BENCHMARKING MANAGEMENT PRACTICES IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

This paper presents the results of the first application of a management evaluation system for benchmarking management practices in the construction industry. The system supports a National Benchmarking System recently established in the Chilean Construction Industry by incorporating qualitative management aspects in addition to quantative performance indicators. Different analysis were made to determine trends in the industry sector by correlating the qualitative evaluations from surveys with the performance indicators. Thirteen construction companies participated in the initial application of the benchmarking system. A correlation analysis found that safety performance was strongly related to companies having superior planning and control, quality management, cost control and subcontractor management policies. An factor analysis undertaken found that Central office priorities center on strategic management policies having longer term competitive impact, whilst site management emphasizes tactical management dimensions consistent with shorter term impact. There is scope to elevate the profile of continuous improvement initiatives to strategic significance at central [1]office level.

KEYWORDS

Qualitative Benchmarking, Management Dimension, Performance Indicators, Management Evaluation System.

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INTRODUCTION

Benchmarking is an important continuous improvement tool that enables companies to enhance their performance by identifying, adapting and implementing the best practice identified within a participating group of companies (CII 2002) (CBPP 2002) (Knuf 2001) (Smith 1997).

A group of 24 companies in the Chilean construction industry has participated in a National Benchmarking study that also provides reference to international benchmarks (Alarcón et. al 2001). The National Benchmarking System was developed by the Corporation for Technical Development (CDT) of the Chilean Chamber of Construction, with the support of the Program for Excellence in Production Management of the Pontificial Universidad Católica de Chile (GEPUC). By comparing key performance indicators, the CDT hopes to identify best practices and generate short term improvement opportunities for the participating companies (FDI 2001). However, using performance indicators to measure the "gap" between individual company performance and the industry leader will generally not enable the root cause of the difference to be determined. To identify the management practices that underpin these performance differences, it is necessary to complement a quantitative benchmarking system with a qualitative one based on a structured industry questionnaire. Qualitative benchmarking provides information on different management dimensions to help identify best practices and explain observed performance differences.

MANAGEMENT EVALUATION SYSTEM

This paper advances the use of a structured questionaire to evaluate aspects related to the organizational culture and management of construction companies (Figure 1). The results of the questionaire are then correlated against the quantitative performance indices obtained from CDT's National Benchmarking study to establish causal relationships. The proposed system has four input elements; two surveys, one for central office and another for the construction sites, annual project performance indicators and process indicators obtained from benchmarking clubs developed by CDT.

Once the data is entered to the data base, the analysis is divided in three parts with the objectives of performing a qualitative benchmarking among the companies participating in the study, establishing causal relationships between the quantitative and qualitative benchmarking results and identifying industry trends.

THE SURVEYS

Two questionnaires were developed as part of the qualitative benchmarking system (Ramirez 2002). The first of these is directed at employees working at a company's central office involved in administrative and tendering processes. The second is directed at construction site personnel, namely project managers, project engineers and foremen.

The management dimensions considered in the questionaire and the number of questions related to each dimension are shown in Table 1.

