PERFORMANCE MEASURING BENCHMARKING, AND MODELLING OF CONSTRUCTION PROJECTS

Luis F. Alarcón and Alfredo Serpell

Department of Construction Engineering and Management, School of Engineering, Pontificia Universidad Católica de Chile, Santiago, Chile

A research effort currently underway is described in this paper. The project comprises the design and implementation of project performance measurement systems in construction companies, with the dual purpose of supporting continuous improvement for company operations and to generate a database with empirical information on projects. This database will be useful to develop third party benchmarking to contribute to the improvement of the industry as a whole. This research proposes the development of computer models that combine empirical information with expert knowledge to perform model based benchmarking. The achievement of the objectives of this research should affect the way in which performance is measured and decisions are made in projects. The implementation of performance measurement systems, that include measures adapted to lean construction can be a real driver for continuous improvement of project processes. The compilation of empirical information, and its integration with the experience found in the industry and in project teams, will provide new evidence on project performance. This will assist in exploring the mechanisms and existing interactions through the use of simulation models. The proposed analysis may take a first step in deriving first principles on project performance. This research project lends itself to a collaborative research effort which could be carried out in different countries and locations.

1. Introduction

There is consensus among researchers and industry experts that one of the principal barriers to promote improvement in construction projects is the lack of apropriate performance measurement. For continuous improvement to occur it is necessary to have performance measures which check and monitor performance, to verify changes and the effect of improvement actions, to understand the variability of the processes, and in general, it is a necessary to have objective information available in order to make effective decisions.

In recent research by Alarcón and Serpell (1996), a comprehensive review of existing literature was carried out in order to identify performance measures at both company and individual project levels. Concurrently, an exploratory study was carried out in seven major chilean construction companies to assess the performance measures used in current construction practice. The purpose of this research is to promote and support the implementation of performance measurement systems in Chilean companies. In supporting the continuous improvement within this companies and establishing a basis for the accomplishment of third party benchmarking, the research will contribute to the progress of the construction industry.

Currently, a group of Chilean companies supported by a private research corporation is trying to implement a permanent plan for compilation of empirical information to develop model based benchmarking. Development of models using empirical information from the project database would contribute to a better understanding of the causalities and mechanisms by which the projects obtain better or worse results.

In a subsequent stage, this research intends to implement the analysis and the validation in time of the developed models, using computer simulation. The result will be a decision support tool to analize strategies and predict project results. This paper summarizes the main aspects of this research, which can be enhanced with the collaboration of researchers in other countries particularly with respect to the development and compilation of project performance measures.

2. Measuring Performance

Through the implementation of performance measures (what to measure) and selection of measuring tools (how to measure) an organization communicates to its members the priorities, objectives, and values which the company looks for in the achievement of strategic objectives. The selection of appropriate measurement parameters and procedures is very important to achieving a good monitoring, control and evaluation of variations and improvements. The definition of what parameters to use as performance measures will depend on the specific characteristics of each case.

It is important to recognize that traditional performance measurement practices are usually inadequate and that very often performance is strongly associated with a reward and punishment system. This is part of a control philosophy where many times the objective is to find the guilty party and to impose a sanction. Thus, a the primary objective of improving the organization in a team effort is overlooked. Under these circumstances it is difficult to find unbiased performance information and a collaborative attitude of people. Therefore, the implementation of an unbiased performance measurement system makes it necessary to change this philosophy of control. The measurement of performance should be oriented toward the search of "improvement opportunities," where all the participants are actively involved in the improvement effort.

It is also important to note that traditional performance parameters measured in projects, namely costs and schedule, are not appropriate for continuous improvement; because they are not effective in identifying causes of productivity and quality losses. These parameters do not provide an adequate vision of the potential for improvement and the information obtained usually arrives too late to take corrective actions. Nearly all non value-adding activities become invisible within traditional control systems since these center their attention in conversion activities and ignore flow activities. For this reason it is of great importance to incorporate performance measures that promote continuous improvement in company processes and make visible non value-adding activities.

