Web-Based Benchmarking System for the Construction Industry

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Abstract: The construction industry has been slow to adopt competitive benchmarking as a tool for continuous improvement. The nature of the industry, its projects, participants, and methods of execution differ widely from the manufacturing sectors making traditional benchmarking models developed for manufacturing difficult to adapt. This paper presents a benchmarking system developed by the Construction Industry Institute (CII) for broad application in the construction industry. During the past couple of years, the CII Benchmarking and Metrics (BM&M) system has been ported to a web-based system of data collection, performance and practice use reporting, and industry analysis. CII serves as a third-party facilitator and data clearinghouse to permit the sharing of highly confidential project data in a competitive environment. Cost, schedule, safety, practice use, and productivity data are now collected on-line during project execution 24/7 from the most remote project sites. Confidential reports are returned online showing metric scores, performance quartiles, and graphical comparisons of individual project performance to a database of similar projects. This paper addresses many of the issues that have served as barriers to benchmarking for the construction industry and provides an overview of how CII is confronting these issues. A background and a descriptive discussion of the database is provided and a few key findings from the data analyses are presented.

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Introduction

The United States' buildings and physical infrastructure are critical assets—estimated to be worth $20 trillion (Belle 2000). In support of this infrastructure, the engineering and construction industry is the largest industry group in the United States accounting for roughly 13% of the U.S. gross domestic product (Belle 2000). Despite its significance, the construction industry is still characterized by low productivity, fragmentation, divided responsibility, and conflicting objectives (Lema and Price 1995). Benchmarking as a tool for continuous improvement offers great promise for improving performance of the capital project delivery system and thus, performance of the industry in general. This paper explores issues confronting industry companies that attempt to apply benchmarking and presents a system developed by industry representatives to promote the practice.

Complications in implementing benchmarking within the construction industry were addressed by Zairi (1992). The nature of the construction industry presents many of the challenges for implementation. Hellard (1993) noted that the concepts and principles of benchmarking are difficult to apply to construction due to the project-based activities executed in different locations. A second complication results from the general lack of a systematic framework to follow. Lema and Price (1995) documented the need to develop a framework and methodology for a more broad adoption of benchmarking by the industry. Consistent with this finding, Fisher et al. (1995) concluded that there were currently no available benchmarking standards for the construction industry. Eight years later, a system has emerged offering the industry an effective means of benchmarking which is available to virtually all sectors of the construction industry except residential. Leveraging efficiencies of web-based technology, the Construction Industry Institute (CII) has developed a system that makes benchmarking for continuous improvement feasible for all projects regardless of location or size. This paper presents the development of the CII Benchmarking and Metrics (BM&M) program, its database, and the ensuing metrics that show promise for establishing industry norms.

Construction Industry Institute Benchmarking Program

The CII was established in 1983 to improve the performance of the capital project delivery system and, thus, the competitiveness of its member companies. It is a privately funded research institute located at the University of Texas at Austin. Its membership consists of owner, contractor, and vendor organizations representing a broad range of construction industry interests. To support its mission, member companies identify specific research priorities

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and volunteer support to staff committees and research teams. The CII BM&M program is supported by a standing committee of industry representative and a small core staff section. The CII BM&M Committee provides oversight for the development of the metrics, survey questionnaire, analysis methodology, and reports. The knowledge and experience of the committee members is an essential part of the program's success. Data have been collected and reports produced by this group since 1996.

Construction Industry Institute Benchmarking Objectives

Objectives of the CII BM&M program are to:

- Provide the industry with a common set of metric definitions,
- Provide the industry with project performance norms,
- Measure the level of use of selected best practices,
- Quantify the value of implementing CII recommended best practices,
- Provide participating companies tools for self-analysis,
- Facilitate the development and sharing of benchmarking knowledge within the construction industry, and
- Provide a credible and member accessible database that is efficient in terms of resources required for data submission, analysis, and the reporting of findings.

Construction Industry Institute Benchmarking Scope

CII benchmarking provides companies with tools that allow self-analysis of project performance and the identification of improvement opportunities. These tools include: reports on performance and practice use, norms for comparison purposes, and reports of industry analyses documenting practices that correlate with successful project performance. These tools support both internal and external benchmarking. Confidential, quantitative reports are provided as feedback to participating companies; however, the scope of CII benchmarking does not include detailed, judgmental analyses of individual project or company performance. It does, though, provide assessments suitable for identifying the source of performance problems and critical links to research based tools essential for addressing these problems. These tools are accessible to the project team throughout project execution via a web-based benchmarking system.