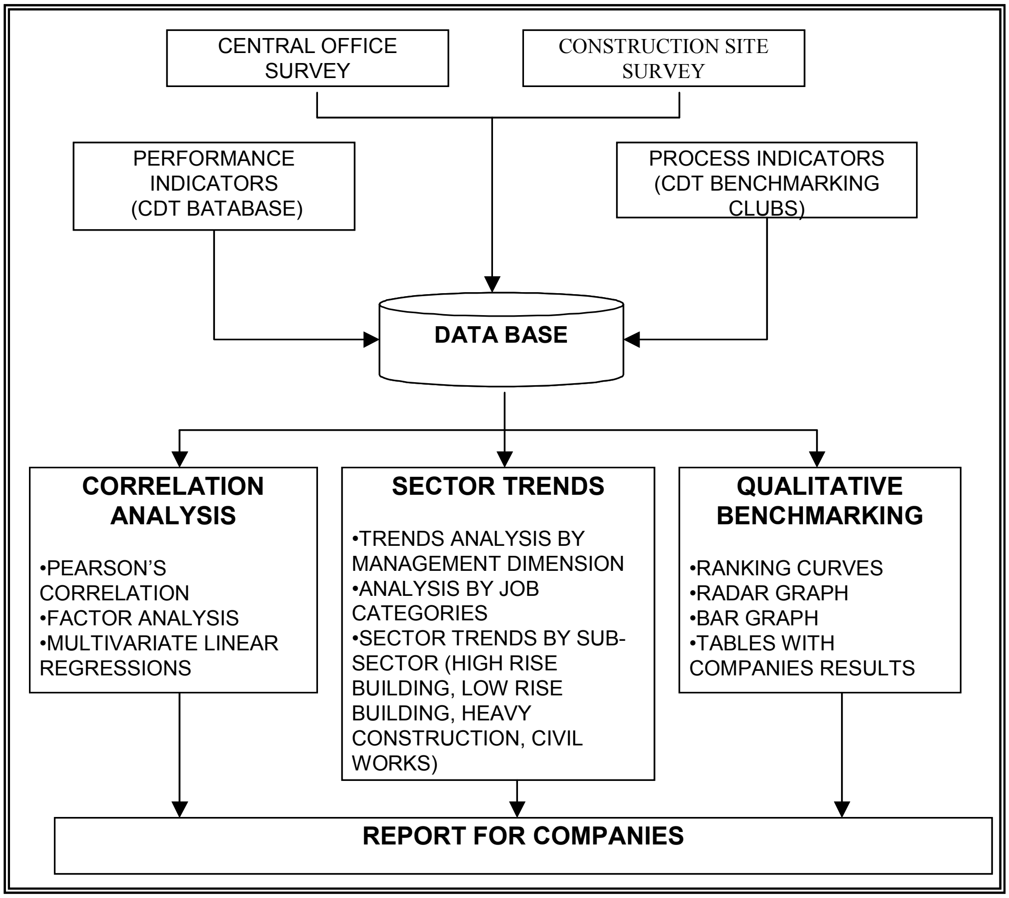

Figure 1: Diagram of Management Evaluation System

Table 1: Management dimensions considered and number of related questions.

Management dimension	Central Office Questionaire	Construction Site Questionaire
Leadership	5	8
Understandable Goals	5	5
Human Resources and Training	12	12
Organization for change	7	6
Planning and Programming	7	9
Production System	9	7
Use of Information and Communication Systems	11	11
Cost and Due Date Control	4	5
Quality	8	10
Purchasing and Inventory Control	4	11
Subcontractor Management	5	6
State of Technology	11	11
Relationship with Owner	0	5
Relationship with Designers	0	5
Safety Practices	0	5

The questionnaires were prepared on the basis of a review of relevant literature (CII 2000) (Buzzoni 2000) (Gonzales 2001) (Oddo 2000), as well as advice from well-known professionals in the sector and professionals from CDT and GEPUC. All questions were closed, requiring the user to respond from five distinct possibilities varying from "complete disagreement" to "complete agreement". An indice from 1 to 5 was assigned to each answer, with 1 corresponding to "complete disagreement". The questionnaires developed for the construction sites included the option "unknown", which was assigned a value 0. This was included to reflect the educational level and access to information of some of the potential respondents.

PERFORMANCE INDICATORS

The performance indicators measured during the year 2001 by (FDI 2002) are shown in Table 2. The median of these indicators is entered directly to the database that makes up the system.

Table 2: Performance Indicators Used

Area	Indicator	Units
Cost	Deviation of Cost by Project	(Real Cost – Budgeted Cost) / Budgeted Cost
Due Date	Desviation of Construction Due Date	(Real Due Date – Initial Due Date Budgeted) / Initial Due Date Budgeted
Scope of Project	Change in Amount Contracted	Sale Final Contract / Sale Initial Contract
Safety	Accident rate	(Number of Accidents)*100/ Total Number of Workers
	Risk Rate	(Number of Days Lost)*100/ Yearly Average of Workers
Labor	Efficiency of Direct Labor	Direct Hours Budgeted / Direct Real Hours
		Budgeted Cost Direct Hours / Cost Real Direct Hours
Construction	Productivity – Performance	Sale Final Contract / Direct Real Hours Labor at Construction Site
		Sale Final Contract / Relevant Units Executed
Subcontracts	*Rate of Subcontract*	Amount Sub-contracted / Sale Final Contract
Quality	Cost Client Complaints	Cost Client Complaints / Total Cost of Project
		Cost Client Complaints /Number of Complaints per Client
Procurement	Urgent Orders	Number of Urgent Orders / Total Number of Orders
Planning	Effectiveness of Planning	% Completed Activities (PCA) = Number of Activities Completed / Number of Activities Programmed