3. Performance Measurement Practice in Chilean Projects

An exploratory study which included more than seventy interviews with personnel from seven selected construction companies was carried out in order to evaluate the current performance measurement practice in Chile. This section summarizes, some conclusions of this study.

The interviews which were conducted revealed that performance measurement in the construction industry in Chile is fundamentally focused on projects, and specifically on monitoring cost, and schedule and sometimes quality performance. A secondary focus is the tracking of labor and equipment productivity during project execution and at completion.

The measurement of non construction performance and internal benchmarking practice for projects done by the same company does not exist. Approximately 70% of the respondents informed that there were no formal performance measurements of processes in which they participated. The remaining 30% who responded afirmatively belonged to the operations areas and were associated with construction execution processes.

The most commonly used measurement paremeters for projects are listed below. Most of these are used periodically during construction as well as at completion:

- Actual Cost / Budgeted Cost
- Actual Man Hours/Budgeted Man hours
- Actual Duration/Planned Duration
- Labor and Equipment Productivity
- Project Profit
- Progress Measurements
- Accident Frecuency Rate

The persons interviewed were consulted on the objectives, benefits, and desirable characteristics of a performance measurement system, and on their own experience in the implementation of performance measurements. In spite of the scarce use that the industry makes of the measurement of process performance, the interviewees expressed interest in the topic and their responses were in line with the information found in the literature. The potential benefits from performance measurement were identified as:

- Potential for better control.
- Identification of areas with problems or with potential for improvement.
- Well informed and timely decision making

On the other hand, the interviewees expressed that a performance measurement system should have the following characteristics:

- Measurement parameters should be simple and limited in number.
- Definition of the system objectives should be clear and transparent.

The problems most frequently found when implementing performance measurement systems were:

- Lack of commitment from personnel directly involved and middle management.
- Rejection to performance measurement due to lack of visualization of their benefits.
- Rejection to performance measurement due to fear of punishment.

The main recommendations given to facilitate the implementation of performance measurements were:

- To define and to communicate clearly the objectives of the system.
- Promote participation of personnel in the design of the measuring system.
- Promote commitment by illustrating the benefits which can be obtained.

4. Performance Indicators for Benchmarking

The principal requirement of the research sponsor, the Chilean Chamber of Construction, was that the study by Alarcón and Serpell (1996) generate performance parameters that could be used by construction companies analyzing, quantifing and comparing their own performance as well as comparing their performance with that of other construction companies. The discussion below reviews some important aspects of the use of benchmarking as an improvement tool.

Benchmarking in other Industries

Xerox which began the benchmarking in United States in 1979 provides the following example:

> "The continuous process of comparing products, services and practices with those of the strongest competitors or with the leaders of the industry".

AT& T defines benchmarking as:

> "A process in which the companies are focused to study key improvement areas in their operations, identify and study the better practices of others in their areas, and put under way new processes and systems to improve their productivity and quality".

Benchmarking in Construction

Benchmarking is a new topic in the construction industry. To this date there is almost no available information that describes the potential that benchmarking offers to construction. Fisher (Fisher 1995) confirms this observation concluding that today there are not available standards for benchmarking in the construction industry. The scarce experience with benchmarking in the construction industry has been limited to comparing project results. The database created by the Houston Business Roundtable (HBR), one of the first attempts to develop a plan of benchmarking in construction, only contains information on global results of the projects allowing the parties to compare their performance with that of the rest of the projects of this database. This database was developed by sending questionairs to company representaties to determine if there was any interest in benchmarking, and if so what parameters should be used. The following were the parameters propose by the participating companies:

- Authorized vs. actual cost
- Authorized vs. actual schedule
- Actual labor vs. estimate
- Scope change vs. original scope

The proposed parameters reflect an interest in comparing measures of results rather than identifying the deficiencies in practices which affected the results. Actually, this is more of a competitiveness analysis than a benchmarking (Muñiz 1995). It is important to note that the information of the HBR has been used in Chile recently by CODELCO, the world's largest copper producer, to compare the results of approximately twenty projects (Salmona 1995).