The Database

The CII Benchmarking System operates in a continuous data collection mode and, thus, the size of the database is constantly changing (CII 2002). As of March 2003, the database consists of 1,112 projects valued at more than $58 billion in total installed costs. There is an almost even split between owner and contractor submitted projects as shown in Fig. 1. One of the more notable changes in the database is a trend toward more international projects. Nearly one-quarter of all projects in the database are now international. While a majority of the international projects are from Europe, a considerable number are from the Middle East, Asia, and South America. Fig. 2 depicts the number of projects by geographic region.

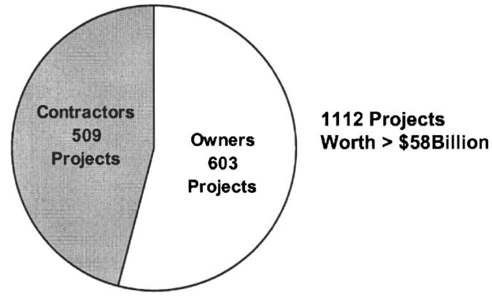

Fig. 1. Database by respondent type

Database by Project Characteristics

For purposes of analysis, CII recognizes four construction industry groups; buildings, heavy industrial, infrastructure, and light industrial (CII 2001). Table 1 shows the breakdown of projects by industry group. Heavy industrial projects comprise a majority of the database; of these 55% were submitted by owner organizations and 75% from contractor organizations. The percentages are based on the number of projects submitted by the owner and contractor organizations, respectively. While the database remains largely heavy industrial, adequate numbers of building and light industrial projects are now available to support analyses in these areas. Projects are further categorized by their nature as grass roots, add-on, or modernization. Table 1 shows the breakdown by nature of project. A grass roots project indicates a completely new facility from the foundation up. A modernization project is a facility for which a substantial amount of the equipment or structure is replaced or modified, and may also expand capacity. An add-on is classified as a new facility tying into an existing one, often intended to expand capacity. Table 1 also shows the distribution of projects by cost category. The database represents a wide range of project sizes in terms of project cost. As shown in Table 1, 55% of the owner projects and 42% of the contractor projects cost less than $15 million. The trend to smaller projects has accelerated in recent years. Projects are further categorized by type such as chemical manufacturing, oil refining, or laboratory. Table 2 shows the 15 most predominant categories of project type. Chemical manufacturing and oil refining projects are currently the most heavily represented project types in the database with 264 chemical manufacturing and 166 oil refining projects.

Database Limitations

The number of heavy industrial and building projects provides adequate data for most analyses of these industry groups. The relatively small sample size for the other industry groups limits the statistical significance and the publication of many metrics for these groups. With each year of data collection, however, more analysis is possible as more projects are added to these industry groups. Another possible limitation of the program concerns the application of findings from the database to the broader industry. The data reported primarily reflect the experiences of CII member companies, not the entire construction industry. Although CII membership is broad, care should be exercised when applying conclusions to the entire industry.

Data Confidentiality

CII recognizes the importance of maintaining the confidentiality of data provided by participating companies. Strict procedures have been implemented governing access and use of the data to

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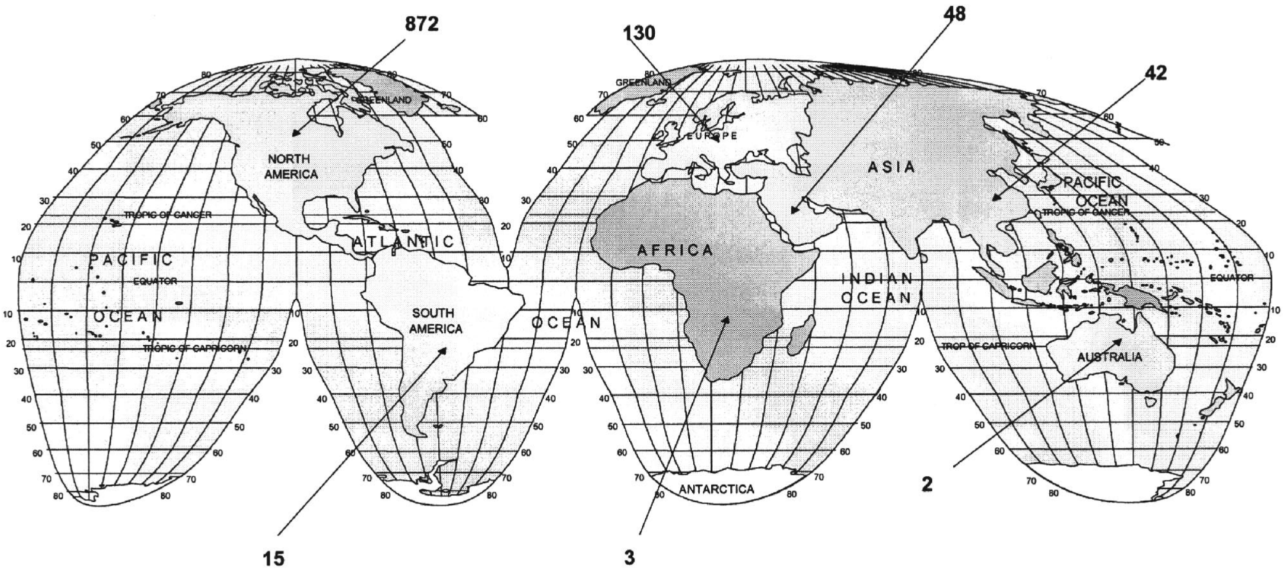