PROCESS INDICATORS

Process indicators are indicators concerning the efficiency of the construction process (m^3/manhour concrete, m^2/manhour formwork, for example). These indicators originate from information compiled and administered by CDT through benchmarking clubs.

The system uses two data sub-bases; one with information originating from central offices and another with information derived from the construction sites with their corresponding process indicators.

DATABASES

A weighted average for each management dimension between 0 and 1was calculated. The questionnaires were designed so that best-practice was always the option "complete agreement" or "yes" in the case of the dichotomous questions. The questionnaires also included a group of questions unrelated to best practices with the purpose of capturing information regarding the relationship of construction companies with their clients and engineering design firms.

RESULTS FROM THE FIRST APPLICATION OF THE BENCHMARKING SYSTEM

13 companies associated with the National Chilean Benchmarking System participated in the first application of the qualitative benchmarking system. 42 questionnaires were completed by central office personnel and 87 by construction site representatives.

QUALITATIVE BENCHMARKING

Comparison of the performance of individual companies with their corresponding industry sub-sector (high rise building, heavy construction etc.) was made through comparisons with the class median. The median best represents the real situation of the industry sub-sector and has the effect of filtering out-of-range data which is included in calculation of the mean (FDI 2001). Figure 2 shows the resulting radar graph for the G company compared with the results of the 13 other companies. Each axis represents a management dimension. Best and worst case results are shown, as well as the sample median. This type of graph permits each company to evaluate its position relative to the other companies. For the company analyzed (company G), "Understandable Goals", "Leadership", "Organization for Change" and "Purchasing and Inventory Control" show greatest potential for improvement.

As Figure 2 shows, "Quality" was the dimension where a greater variability was registered. Curiously enough, this situation was repeated in the case of the construction site survey. "Use of technology" registered the lowest maximum both for the central office and construction site surveys. The highest median attained was "Safety" (0.80) for the central office, and "Leadership" (0.85) for the construction sites. "Purchasing and Inventory Control" registered the lowest median in both cases.

To complement the radar graphs of global company performance, radar graphs were also prepared that grouped companies according to their relative position as determined by specific key performance indicators. Figure 3 shows such a graph prepared on the basis of the key performance indicator "Delay in Completion". Curves are shown for the performance of companies grouped in the top third, middle third and last third of the range of values recorded for this indicator. It can be seen that companies that better comply with completion dates also obtained better results in most of the other management dimensions.