Another recent study by the Construction Industry Institute of Australia (CIIA 1995) (Mohamed 1995), carried out a literature review and the analysis of three case studies, and found that all the comparisons were done using cost and schedule results of projects. However, in this study a long list of causes of project poor results was identified, which represents a step forward with respect to the effort by the HBR.

Benchmarking project results (cost, schedule, etc.) has a limited value since, at the most, it identifies global problems areas, but does not help to select a possible improvement strategy. A company can know if its planned schedule or cost performance is met, but it can not know the source of the problems that exist nor can it know why its competition is more successful in achieving its results. This can only be achieved analyzing the factors, which lead to a successful performance.

Benchmarking the results of a project leaves a company part way in the utilization of this improvement tool, since it arrives only at the first stage (Watson 1994):

1. To understand own processes and to detect its weaknesses and strengths.

   But it does not accomplish the following stages:

2. To understand the leaders of industry or competitors; to identify, to understand and to compare the better practices.
3. To incorporate the best; to copy, to modify or to incorporate the better practices in its own processes.
4. To gain superiority by combining it's own strengths with better existing practices.

These last three stages constitute the base of the benchmarking as improvement tool.

5. Model Based Benchmarking

Model based benchmarking can be used to enhance the value of benchmarking as an improvement tool in construction (Muñiz 1995). This paper proposes to use performance measures not only for results but also for processes and other key factors of projects in order to make possible a model based benchmarking. This is, a combination of strategic and operational benchmarking (Fisher 1995) which will allow:

- To educate the industry about the causality of the results and to achieve a better understanding of the reasons behind reaching a better or worse performance.
- To identify the processes which have greater potential impact in the results of the projects.
- To identify better practices in those key processes.
- To develop a model that anticipates results in specific projects.
- Greater tolerance to voids of information, since the relationships among the variables will be known

Modeling Bases

Statistical analysis serves as a traditional tool for developing models from empirical information. However, recent studies provide other options that result very attractive for developing models using information gathered on project performance (Alarcón & Ashley 1992, 1996). Alarcón has recently developed a methodology to evaluate project management strategies whose principal components are indicated below:

1) A general methodology for the acquisition and modeling of expert knowledge for evaluating decisions in projects (Alarcón &Ashley 1995a).
2) A mathematical model based on concepts of cross-impact analysis and statistical inference (Alarcón & Ashley 1995b).
3) A representation scheme to support communication and problem structuring during the modeling process.
4) A prototype computer implementation to automatize capturing and processing of information to analyze a model (Alarcón et al 1995).

The methodology consists of a conceptual, qualitative model structure and a mathematical model structure. The conceptual model structure, called the General Performance Model (GPM), is a simplified model of the variables and interactions that influence project performance. The mathematical model uses concepts of cross-impact analysis and probabilistic inference to capture the uncertainties and interactions among project variables.

A key success achieved by this study is a simple model structure to capture, store and link the special expertise of many different parties in the construction industry. The model combines the client's preferences, or weights, toward outcomes such as schedule or budget with the special insight of the project team charged with the design, procurement and construction of the facility. The structure of the GPM is summarized in Figure 1.