Fig. 2. Project location by region

ensure that confidentiality is maintained. Data and findings are published as aggregated results precluding identification of individual company or project performance. Furthermore, publication of aggregated data will be suppressed if the subset of the data being analyzed is sufficiently small that identification of individual project or company performance might be possible.

Table 1. Database by Project Characteristics

Project characteristics (1)		Owner Number (2)	Owner Percent (3)	Contractor Number (4)	Contractor Percent (5)
By industry group	Buildings[a]	147	24%	34	7%
	Heavy industrial[b]	334	55%	382	75%
	Infrastructure[c]	52	9%	41	8%
	Light industrial[d]	70	12%	52	10%
By project nature	Add-on	163	27%	176	34%
	Grass roots	192	32%	202	40%
	Modernization	248	41%	131	26%
By project size	<\$15 million	330	55%	212	42%
	\$15–\$50 million	150	25%	155	30%
	\$50–\$100 million	62	10%	61	12%
	>\$100 million	61	10%	81	16%

[a]Buildings: Communications Center, Dormitory/Hotel, Lowrise Office, Highrise Office, Hospital, Housing, Laboratory, Maintenance Facilities, Parking Garage, Physical Fitness Center, Restaurant/Nightclub, Retail Building, School, Warehouse, Residential, Prison, Movie Theater, Other Buildings.

[b]Heavy Industrial: Chemical Manufacturing, Electrical (Generating), Environmental, Metals Refining/Processing, Mining, Natural Gas Processing, Oil Exploration/Production, Oil Refining, Pulp and Paper, Other Heavy Industrial.

[c]Infrastructure: Airport, Electrical Distribution, Flood Control, Highway, Marine Facilities, Navigation, Rail, Tunneling, Water/Wastewater, Pipeline, Gas Distribution, Telecom/Wide Area Network, Other Infrastructure.

[d]Light Industrial: Automotive Assembly, Consumer Products Manufacturing, Foods, Microelectronics Manufacturing, Office Products Manufacturing, Pharmaceutical Manufacturing, Other Light Industrial.

Data Analyses

There are many differences in owner and contractor participant perspectives and level of project involvement. These differences have led separate owner and contractor definitions for cost and schedule performance metrics. Even in cases where metrics are defined in the same way, the different perspectives and levels of involvement dictate the publication of separate norms for each group. For these reasons, owner and contractor data are separated for all analyses.

Performance metric norms have been established for cost, schedule, safety, changes, and rework (CII 2001). Construction and Engineering productivity metrics have been established, and data collection for these metrics has begun. Norms for these metrics will be published when sufficient data are available. Practice use norms are published for preproject planning, constructability,

Table 2. Database by Project Type

Type (1)	Owner number (2)	Contractor number (3)	Both Number (4)	Both Percent (5)
Chemical manufacturing	102	162	264	23.7%
Oil refining	85	81	166	14.9%
Electrical (generating)	43	26	69	6.2%
Pulp and paper	21	47	68	6.1%
Low-rise office	45	4	49	4.4%
Metals refining/processing	31	12	43	3.9%
Natural gas processing	18	20	38	3.4%
Oil exploration/production	19	17	36	3.2%
Foods	24	11	35	3.1%
Consumer products manufacturing	13	20	33	3.0%
Laboratory	24	7	31	2.8%
Water/wastewater	23	8	31	2.8%
Environmental	13	13	26	2.3%
Pharmaceuticals manufacturing	12	11	23	2.1%
Automotive assembly	16	3	19	1.7%

