractor evaluating the other and the other evaluating him but this distillation study only considers the degree of use of the criterion/factor used by his own type of contractor. The degree of use of each criterion/factor was stated against the levels of "never", "sometimes", "most times" and "always" and these were summed for each level for office and site staff of each of general and subcontractors.

In this distillation study these results were multiplied by a weighting factor for each use level, i.e., "never" weighs 0, "sometimes" weighs 1, "most times" weighs 2 and "always" weighs 3 to produce a total score for each criterion.

Then two separate hierarchies were produced for the combination of office and site staff of each of general and subcontractors by grouping the criteria/factors related by their meaning to elements of each hierarchy.

Next the values of criteria/factors falling under each element of the two hierarchies had their weighting scores applied to the appropriate elements of each hierarchy. Where original criteria influenced the meaning of more than one element the scores were divided evenly to the appropriate elements of the hierarchy.

Finally these two hierarchies were combined to form the generalized hierarchy with its elements and their weighting values shown in Figure 1.

Scope of Cost and Duration Variances for the Participants in the Construction Process

The original study also established the cost and duration effects of very good and very bad performance against the criteria/factors and hence against the elements of the generalized hierarchy by general and subcontractors.

Regarding construction costs, i.e., contractors expenditures, in broad terms, the conclusions can be read that for the whole construction process about 10% of the expected costs of normal performance can be saved by a very good performance by the contractors against the elements of the generalized hierarchy and cost overruns of about 20% can occur from a very bad performance by the contractors against the same.

Similarly regarding construction durations, i.e., duration spent for construction, the conclusion is that about 15% of a normal duration can be saved from very good performance by the contractors but a duration overrun of about 22% can occur from a very bad performance against the elements of the above generalized hierarchy of managing construction. Space constraints preclude more detailed presentation of these results and calculations.

Furthermore, it should be realized that the sources of the above results were from peer selected experts rather than average contractors and it would seem reasonable that the range of potential savings and increases would be greater

for the average and poor quality contractors than the above results from top quality expert contractors.

Sources of Input Data and Research Distillation Process

The input data for this research project was derived from a very carefully formated research process which was obtained from top quality general contractors and subcontractor office and site staff the criteria/factors they use to evaluate the managerial performance of each other. Top quality of these sources was achieved by seeking such experts by the recommendation of their peers and contractor organizations. That their responses were appropriate for extrapolation to benefit the whole of North America was that the scope of the work marketplace of the above quality of contractors was that of the greater Detroit, U.S.A. construction market which encompasses a population of some six million people and a spread of industry and commerce which is reasonably typical of and at least as competitive entrepreneurially as other construction markets in North America. The selection of the contractors from within the above high quality group was made with appropriate random selection research processes, etc.

The research and distilling process which produced this generalized hierarchical model comprised four major phases, I Input Stage, II Synthesising The Data, III Building The Model and IV Writing The Report and Paper.

Phase I was the input stage, which consists of analyzing three parts; (1) general systems theories, (2) theories on management of humans, and (3) the input criteria/ factors. Information about parts (1) and (2) was gathered from relevant literature most important of which are listed in the bibliography below while part (3) was as described above.

Phase II was the stage of synthesizing the information gathered from Phase I by selecting the most appropriate approaches for this research and grouping by their meaning of the criteria/factors of part (3) of Phase I to form the input for Phase III.

Phase III was the building of the generalized hierarchy as described above.

Through the process of Phases I through III there were a considerable number of iterations and feedbacks to evolve compatibility of model to the management theories and pragmatic construction practices and to eliminate the writers' subjectivity as much as possible.

Phase IV was devoted to the writing of the report and this paper.

REQUIREMENTS FOR A PRAGMATIC EXPERT SYSTEM TO FORECAST MANAGERIAL PERFORMANCE ON A CONSTRUCTION PROCESS

Overview

It appears that the three major requirements for a pragmatic expert system to forecast management of construction performance are (a) Participants, (b) Project Data and (c) Parameters of Performance.

"Participants" is comparatively easy to consider in that someone or an organization manages a construction process now, has done in the past and will again do so in the future. Thus, any person or organization who manages a construction process is a "Participant" whose performance has to be captured from the past, stored and forecast for the future.

"Project Data" is a variable in that construction projects vary one to another but all have to be constructed. There appear to be (i) inherent characteristics such as type of end product, size, complexity, etc., (ii)

site characteristics such as location, surrounding environment, site conditions, etc. and (iii) temporal conditions such as calendar time of construction, competitive construction climate at time of construction, type of construction contract (e.g. lump sum bid, cost plus, etc.), etc.
"Parameters of performance" comprise meaningful parameters by which the performance of managing the construction process can be analyzed, stored and forecast.