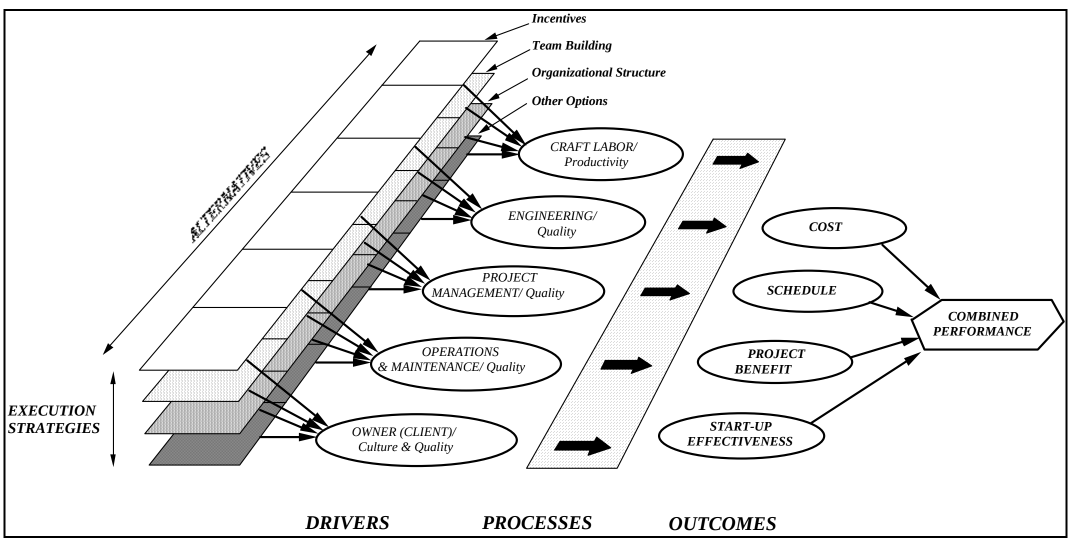

Figure 1 - General Performance Model

The computational scheme utilized within the model allows for different execution strategies to be compared on a relative basis. Preferred strategies are ranked either on the basis of combined performance or on any single chosen criterion. Sensitivity analyses help determine the robustness of any highly-ranked strategy, as well as which drivers or processes have greater impacts on outcomes.

This work provides a conceptual and theoretical framework for modeling decision situations that will serve as a base for the development of the proposed models. The prototype computer implementation will help in the development and analysis of the models built in this research and will serve as base for the development of a computer platform for the practical application of benchmarking models.

A recent research project *Prediction of Integration Impacts on Engineering-Procurement-Construction (EPC) Processes on Industrial Facility Quality,* developed by Ashley & Teicholz (1993) used the GPM modeling approach to develop a predictive model of project performance based on technical and organizacional integration measures in EPC projects. The results that this model is capable of predicting are: cost, schedule and quality of the processes and finished facilities in an EPC project. The model has permitted to explore the causes of problems in EPC projects and to know why integration and other variables of the process impact the quality of the finished facilities.

There are several aspects of the Ashley & Teicholz (1993) study that contribute to the research described in this paper, however, the most notable aspect is referred to the use of empirical information in the modeling scheme. While previous research (Alarcón 1992) and (Alarcón 1996) used expert subjective assessments as its primary input, Ashley & Teicholz´s model was developed integrating expert assessments with empirical data from seventeen EPC projects. The model developed by Ashley & Teicholz is an attempt to derive and include first principles for key interrelationships within a project model. The research described in this paper is attempting to consolidate a methodology to accomplish this evolution from “heuristic information” to “first principles” in the chosen decision areas. Figure 2 depicts how a new domain evolves from "no knowledge" to "compiled knowledge." So far, what we know about project strategies and their impacts on final performance would classify as heuristics or "rules of thumb". The subsequent step is to search for the first principles and axioms that can be utilized in furthering this field of study. In the proposed research, it would be possible to strive toward compiling the "deep knowledge" by analyzing project performance data and then replacing expert heuristics with these derived principles. The model structure should allow this replacement to occur incrementally and on an ongoing basis, thus continually improving with more research.