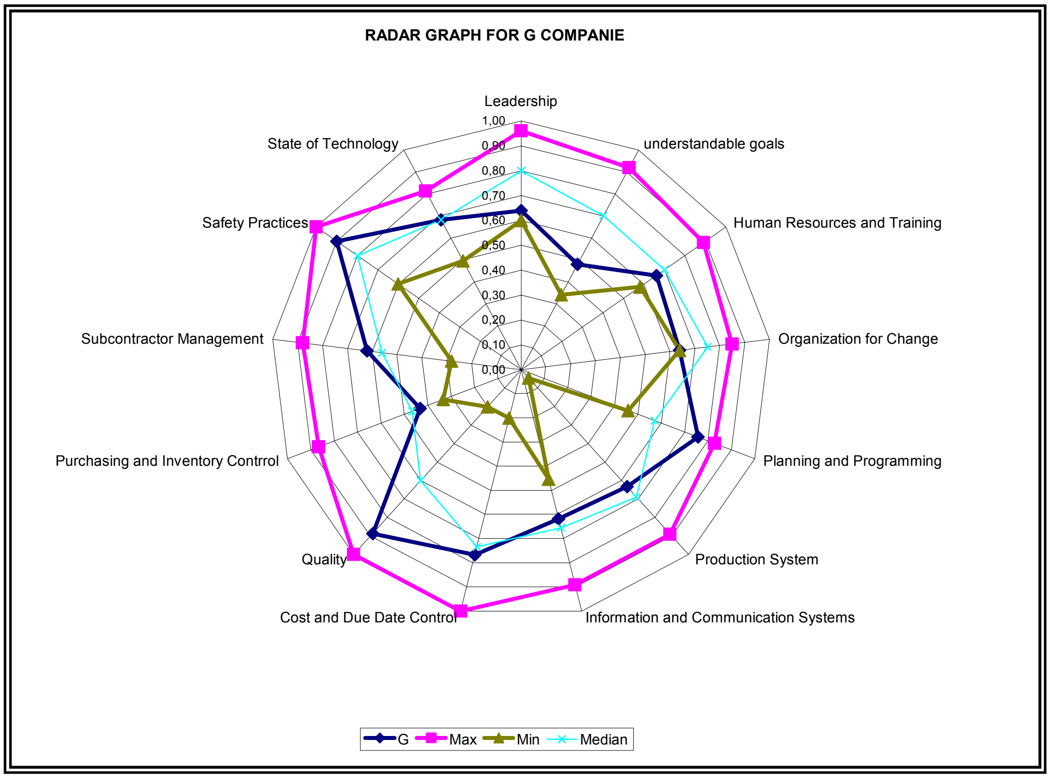

Figure 2: Example of radar graph for a company.

Figure 4 shows a radar graph for the performance indicators as a function of the management dimension “Production System”. This graph attempts to explain which performance indicators are most related to the management dimension. In the example shown, the characteristics of the production system affects the indicators “Deviation from Due Date”, “Risk Rate”, “Labor Efficiency (Mhrs)”, “Labor Efficiency (Cost, in UF) and “Labor Performance (UF/hours)”. However, some inconsistencies can be detected, since it is to be expected that the curve of the middle third, should be positioned in between the upper and lower thirds. This inconsistency is attributed to the small data set where the presence of out-of-range data may contaminate the results.

Although figures 3 and 4 are not conclusive due to the small data sets available, they indicate a trend that would be interesting to confirm. To this extent, the following section of the paper deals with a correlation analysis both between the different management dimensions and between the performance indicators and the management dimensions. In many cases, statistically significant correlations were found.

Radar graphs were also prepared for the inverse case.

