



CONSTRUCTION INDUSTRY INSTITUTE®

ENGINEERING PRODUCTIVITY MEASUREMENTS II

Construction Industry Institute

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Abbott Laboratories	ALSTOM Power
Air Products and Chemicals	AMEC
Amgen	AZCO
Anheuser-Busch Companies	BE&K
Aramco Services Company	BMW Constructors
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Cargill	Black & Veatch
Celanese	Bovis Lend Lease
ChevronTexaco Corporation	Burns & McDonnell
Colelectric Partners	Butler Manufacturing Company
ConocoPhillips	CB&I
Dofasco	CCC Group
The Dow Chemical Company	CDI Engineering Solutions
DuPont	CH2M HILL Constructors/IDC
Eastman Chemical Company	CSA Group
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General Motors Corporation	Dick Corporation
GlaxoSmithKline	Emerson Process Management
Intel Corporation	Fluor Corporation
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Eli Lilly and Company	Fru-Con Construction Corporation
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Naval Facilities Engineering Command	Hatch
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The Procter & Gamble Company	Kiewit Construction Group
Rohm and Haas Company	Kværner
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U.S. Department of State	Technip USA Corporation
U.S. General Services Administration	Turner Construction Company
U.S. Steel	Victaulic Company of America
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	Williams Group International
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	Zurich North America

Engineering Productivity Measurements II

**Prepared by
The Construction Industry Institute
Engineering Productivity Measurements II Project Team**

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Cautionary Statement and Appropriate Uses of PT192 Products

CII emphasizes the importance of measuring and assessing engineering productivity. CII also recognizes the extreme complexity of the issues of this research and the many decisions that the project team faced in producing its productivity measurement system.

The “off-the-shelf” (OTS) approach is in a validation stage, and organizations are encouraged to validate the OTS model to confirm applicability to their particular projects. They are also encouraged to share results with CII to facilitate validation of the tool. The OTS tool is not intended for use on individual projects, either for estimating or for productivity. While data are collected for individual projects, analysis of the results should be based on groups of projects.

The “custom-tailored” approach is more suited to individual project applications and to applications in industry settings outside the PT 192 database.

Contents

<i>Chapter</i>	<i>Page</i>
Executive Summary	v
1. Introduction	1
2. Data Analysis	7
3. Findings	9
4. Application and Implementation	12
5. Conclusions and Recommendations	15
Appendix 1: Statistical Results	16
Appendix 2: Selected Project Results – Family of Measures	21
Appendix 3: Productivity Index Distributions by Discipline	27

Executive Summary

Improving the productivity of detailed design engineering is a critical step in improving the overall effectiveness of capital projects. To improve productivity, a good system is needed to measure and track productivity so that the impact of productivity improvement efforts can be judged. This research provides two effective approaches to measure and track engineering productivity, one to monitor current and future projects, the other to develop equations for company-specific project or work processes. Both offer opportunities for continuous improvement.

CII recognized there were no consistent standards used throughout the industry to measure engineering productivity and commissioned the Engineering Productivity Measurements II Project Team (PT 192) as a follow-on to the Engineering Productivity Measurements Research Team (RT 156). The objective for the research was to develop a standardized productivity measurement methodology. The project team focused on measuring engineering design hours against physical design quantities rather than the typical “intermediate deliverables” such as drawings or specifications that are traditionally used. Measuring productivity against physical design quantities was considered to be a more consistent and reliable method and not subject to differences in work processes across the industry.

Two different methods are available to measure engineering productivity using these techniques:

- The “off-the-shelf” approach – uses “basis hours” equations developed from the PT 192 data set to measure productivity and establish baselines. It can be used immediately with minimal startup costs to monitor current and future projects.
- The “custom-tailored” approach – uses the same methodology as described in step-by-step detail in CII Research Report 192-11 to develop organization- or project-specific equations to measure or benchmark productivity. The “custom-tailored” approach may provide a more accurate system linked to company-specific projects or work processes.

Introduction

Costs associated with a typical heavy industrial major capital construction project can be broken into three general categories with corresponding general percentages:

- | | |
|-------------------------|--------------------|
| 1. Cost of materials | 45 percent or more |
| 2. Cost of construction | 35 percent or more |
| 3. Cost of engineering | up to 20 percent |

Although engineering may only account for up to 20 percent of total project costs, the output of the engineering team has direct bearing on the other 80 percent of project costs. Engineering generally sets the pace for compliance with project schedule requirements. For these reasons, it is important to be able to effectively measure engineering productivity.