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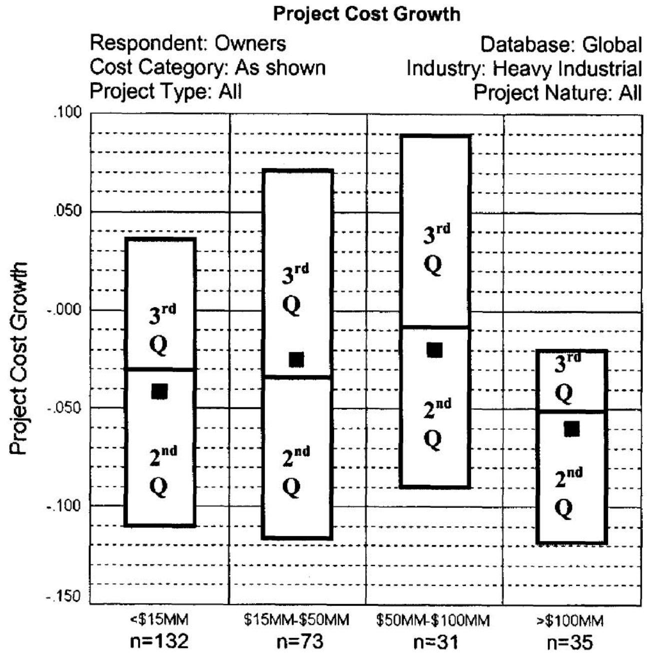

	<15	15-50	50-100	>100
Best	-0.505	-0.292	-0.472	-0.385
100%	0.231	0.250	0.241	0.152
75%	**0.036**	**0.071**	**0.089**	**-0.020**
50%	**-0.030**	**-0.034**	**-0.008**	**-0.051**
25%	**-0.110**	**-0.116**	**-0.090**	**-0.118**
0%	-0.276	-0.292	-0.275	-0.250
Mean	**-0.042**	**-0.025**	**-0.020**	**-0.060**
SD	0.112	0.122	0.120	0.091
N	132	73	31	35

Note: Project Cost Growth= $\frac{\text{(Actual Total Project Cost - Initial Predicted Project Cost)}}{\text{Initial Predicted Project Cost}}$

Fig. 3. Project cost growth—owner

team building, zero accident techniques, project change management, design/information technology, planning for start-up, and materials management (CII 2001). Data also have been collected for quality management; however, sufficient data will have to be accumulated before norms can be established for this practice. Analyses of the correlation between performance and practice use metrics have produced the quantitative benefits attributed to the use of best practices (CII 1999; Lee 2001; CII 2003).

Performance Metric Norms

Performance norms are published periodically in graphic and tabular formats for the metric categories listed above. Fig. 3 is provided for illustration. Here norms for mean and median performance and quartile cutoffs are provided to assist in measuring individual project performance against the database. Mean performance is indicated by the black square symbol, and a horizontal line separating the second and third quartiles indicates the median. Mean performance can be a good basis to compare individual project performance when the overall distribution of scores approximates a normal distribution. In the presence of statistical outliers, the median can be a more stable measure of performance since it de-emphasizes the effects of extreme scores. Quartile cutoffs are used to define categories of performance. The second quartile includes those scores that fall between the 25th percentile and the 50th percentile (the median) of scores. The third quartile includes those scores that fall between the 50th and the 75th percentile of scores. Performance metric charts such as Fig. 3 depict only the middle two performance quartiles since program objectives are oriented on performance norms. The "best in class" performance is also shown, however, for each metric in the table adjacent to the chart. Fig. 3 depicts project cost growth performance for all owner heavy industrial projects included in the global data set, segregated by project cost categories. Although all four quartiles of data are provided in the table, only the middle two quartiles are plotted in the chart.

While overall project cost growth is a primary concern to the owner, contractors often prefer a cost performance metric that takes specific account of change order impact. To accommodate this preference, the project budget factor is reported. Calculated from contractor data, the project budget factor provides a ratio of actual total project cost to the sum of the initial predicted cost plus approved changes. Fig. 4 illustrates such a chart for global design and construction contractors. To permit the most meaningful comparisons this chart is segregated by the nature of the project: add-on, grass roots, or modernization. Many breakouts are provided for such metrics to include breakouts by contractor function, project cost category, industry groups, and location.

Schedule metrics parallel cost metrics in definition. For example overall schedule growth, which is of particular interest to owners, is published as is project schedule factor for contractors. Project phase metrics permit the establishment of norms for cost and duration for each phase of the project. Fig. 5 depicts a sample chart showing phase cost factor norms for global owner projects. The phase cost factor is defined as the actual phase cost divided by the total project cost. This chart answers common questions presented to CII concerning the proportion of costs typically spent on the various phases of a project.