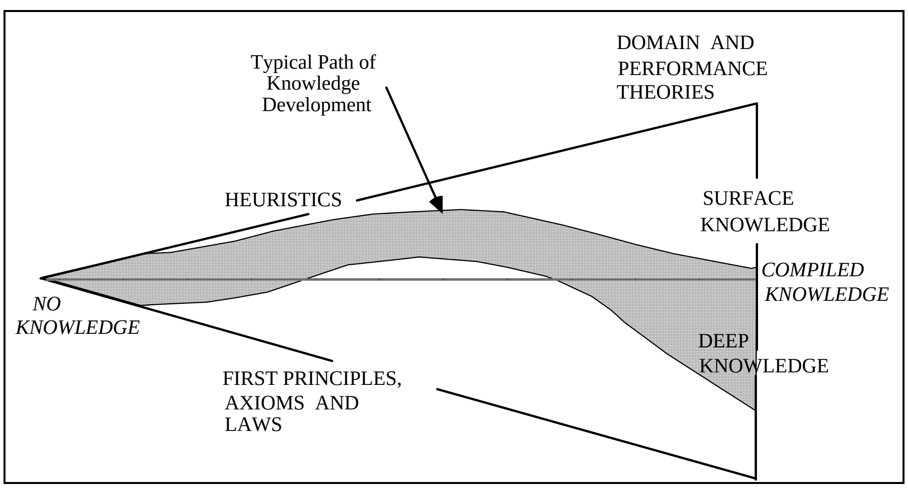

Figure 2 - Evolution of Domain Knowledge (after Harmon & King [Harmon85, p. 33])

6. A Preliminary Proposal for Measuring Performance

In order to carry forward this study Alarcón and Serpell (1996) have selected processes and project results used in models developed recently in Chile and abroad. They are listed in Table 1, with proposed measures of performance which can be used for these variables. Currently, an effort is being carried out with a group of companies to implement a performance measurement system which includes this set of measuring parameters.

TABLE 1 Proposed Project Performance Parameters

RESULTS	PARAMETERS	UNITS
Cost	Cost varation	Actual cost/Budgeted cost
Scheduled duration	Schedule variation	Actual duration/Planned duration
Quality	Rejection of work	% Sample rejections
Scope of work	Change in scope of work	Change orders/Budgeted cost

PROCESS	PARAMETERS	UNITS
Procurement	Delivery time	Delivery cycle time
	Compliance w/specs	% compliance w/specs
Construction	Labor (MH)	Actual labor MH vs Planned MH
	Productivity	Actual vs Planned
	Rework	Rework MH/Total MH
	Material waste	% Material waste
	Equipment	% stand by hours.
	Activities at planned rate	% activities working at planned rate
Planning	Planning effectiveness	% Planned Activities Completed
Engineering Design	Design changes	Number of changes/ Total number of drawings
	Errors /Omissions	Number of errors/ Total number of drawings

OTHER VARIABLES	PARAMETERS	UNITS
OH & S	Accident frequency	Number of accidents*100/ Total number of workers
	Risk rate	Number of days lost*100/ Annual Average of workers
Subcontracts	Subcontracted MH	% MH subcontracted
	Subcontracted $	% of cost subcontracted
Others		

The collection of information on these performance parameters will allow, as the database grows, to statistically study the existing correlations among results, characteristics and intermediate processes of projects and to develop models to explain the existing causalities;

all of which will help to identify the sources of success and failure in construction projects. In this way it will be possible to focus on more accurate studies of operational benchmarking to identify best practices for the industry to improve as a whole.

7. Summary and Conclusions

This paper has summarized the main aspects of a research effort currently underway. The project lends itself to a collaborative research effort. The principal aspects of this research can be summarized in the following specific objectives:

1. To propose and support the implementation of project performance measurement systems in construction companies, with the dual purpose of supporting continuous improvement for company operations and to gather empirical evidence in a standard form.

2. To generate a database with empirical information on projects, which will be useful to develop third party benchmarking which contributes to the improvement of the industry as a whole. With respect to the limitations of benchmarking of results, it is proposed that benchmarking parameters include the measurement of processes and other intermediate factors present in projects.

3. To develop models that combine empirical information with expert knowledge. These models will be used to develop first principles of project performance in the areas of interest.

4. To develop a computer platform to facilitate continuous updating of the models and their use as decision support tools by industry people.