CII has a long history of study and implementation development related to engineering performance and productivity (see Table 1, next page). In spite of this extensive effort, CII recognizes that engineering performance, and engineering productivity in particular, are difficult to measure quantitatively. CII has also determined that the industry has no standardized methods for the measurement of engineering productivity compared to those, for example, in the construction portion of the project delivery process.

The importance of productivity measurement in every industry is well established. Construction productivity, long an interest area for CII research, allows for measurement and improvement of construction processes and can be built into estimating and progress reporting processes. The belief that standardized engineering productivity metrics that are based on a viable output measure would lead to improvement for the engineering effort led CII to consider engineering productivity.

Table 1. CII Research Projects and Products Relating to Engineering Productivity and/or Performance

Year	Research/Project Team	Products
1986	Task Force 84-8, Design	“Evaluation of Design Effectiveness” (SD-16) “Defining and Evaluating Input Variables Impacting Design Effectiveness: Research Phase I” (SD-19)
1989	Task Force 84-8, Design	“Cost Effectiveness of Computerization in Design and Construction” (SD-50)
1994	Total Quality Management Task Force	<i>Implementing TQM in Engineering and Construction</i> (SP 31-1)
1997–1998	Research Team 112	2% <i>Engineering – Can It Work for You?</i> (RS 112-1) “A Framework and Practices for Cost-Effective Engineering in Capital Projects in the A/E/C Industry” (RR112-11)
2000	Research Team 152	“Three-Dimensional Computer Models and Fully Automated Project Processes for the Management of Construction” (RR152-11)
2001	Research Team 156	“Engineering Productivity Measurement” (RR156-11)

In its research effort in the late 1990s, the CII Engineering Productivity Measurements Research Team advanced the concept of measuring engineering productivity not by the engineering output of “intermediate deliverables” such as drawings and specifications, but by the fundamental output of quantities to be installed in the field. The research team conducted a detailed evaluation of the piping design process and sought correlations between the piping engineering hours and physical measures of the quantities of designed goods. Good correlation was found between hours and total length of pipe designed and the number of equipment pieces, (which was seen as an indication of project complexity). The team then developed a conceptual model in which detailed design engineering productivity would consist of a raw productivity (hours per designed quantity), which could be adjusted

to account for the project complexity, the quality of input to detailed design, and the quality of the design output.

Using the results of this research as proof of the concept, CII established the Engineering Productivity Measurements II Project Team to extend the concept to other engineering disciplines. The project team reviewed a designed quantity-based engineering productivity system in use at Dow Chemical Company, reviewed the results of efforts by the CII Benchmarking and Metrics Committee to establish engineering productivity metrics from the earlier concept, and conducted a series of discipline workshops. The project team then developed a data collection instrument targeting engineering designed quantities, discipline hours, and possible input/output measures. The instrument provided extensive detail on the engineering process (see Table 2).

Table 2. Summary of Data Collection Instrument

		Number of data points collected
	Project Description	80
	Input/Output Quality	49
Disciplines	Architecture	6
	Civil	24
	Mechanical	63
	Piping	16
	Instr. & Controls	13
	Electrical	29
	Process	15

The resulting data came from 118 projects with a total installed cost of approximately \$15 billion from 14 different CII member design firms. The large number and different types of construction firms in the CII membership provide a good target population for empirical studies. The experience levels of persons completing the instrument, which averaged 23 years’ experience in the industry, are indicative of data quality.

Discipline workshops, discipline conference calls, and team discussions yielded a strong conceptual basis for the design components to include. Empirical results were used to confirm these components and to develop models and coefficients. An equation was developed for each discipline that uses design component quantities to calculate “basis hours” for each discipline.

A productivity index for each discipline can be calculated by dividing the actual discipline design hours by the discipline basis hours. It is expected that over time the productivity index for a given organization or discipline would improve as changes are made to work processes and procedures. An organization needs to gather data on a set of projects to establish a baseline.

Data collected from the different projects can be categorized on a number of different dimensions. The following tables and figures provide descriptive data for several different ways to categorize the projects. Table 3 lists the type of companies providing the data. Figure 1 describes the projects in terms of industry category. Figure 2 describes the types of projects, and Figure 3 looks at the projects in terms of size as defined by dollar value.

Table 3 and Figures 1–3 demonstrate the breadth of projects included in the database. While this makes the results more representative of the entire industry, it also increases the variance across projects. The strength of results is surprising given the variety of projects.

Table 3. Type of Companies Providing the Data for Study Sample)
(n= 118)

Type of Company	Number in Sample	Percentage of Sample
Owner with in-house capabilities	27	23
Owner without in-house capabilities	8	7
Constructor	20	17
Designer/Constructor	28	23
Full-service firm	35	30