CII uses standard safety metrics, as defined by the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, for measuring safety performance: the recordable incidence rate (RIR) and lost workday case incidence rate (LWCIR). Fig. 6 shows RIR norms for heavy industrial contractors by cost category. These breakouts illustrate the impact of project size on safety performance. While smaller projects may be

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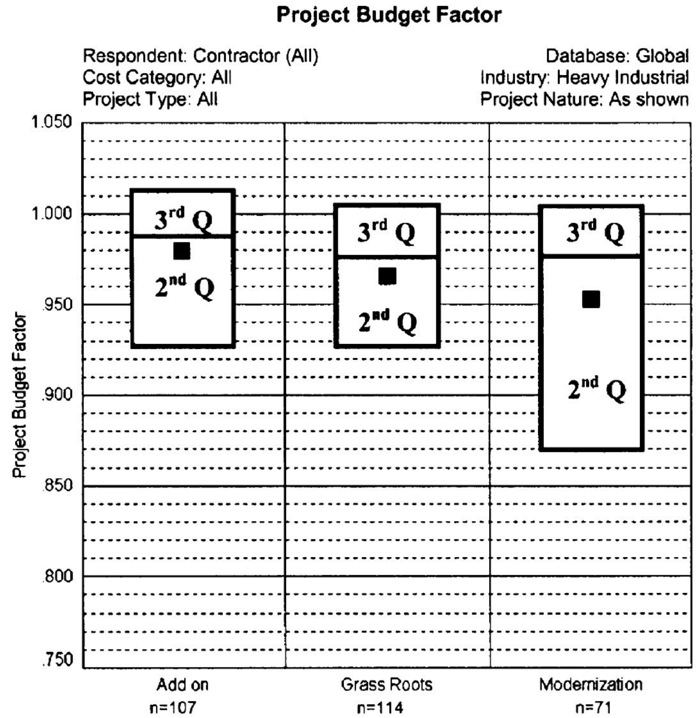

	Add	Grass	Modern
Best	0.482	0.717	0.132
100%	1.151	1.153	1.155
75%	**1.013**	**1.005**	**1.004**
50%	**0.988**	**0.976**	**0.977**
25%	**0.927**	**0.927**	**0.870**
0%	0.793	0.775	0.780
Mean	**0.978**	**0.966**	**0.952**
SD	0.077	0.078	0.085
N	107	114	71

Note: Project Budget Factor= $\frac{\text{Actual Total Project Cost}}{\text{(Initial Predicted Project Cost + Approved Changes)}}$