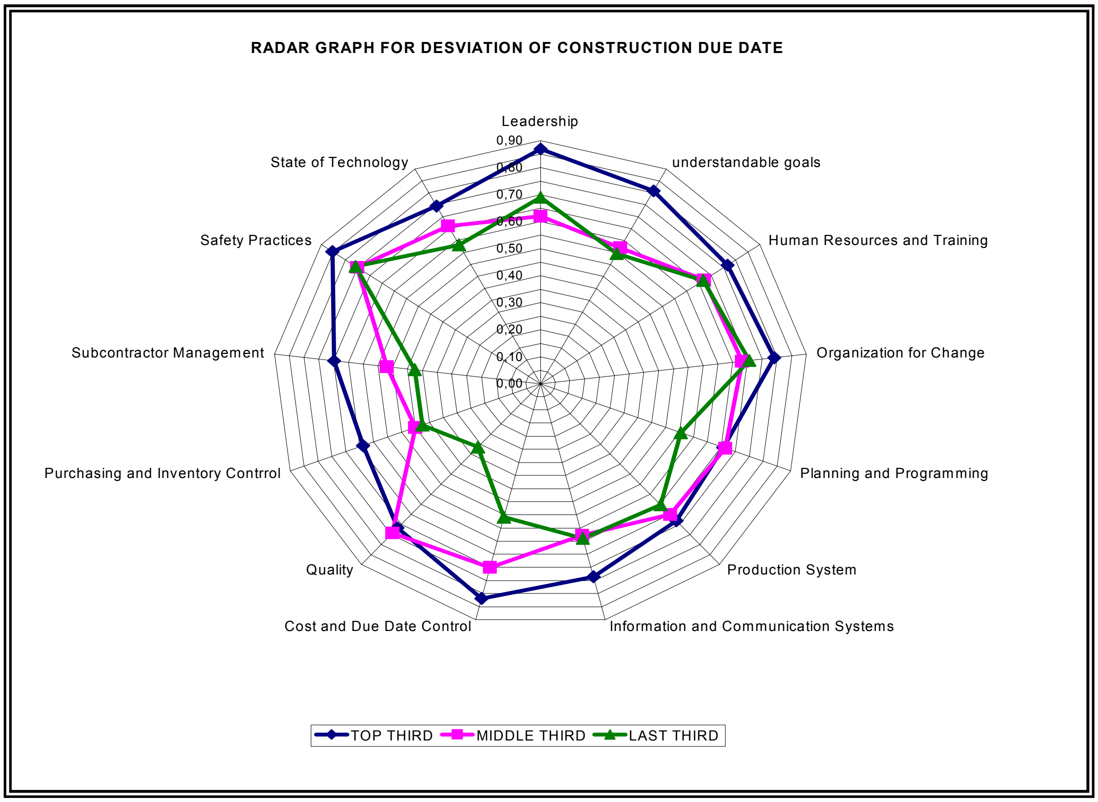

Figure 3: Example of a results analysis for a performance indicator

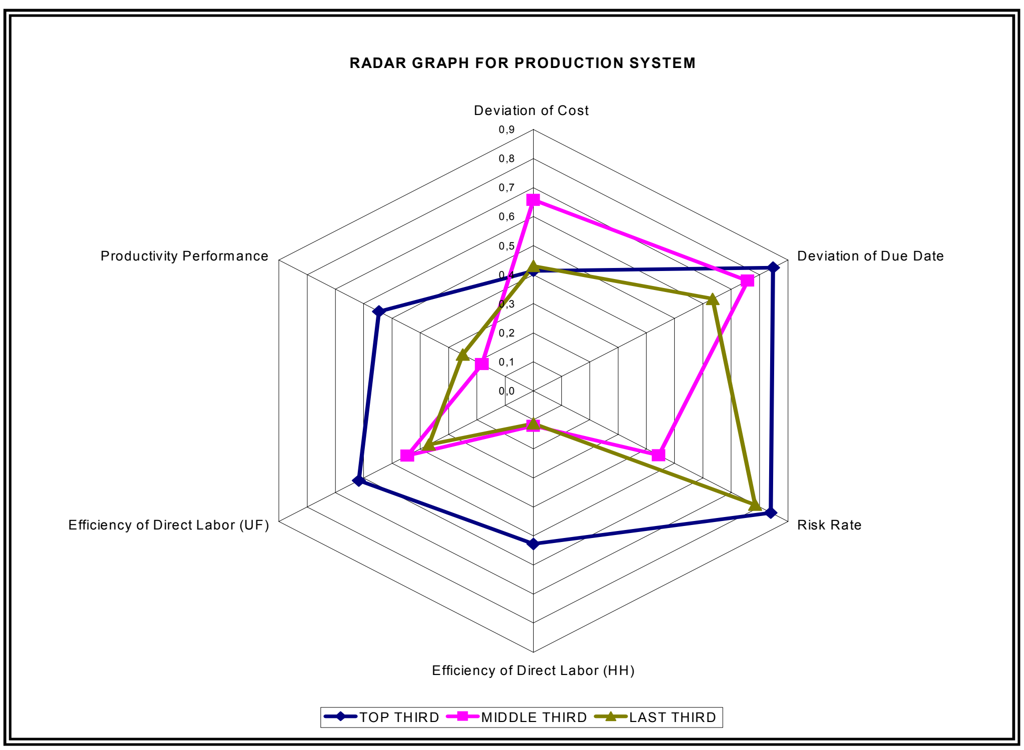

Figure 4: Example of a results analysis for a management dimension

CORRELATION ANALYSIS BETWEEN INDICATORS AND MANAGEMENT DIMENSIONS

This stage of the analysis was performed in three phases. A correlation analysis was performed first, followed by an analysis of principal factors and lastly multivariate linear regressions were performed.