Use of the Generalized Hierarchy in a Pragmatic Expert system

The expert system is used to analyze and crystallize the past performance of one Participant on one Project to produce "One Record". Under the name of the one particular participant that record will contain (a) the managerial performance against meaningful parameters singly and in combination for the whole project and (b) the characteristics of the project against a fixed set of meaningful project parameters. The project characteristics are used as variables from which to select sub sets of the records of possible managerial participants as input to forecasting the managerial effect of each possible participant for one future particular project (measured by the same set of project parameters).

The expert system to analyze, store and forecast performance in management of construction requires pragmatic parameters of performance by which to analyze past performance and from the results of a set of such records be able to forecast a likely future mode or quality level of management by a particular participant on a particular future project.

It is suggested that the elements on the base of the generalized hierarchy (see Figure 1) provide a realistic, meaningful and valid set of parameters of performance of managing construction and that for effectiveness in analysis they should be posed as a set of questions, one question representing each element on the base of the generalized hierarchy.

Thus, this single set of questions comprise the distillation of the base level elements of the generalized hierarchical model which in turn derives its validity from the distillation of all of the individual criteria/factors suggested by the experts of general and subcontractors in the original study.

The resulting fifteen questions in this set of parameters of performance in managing construction are:

- Does he have a cooperative attitude to others working on the project? (Attitude - 8.6%)
- Is he honest, trustworthy and fair-dealing? (Integrity - 9.1%)
- Does he have much experience in this type of construction work? (Experience - 6.6%)
- Does he have enough financial stability for this project? (Financial Stability - 10.5%)
- Does he provide good preconstruction services such as handling shop drawings, samples and lead durations? (Pre-construction Services - 2.9%).
- Does he have and use good planning and scheduling capability? (Planning and Scheduling - 13.5%)
- Does he quickly and effectively define problems, find solutions and make decisions? (Problem Solving and Decision Making - 3.6%)
- Does he arrange construction resources flows properly by quantity, quality and timing? (Arranging Resources Flows - 10.4%)
- Does he appropriately coordinate his own work with that of all trades? (Coordination - 2.9%)

- Does he put a capable manager (site super or foreman) and site staff on each project? (Staffing - 2.3%)
- Does his site manager have human leadership ability and use it? (Leadership - 2.3%)
- Does he push his work and that of all others to completion? (Ability to Expedite - 6.5%)
- Does he have good communication ability and use it with others involved on the project? (Communication - 14.9%)
- Does he quickly respond to and handle changes in the end product design and in the construction process? (Ability to Handle Changes - 3.2%)
- Is his work inspection adequate to provide the required quality but not too tight? (Quality of Finished Work - 2.7%).

Most of these questions were derived from the meaning of a base level element on the hierarchy and the thrust of the original criteria/factors from which that element was created but some of them were an original question/criteria/factor derived from the original input data for this study.

The format of a question is appropriate to analyze past performances where it can be seen as an evaluative criterion. It would appear advantageous to establish a fixed set of performance levels ranging from Excellent to say Terrible against which each above performance question would be answered. These performance levels may or may not be given fixed numerical values. If so they should use a satisfactory or normal performance as 1.0 and Excellent and Terrible arrayed on either side of normal with appropriate numerical values.

The so captured single performances of a participant can be combined mathematically to a single value for each record or left in the more complex original format. The resultant performance record for one participant on one project can be combined with other performance records of the same participant as a time series or a subset of values from a set of projects chosen due to their similarity to the future project (against the same set of meaningful project parameters). However, the use of the base level elements of the hierarchy of managing construction as the source of the above performance parameters gives validity to the processes of analysis, storage and forecasting by them.

CONCLUSIONS

Much effort has been spent over the past few years on developing "value engineering" of construction. Virtually all of this effort has been directed at modifying the design of an end product to reduce the cost of its construction, i.e., reduce the volume of consumption of resources in the construction process but with no attempt to improve or increase the value of the construction process and its quality of management which is its most crucial feature of efficiency.

In response to the above vacuum, this paper presents the distillation of the results of research directed at "value engineering the management of the construction process" itself. It is the management of construction which selects, permutates and controls all the resources of the construction process yet apart from the research underlying this paper little objective research has been directed at establishing the parameters and their relative values of that management and their cost and duration effect upon the construction process.

In general, if the elements of the generalized hierarchy of managing construction presented in this paper are performed very well there can be a combined savings in cost and duration of the construction process of about 12½% from normal performance by experts and conversely a very poor managerial performance will add about 20% over the combination of normal expenditures of cost and time. It should be noted that nothing has to be changed in any end product to be constructed to achieve these variances. Such savings and overruns come from the degree of quality of performance of management of construction alone against the distilled elements of management of construction presented in this paper.