Fig. 4. Project budget factor—contractor

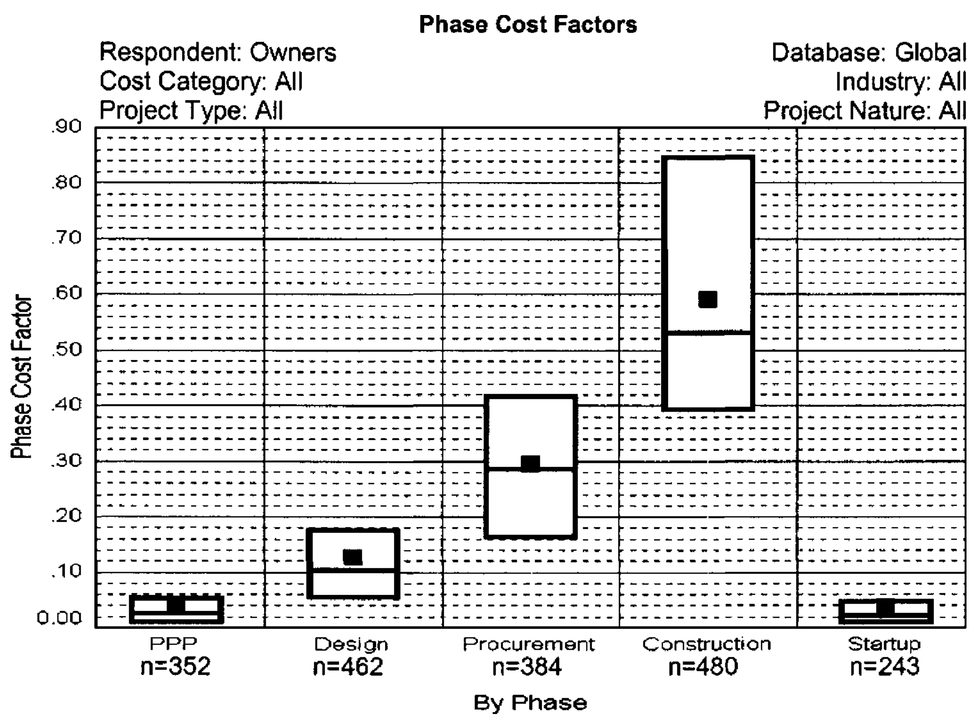

Fig. 5. Phase cost factors—owner

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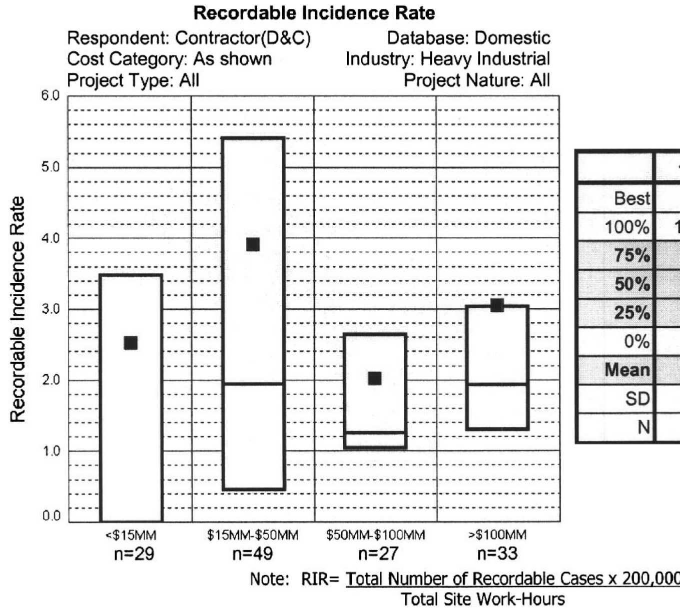


	<15	15-50	50-100	>100
Best	0.000	0.000	0.000	0.000
100%	15.860	21.980	8.870	11.620
75%	3.490	5.410	2.640	3.040
50%	0.000	1.940	1.250	1.930
25%	0.000	0.460	1.040	1.300
0%	0.000	0.000	0.000	0.000
Mean	2.491	3.883	2.009	3.044
SD	4.151	5.136	2.109	3.087
N	29	49	27	33

Fig. 6. Recordable incidence rate—contractor

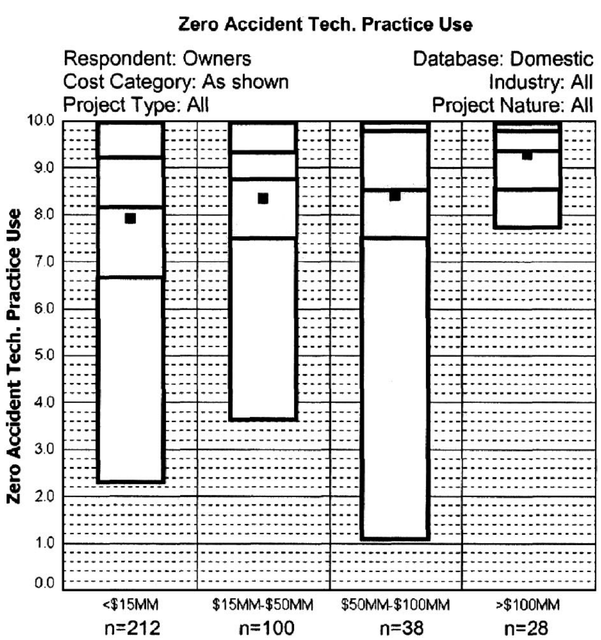
able to achieve zero accident performance, the number of craft work-hours on larger projects makes the goal more elusive.

Practice Use Norms

The CII BM&M System assesses the level of implementation of CII recommended best practices for feedback and to permit the quantification of practice impacts on project performance. At present data are being collected on nine CII best practices. These include pre-project planning, constructability, team building, zero accident techniques, change management, materials management, planning for start-up, and quality management. Design/information technology practice use is also tracked, and norms are published, as well. Practice use is scored on a scale of 0 to 10 with 0 indicating no use and 10 indicating full use. Data are presented in a format similar to that used for the performance metrics; however, all four quartiles of use are plotted on the chart since scaling is not a problem due to the fixed metric scales. Fig. 7, provided for illustration, shows zero accident techniques practice use norms for owner domestic projects segregated by cost category. Project size has a significant impact on the level of practice use as depicted in the figure. Larger projects report greater practice use on average than smaller projects.

The Value of Best Practices

A key objective of CII Benchmarking is the assessment of the value of CII recommended best practices. Given project perfor-



	<15	15-50	50-100	>100
Best	10.00	10.00	10.00	10.00
100%	10.00	10.00	10.00	10.00
75%	9.23	9.33	9.79	9.79
50%	8.16	8.76	8.54	9.36
25%	6.67	7.50	7.50	8.54
0%	2.29	3.62	1.12	7.71
Mean	7.89	8.36	8.40	9.17
SD	1.65	1.42	1.70	0.72
N	212	100	38	28