To check for statistical independence, cumulative frequency curves were constructed for the values of each management dimension for both the central office and construction site surveys. In all cases, with the exception of the dimensions “Use of Technology”, “Safety Practices” and “Leadership”, the curves were observed to have smooth gradients and little variance. It was concluded that these data were homogeneously distributed.

For the correlation analysis, Pearson´s correlation coefficient was used. This correlation coefficient aims to measure the intensity with which two variables, X_i and X_j, are linearly related (Welkowitz 1981). This coefficient represents three possible situations (Downie 1983):

- Xi directly related to Xj (correlation coefficiente aproximately equal to 1)
- Xi inversely related toXj (correlation coefficiente aproximately equal to -1)
- Xi not related toXj (correlation coefficiente aproximately equal to 0).

CORRELATION ANALYSIS FOR THE CENTRAL OFFICE

The correlation analysis performed on the Central Office survey results showed a strong correlation between the different management dimensions. Analysis of the correlation of the management dimensions with the performance indicators generally returned weaker correlations than those observed between the different management dimensions. It is unavoidable that there should exist a degree of dependency between the responses to the qualitative benchmarking survey given that inherent perceptional bias of the individual completing the questionnaire.

Table 3 shows a summary of the major correlations between management dimensions and performance indicators for Central Office. The significance represents the probability of rejecting the hypothesis, therefore significance levels less than 0.05 as those in Table 3 are considered very reasonable.

As can be seen in Table 3, strong negative correlations were found to apply to the safety indicators indicating that, as one variable increases the other decreases. It can be concluded that that the safety levels attained in projects are the result of a combination of elements and not just the result of strong safety policies. These elements are generally related to aspects of planning and control and include quality management, planning practices, cost control and subcontractor management. Another high correlation observed in the table is that between “Use of Technology” and “Deviation from Scheduled Completion Date”. It is interesting that these dimensions are so strongly related.

Other correlations worth mentioning are those observed among the dimensions “Use of Information and Communications Systems” and “Purchasing and Inventory Control” and the performance indicators “Labor Efficiency (hours)” and “Labor Performance (UF/hours)”. This reflects the fact that the companies the companies that better utilize management information systems are more likely to attain better labor performance and be more efficient in their use of direct labor.

Table 3: Major correlations between management dimensions and performance indicators for Central Office.

Variables	Pearson's Correlation Coefficient	Significance	Number of data for the correlation
Planning and Programming – Risk Rate	-0,354	0,025	40
Cost and Due Date Control – Risk Rate	-0,388	0,013	40
Cost and Due Date Control – Accident Rate	-0,448	0,007	35
Quality – Rate of Risk	-0,602	0,000	40
Quality – Accident Rate	-0,581	0,000	35
Subcontractors Management – Rate of Risk	-0,374	0,017	40
Safety Practices – Risk Rate	-0,315	0,048	40
State of Technology – Deviation of Due Date	-0,665	0,000	42
Information and Communications System – Efficiency of Labor (hours)	0,385	0,032	31
Information and Communications System – Performance of Labor UF/hours)	0,407	0,023	31
Purchasing and Inventory Control – Efficiency of Labor (hours)	0,501	0,004	31
Purchasing and Inventory Control – Performance of Labor (UF/hours)	0,363	0,000	42

CORRELATION ANALYSIS FOR CONSTRUCTION SITE

In this case, no significant correlations were found between management dimensions and performance indicators. This situation is explained by the non-uniformity in the way in which the performance indicators are measured and the small data samples (on average, 9 data per process indicator).