By the average managers of construction, appropriately allocating their attention to the elements of the generalized hierarchy they can improve their performance in managing the construction process towards the level of the experts from whom the original criteria/factors were drawn and from which all the above results derive their validity.

The paper also suggests an outline of a pragmatic expert system for analysis, storing and forecasting of performance level of a possible manager of construction for a future construction process, which uses the elements of the hierarchy as parameters of performance.

BIBLIOGRAPHY

Anderson, David R., Sweeney, Dennis J. and Williams, Thomas A., "Essentials of Management Science", West Publishing Co., St. Paul, 1978.

Beer, Stafford, "Management Science - The Business Use of Operations Research", Doubleday & Company, Inc., Garden City, N.Y., 1968.

Birrell, George S., "The Criteria by Which Construction Prime and Subcontractors Evaluate The Management Performance of Each Other," Ph.D dissertation, Graduate School, University of Michigan at Ann Arbor, Ann Arbor, 1978.

Birrell, George S., "General Contractors' Management: How Subs Evaluate It", Journal of Construction Engineering and Management, Vol. 111, No. 3, September, 1985.

Burns, Tom and Stalker, G.M., "The Management of Innovation", Social Science Paperbacks in association with Tavistock Publications, London, 1966.

Burton, R.M. and Obel, B., "Designing Efficient Organizations; Modelling and Experimentation", North Holland Publishing Co., 1984.

Churchman, West C., "The Systems Approach", Delacorte Press, New York, 1968.

Handler, Benjamin A., "Systems Approach to Architecture", American Elsevier Publishing Company, Inc., New York, 1970.

Katzan, Harry, Jr., "Systems Design and Documentation, An Introduction to the HIPO Method", Van Nostrand Reinhold Company, New York, 1976.

Krone, Robert M., "Systems Analysis and Policy Science", John Wiley & Sons, Inc., New York, 1980.

McGartland, Martin R. and Hendrickson, Chris T., "Expert Systems for Construction Project Monitoring", Journal of Construction Engineering and Management, Vol. 111, No. 3, September, 1985.

Optner, Stanford L., "Systems Analysis for Business Management, 2nd ed.", Prentice-Hall, Inc., Englewood Cliffs, N.J., 1978.

Rehak, Daniel R. and Fenves, Steven J., "Expert Systems in Civil Engineering, Construction Management, and Construction Robotics". Department of Civil Engineering, Carnegie Mellan University.

Rivett, Patrick, "Model Building for Decision Analysis", John Wiley & Sons, Inc., Chichester, 1980.

Stoner, James A.F., "Management, 2nd ed.", Prentice-Hall, Inc., Englewood Cliffs, N.J., 1982.

Wilson, Ira G. and Wilson, Marthan E., "From Idea to Working Model", John Wiley & Sons, Inc., New York, 1970.

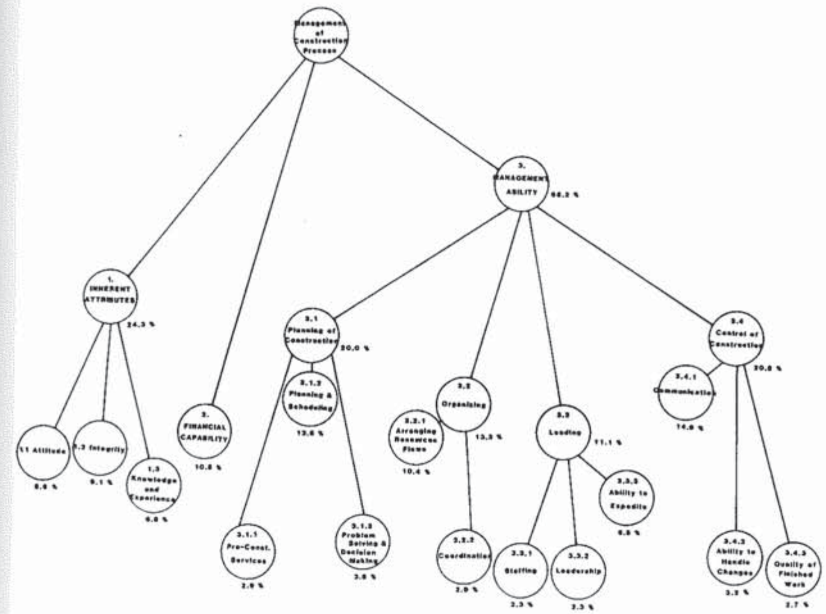

Figure 1 Hierarchy of the Essentials of Managing Construction Projects