Fig. 7. Zero accident techniques practice use—owner

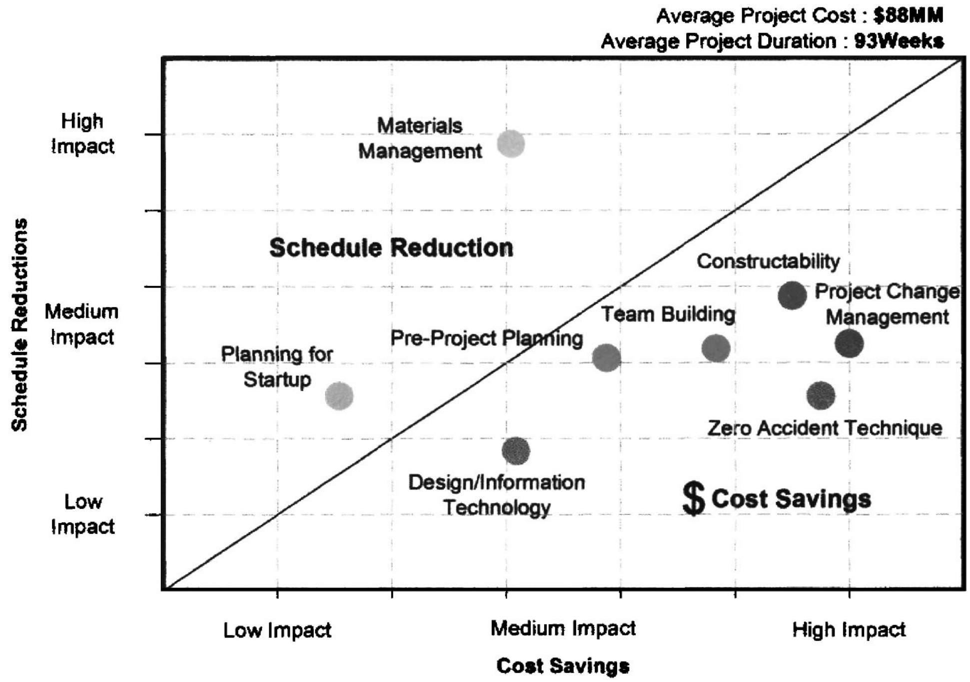


Fig. 8. Contractor benefit of practice use

mance and practice use metrics, correlations can be used to determine the value of implementing these practices (CII 1999; Lee 2001; Lee et al. 2004; CII 2003). Fig. 8 summarizes cost and schedule analyses for heavy industrial contractors (CII 2003). This chart allows ready comparison of both cost and schedule benefits for all practices with sufficient data available. Fig. 8 shows that for the average heavy industrial contractor, materials management has a high impact on schedule performance and a low-to-medium impact on cost performance. Constructability, project change management, and zero accident techniques best practices have a high impact on cost performance but only moderate impacts on schedule performance. Many factors affect cost and schedule performance besides the practices included in these analyses. These include project characteristics of nature and size as well as other environment variables. Many of these variables are surveyed in the CII Benchmarking system and are considered in the analyses where data are available.

Fig. 9 illustrates cost savings attributed to the use of zero accident techniques. This chart shows the potential improvement in average LWCIR expected when moving from the lower quartiles of practice use to the first quartile of use. The potential improvement in LWCIR can be converted to expected workdays saved and the resulting dollar savings based on historical costs of lost workday cases (CII 1993). The data below the chart show that on average, the expected savings associated with the number of lost workday cases avoided can be substantial. The typical owner heavy industrial project costing $37 million and averaging 347,000 work-hours could expect to save $72,000 by avoiding lost workday cases through the increased use of CII recommended zero accident techniques. The importance of these analyses is significant. Owners and contractors can now identify those practices that will help them achieve improvements for the specific performance metrics of interest and have data on potential benefits calculated from actual project experiences. Many construction industry stakeholders desire such information to support benefit/cost analyses when evaluating the use of a practice.

While these analytic results are an important advancement in the quantification of the value of using best practices, it is essential that results be interpreted with due qualifications. The findings allow industry participants to identify those practices that are likely to improve performance for cost, schedule, and safety. They also provide an indication of the relative benefit of these practices and suggest potential savings for using the practices. No one project, however, is likely to replicate the characteristics of the