This situation reflects the deficiencies in the sector with respect to process measurement. Most companies do not measure their processes and those that do use different measurement standards that complicate direct comparison. CDT is attempting to modify this situation with the support of GEPUC. One of the objectives of the National Benchmarking System is to standardize the measurement criteria using by participating companies so as to facilitate effective comparisons (FDI 2002)

FACTOR ANALYSIS FOR THE CENTRAL OFFICE

Factor analysis by undertaken using the method of principal components to determine the underlying structure amongst the different management dimensions and identify relationships not previously established. The commonality table, one of the outputs of this analysis, represents the proportion of the variance explained by the component or factor. In general any variable having a commonality less than 0.3 has little in common with the rest of the variables and cannot not be explained by other components (Pérez 2000). All of the management dimensions have commonality values higher than 0.3 and are therefore considered in the analysis.

It is easier to visualize the variables that make up the factors by rotating the matrix of factors. An orthogonal rotation was performed using the VARIMAX method which, for each factor identified, seeks to minimize the number of variables having high commonality weights. Table 4 shows the matrix of rotated components. In the case of the central office survey, three factors were identified as shaded in Table 4. The first factor links the dimensions of "Leadership", "Understandable Goals", "Use of Information and Communications Systems", "Production Systems". With the exception of the latter, these dimensions represent strategic management dimensions involving decisions with longer term pay-back. The second factor is comprised on tactical management dimensions that deal with day-to-day planning and control functions (quality control, subcontractor management, planning and programming systems, cost control and use of technology). With the exception of "Purchase and Inventory Control", the third factor is related to continuous improvement, ("change management", and "Human resource and training").

Note that the "Planning and Control" dimension has similar weights assigned to each of the factor, hence, it is of equal importance to each factor. This is logically consistent, since each factor – strategy, tactics and continuous improvement - requires planning and control. In addition, the "Human Resource and Training" dimension shows a slightly lower weight assigned to the first factor than to the third one, and therefore this variable is also be strongly related to the strategic variables.

Table 4: Matrix of rotated components for Central Office

	Component		
	1	**2**	**3**
Safety Practices	0.782	0.363	-0.156
Leadership	0.735	0.150	0.357
Understandable Goals	0.681	0.100	0.521
Use of Information and Communication Systems	0.671	0.289	0.199
Production System	0.589	-	0.176
Quality	0.125	0.812	0.270
State of Technology	0.125	0.746	-
Subcontractor Management	0.391	0.712	0.449
Cost and Due Date Control	0.266	0.665	0.339
Planning and Programming	0.404	0.496	0.425
Organization for change	0.259	-	0.786
Purchasing and Inventory Control	-	0.396	0.786
Human Resources and Training	0.552	0.382	0.575

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kayser Normalization

Factor Analysis for the construction site survey.

A factor analysis of the construction site survey results yielded four factors, as shown in Table 5. Note that, in this case, most of the variables associated with the first factor are of tactical importance (Use of technology, Purchasing and Inventory control, Subcontractor management. The second factor includes variables of strategic importance (Understandable goals, Leadership, Organization and Production systems) whilst the third factor is a mix of tactical and continuous improvement variables (Quality control, Cost control and Human resource management and training). Safety and Planning stand out an independent group.

These results reflect the differences in management focus that exist between central office and construction sites. Whilst the central office is concerned with the strategic aspects of business management, workers at a construction site are primarily concerned with tactical issues of day to day management. For the construction site survey, it is interesting to note that the planning and scheduling dimension is not as strongly linked to the strategic and tactical elements of management as it is for the central office. This can be construed as an improvement opportunity. Site management would no doubt benefit from the development and implementation of new generation tactical planning tools.

Table 5: Matrix of Rotated Components for Construction Site

	Component			
	1	2	3	4
State of Technology	0.844	0.220	-0.156	-
Use of Information and Communication Systems	0.720	0.147	0.291	0.176
Purchasing and Inventory Control	0.633	0.161	0.485	0.223
Subcontractor Management	0.520	0.158	0.463	0.371
Understandable Goals	0.329	0.775	-	-
Leadership	0.184	0.749	-	-
Organization for change	-	0.631	0.246	0.521
Production System	-	0.593	0.541	-0.146
Quality	-	0.137	0.835	-
Cost and Due Date Control	0.327	-0.167	0.490	0.252
Human Resources and Training	0.170	0.470	0.480	0.318
Safety Practices	0.161	0.108	-	0.846
Planning and Programming	0.407	0.127	0.291	0.609

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kayser Normalization

Multivariate Linear Regressions for Central Office

Multivariate linear regressions performed for both the central office and construction site surveys using the performance indicators as dependent variables and the management dimensions as independent variables resulted in uniformly weak correlation coefficients (R^2 less than 0.4), mainly due to the reduced quantity of data. On the basis of these low correlation coefficients, it was decided to discard further evaluation using linear multivariate regression techniques.