The achievement of these objectives could have an important effect in the way in which performance is measured and decisions are made in projects. The implementation of performance measurement systems, that include measures adapted to lean construction can be a real driver for continuous improvement of project processes. The compilation of empirical information, and its integration with the experience found in the industry and in project teams, will provide new evidence on project performance. This will assist in exploring the mechanisms and existing interactions through the use of simulation models. The proposed analysis may take a first step in deriving first principles on project performance.

The practical use of this information would inform to industry about the causality of results and would allow a better understanding of the reasons that lead to a better or worse performance. The application of the model would allow identification of the processes with greater impact on the projects performance and the better practices required in those key processes. In addition, the implementation of a database with information on project performance can provide a very important information source for future research in different areas.

Acknowledgments

The authors sincerely thank the Corporación de Capacitación de la Construcción for its collaboration and the sustained support for this line of research.

References

Alarcón, L. F. , 1992, "Project Performance Modeling: A Methodology For Evaluating Project Execution Strategies," Ph. D. Dissertation, Department of Civil Engineering, University of California, Berkeley, April, 1992.

Alarcón, L. F. and Ashley, D. B., 1995 (a), "Cognitive Aspects of Influence Diagram Modeling", pp. 1479-1486, 6th International Conference on Computing in Civil and Building Engineering, Berlin, Germany, July 12-15.

Alarcón, L. F. and Ashley, D. B., 1995 (b), "Cross-Impact Methodology for Project Decision Making", pp. 767-773, CERRA ICASP-7, 7th International Conference on Application of Statistics and Probability, Paris, France, July 9-12.

Alarcón, L. F. , Venegas, P., and Bastías, A., 1995, "Computer-Aided Project Decision Making", pp. 1553-1560, 3rd International Conference on Computing in Civil Engineering, American Society of Civil Engineers, ASCE, Atlanta, USA, June 7-10.

Alarcón, L. F., y Serpell, A., 1996, "Performance Indicators for Chilean Construction Companies", Proyecto Productividad en la Construcción, Informe de Investigación a la Corporación de Investigación de la Construcción, Escuela de Ingeniería, Pontificia Universidad Católica de Chile, Marzo.

Alarcón, L. F., and Ashley, D. B., 1996, "Modeling Project Performance for Decision Making", Journal of Construction Engineering and Management, ASCE, (programado) Vol. 122, Nº 3, Sept.

Ashley, D.B., and Teicholz, P., 1993, “Prediction of Integration Impacts on Engineering-Procurement-Construction (EPC) Processes and Industrial Facility Quality”, a Proposal to the National Science Foundation, Department of Civil Engineering, University of California Berkeley and Department of Civil Engineering, Stanford University.

Construction Industry Institute Australia (CIIA), 1995 (a), Benchmarking Engineering and Construction, Winning Teams.

Construction Industry Institute Australia (CIIA), 1995 (b), Benchmarking Engineering and Construction, Review Performance and Case Studies.

Fisher, Deborah and Susan Meirtschin, and David E. Pollock Jr., 1995, “Benchmarking in Construction Industry”, Journal of Management in Engineering, January/February.

Harmon, P. and King, D., 1985, Expert Systems, John Wiley & Sons, Inc.

Lema N.M., and Price, A.D.F., 1995, “ Benchmarking: Performance Improvement Toward Competitive Advantage,” Journal of Management in Engineering January/February.

Mohamed, S., 1995, “Benchmarking, Best Practice - and All That”, 3rd Conference on Lean Construction, Albuquerque, USA.

Muñiz, R. , 1995, Benchmarking in the Construction Industry : A Model Based Approach, University of California, Berkeley.

Salmona, M., 1995, Benchmarking en proyectos de Ingeniería y Construcción en la División Chuquicamata de Codelco Chile. Seminario Calidad en la Gestión de Proyectos de Construcción, Santiago, Chile, Mayo.

Watson Gregory H., 1994, “ The Benchmarking workbook “ Productivity Press.