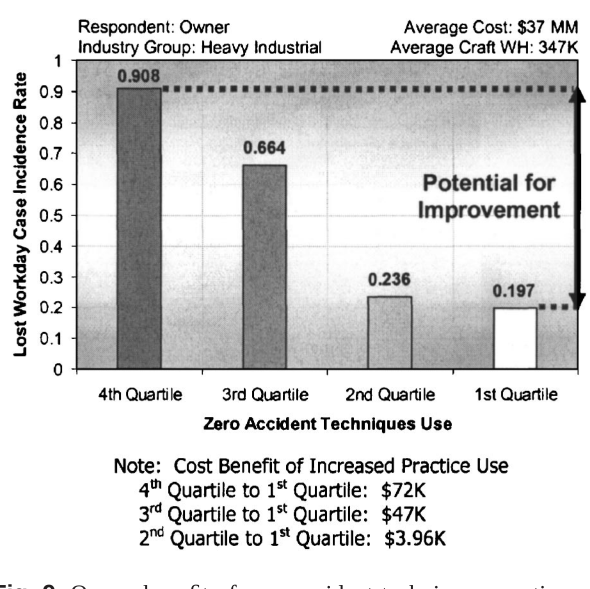


Fig. 9. Owner benefit of zero accident techniques practice use

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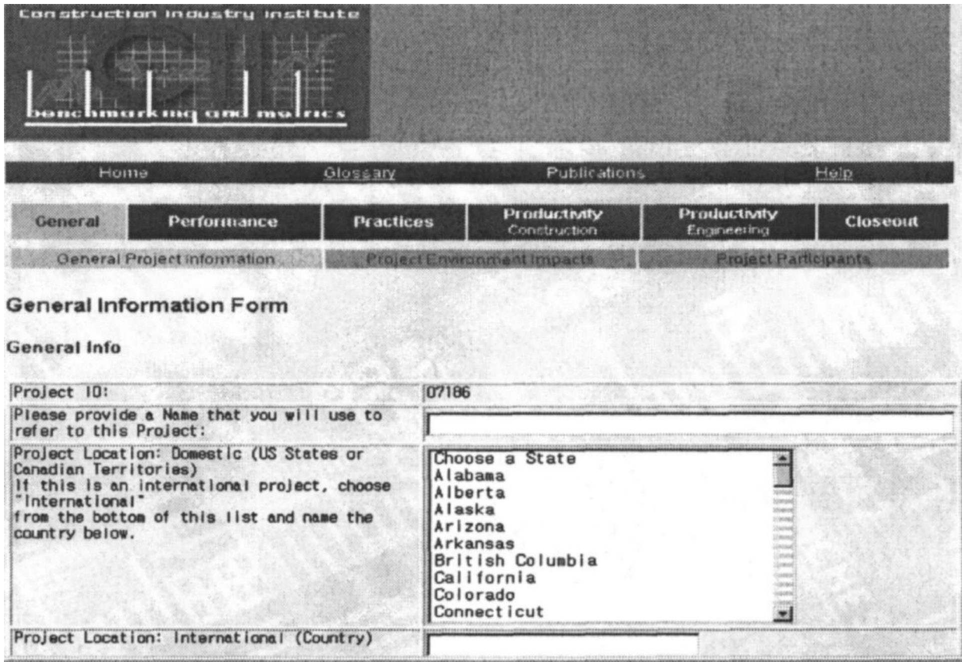

Fig. 10. Web-based benchmarking and metrics questionnaire

aggregated sample, or will it have the same environment as those of the sample. For these reasons, the data should not be used to predict savings expected for any one project. They can however, provide a general indication of potential benefits achievable when these practices are implemented on similar projects.

Benchmarking Acceptance

The project environment is sufficiently challenging and project teams are confronted with a myriad of complex tasks while executing projects. To facilitate broad acceptance of a benchmarking program in this environment, the entire process must be automated to make the system work in a lean and efficient manner necessary to meet participant needs and resource constraints. Significant strides have been made in this regard by using web-based technology. Data are now collected exclusively via a web-based questionnaire and reports are now returned in a similar manner.

The benchmarking questionnaire resides on a CII server, where it can be conveniently accessed with standard browsers. For illustration, Fig. 10 shows the initial questionnaire screen. There are distinct advantages to this method of data collection. Data can be submitted during project execution when it is most convenient to the project team. Web-based data collection also facilitates improved accuracy through use of programmed algorithms that scan for inconsistencies as data are entered. Any detection of inconsistency immediately notifies the person entering data and requests a correction prior to continuing. Further, an on-line glossary and context-sensitive help ensure that valuable reference information is conveniently accessible during data entry. Companies are encouraged to initiate their questionnaires early in the project's life, enter data as the project progresses, and thus require input of final data only as part of the project closeout. As an additional advantage, the feedback provided as data are entered can be used to guide project performance while there is still time to influence the outcome.

Conclusions

Measurement is one of the first steps in any improvement process. The CII Benchmarking System offers participants in one of the nation's largest and most vital industries a system for benchmarking that is tailored to the industry. Companies can submit data 24/7 from the most remote job site and get real time feedback including comparisons to a large database using industry defined metrics. If the submission of data is commenced in the early stages of the project, real time reports can be used to identify processes that can likely be improved resulting in substantial cost and schedule savings. The questionnaire alone serves as an excellent checklist for the implementation of well researched practices for performance improvement. The real time feedback with links to practice implementation tools is truly a benchmarking breakthrough enabled by evolving web-based technologies.

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