SECTOR TRENDS

The methodology adopted for the trend analysis comprises three analyses; firstly histograms were prepared of the responses to each question in the questionnaire; secondly responses were analyzed according to the job category of the respondent; and thirdly responses were analyzed according to construction industry sub-sectors.

The analysis revealed the following insights; for the “Leadership” category in the central office survey, managers auto-evaluated themselves with higher scores than did their subordinates. In addition, central office management was not recognized as providing sufficient leadership and support in implementing improvement initiatives. This situation contrasted with the construction site survey that found that administrators were perceived as positive leaders and were well evaluated by their subordinates. Another interesting observation was that a high percentage of respondents did not consider that the type of construction contract limited their possibilities for improvement. This contradicts conventionally held views within the industry.

For the central office survey, the management dimensions of “Quality” and “Use of Information and Communications Systems” were associated with greater dispersion of responses. For the construction site survey, the dimension having greatest dispersion was “Purchasing and Inventory Control”. These dimensions present improvement opportunities for lower ranked companies.

Categorizing and analyzing the survey results according to construction industry sub-sectors yielded the following conclusions:

- The high rise building sub-sector had the highest medians for all management dimensions. Improvement opportunities with this group of companies are; “State of the Technology” and “Purchasing and Inventories Control” for the central Office, whereas for the construction site they are “Understandable Goals”, “Change management” and “Production System”
- The heavy construction sub-sector recorded the maximum feasible for “Safety Practices”, probably reflecting the adoption of safety practices mandated by mining industry clients. Improvement opportunities for this sub-sector are “Leadership”, “Understandable Goals”, “Change management” and “Production System” both for the central office as well as the construction sites.
- Low rise housing and light industrial assembly showed the lowest standard deviations. However, the medians calculated for most of the management dimensions were below the sample median. There is a great potential for performance improvement in this sub-sector by identifying and adopting the management practices used in other sub-sectors.
- The Civil Works sub-sector is the sector that offers greatest improvement potential. One company in this sub-sector obtained minimum score in more than 60% of the dimensions evaluated.

CONCLUSIONS AND RECOMENDATIONS

A qualitative benchmarking system has been developed for the construction industry that provides information on the basis of the knowledge and perceptions of key personnel. The system forms part of a management evaluation system that aims to compare management practices, discover relationships between performance data and determine industry trends. It can be applied independently of the presence of "hard" performance data, increasing the feasibility of applying the system periodically as part of a continuous improvement program. In addition, the system also helps to determine how employees perceive their work environment and how well informed they are concerning company initiatives.

Thirteen construction companies participated in the first application of the benchmarking system. A correlation analysis performed using Pearson's correlation coefficient found that safety performance was strongly related to companies having superior planning and control, quality management, cost control and subcontractor management policies. A factor analysis undertaken using the method of principal components found that significant differences exist between in the focus and priority of central office management strategies as compared to construction site priorities. Central office priorities center on strategic management policies having longer term competitive impact, whilst site management emphasizes tactical management dimensions relevant with short term impact. There is scope to elevate the profile of continuous improvement initiatives to strategic significance at central office level. In the analysis of industry trends, construction companies working in the civil works and low rise housing sub-sectors were generally found to lag management performance levels registered for the high-rise and heavy construction sub-sectors.

The study identified a generally deficient measurement culture within the Chilean construction industry. The Chilean Benchmarking System, initiated by CDT in collaboration with GEPUC, aims to improve the quality and quantity of information available so that companies can make real comparisons on the basis of reliable data. Used properly, Benchmarking is a powerful continuous improvement tool that will improve construction industry productivity in Chile.

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