

Engineering Productivity Measurement System



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Engineering Productivity Measurement System

Prepared by the

Construction Industry Institute

Engineering Productivity Measurements II Project Team

Implementation Resource 192-2

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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.

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Introduction and System Overview

The Engineering Productivity Measurement System consists of this manual and the associated software. This manual will provide detailed instructions on the use of the software. However, the user is cautioned that the software arises from a statistical analysis of a particular database, and that attempts to use the results for cases too dissimilar from that database may produce inaccurate or misleading results. Accordingly, this manual will begin with a brief summary of the database and its development.

The data for this study were collected during the months of January–December 2002 from a group of engineering design firms and owner-operators that are members of CII (see Chapter 5). The large number and different types of organizations in CII provide a good target population for empirical studies. Data quality is indicated by the experience level of the person completing the questionnaire, which averaged 22.7 years.

In total, historical data on 118 projects were collected from 12 different companies. The projects can be categorized on a number of different dimensions. The following three tables provide descriptive data for several different ways to categorize the projects. Table 1 lists the types of organizations providing the data. Table 2 describes the projects in terms of the type/category of industry and the type of project. Table 3 looks at the projects in terms of their size as defined by the area, dollar value, and the amount of total detailed design hours.

Table 1. Types of Organizations Providing the Data for Study Sample) (n= 118)

Type of Organization	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	24
Full-service firm	35	30

Table 2. Industry Breakdown of Projects in the Study Sample (n=118)

Description	Number in Sample	Percentage of Sample
Type of Industry		
Heavy	114	97
Light	4	3
Category of Industry		
Chemical	45	38
Power	44	37
Environmental	19	16
Oil refining	3	3
Metals refining	3	3
Pharmaceutical	1	1
Optical fiber	3	3
Type of Project		
Greenfield	38	32
Retrofit	14	12
New plant in existing facility	40	34
Expansion of existing facility	15	12
Modernization	8	8
Other	2	2

Table 3. Descriptors of Size of Projects in the Study Sample (n= 118)

Description	Units	Mean	Median	Minimum	Maximum
Size of plant in terms of area	Sq. Feet	750,901	259,770	3,500	7,500,000
Number of raw materials	#	4	3	1	19
Number of finished goods	#	2	1	1	12
Number of design sites	#	1	1	1	4
Number of startup systems	#	58	30	1	337
Detailed design cost	\$	7,756,428	4,073,000	1,023	65,751,000
Total installed cost	\$	118,884,956	77,500,000	249,931	549,900,000
Total detailed design hours	Hours	70,164	39,982	219	935,215

Based on this database, statistical methods were used to develop equations for the empirical relationships between design hours for a discipline and the design quantities for that discipline. The empirically calculated number of hours for each discipline is then used as the basis for the productivity index. The actual discipline hours for a given project divided by the productivity basis hours (from the empirical calculation) is defined as the productivity index for that project.

$$\text{Productivity Index} = \frac{\text{Actual Design Hours}}{\text{Productivity Basis Hours (calculated from designed quantities)}}$$

An organization that is improving its detailed engineering process would see this ratio decrease over time. The productivity basis hours are a function of the designed quantities and other complicating factors for each discipline, and provide a baseline for calculating relative productivity over time. (NOTE: The resulting hour coefficients on the statistically significant explanatory design quantities are used to compute an expected number of discipline design hours to be used in a productivity index ratio with actual discipline hours, and are not intended as a way to estimate the discipline hours that will be needed to complete a specific project.)

The “Actual Design Hours” include only direct hours (from discipline engineers, designers, and technicians), not indirect hours (for document control, reproduction graphics, project management, project controls, project engineer, secretary, clerk, procurement, construction support, quality assurance, accounting, and legal). Users of the productivity model should use the same basis.

Notes on the use of the system:

If an organization has kept good records of design hours per discipline and physical quantities installed for recently completed capital projects, the Engineering Productivity Measurement System can immediately be used to begin establishing an engineering productivity baseline. Data from at least 30 projects that are a representative cross-section of projects will yield enough results for a productivity measurement starting point. The engineering productivity results from these projects, both by discipline and overall, measures relative productivity versus the 118 projects in this database and does not necessarily represent good or poor productivity. The results do represent, on a relative basis, a starting point for measuring improvements in an organization’s engineering productivity over time due to specific actions taken.

An organization may also choose to begin collecting project data to establish this productivity baseline on a going-forward basis. Individuals collecting data for projects to be included in this productivity baseline should become familiar with the type of data to be collected and maintain good records of engineering hours per discipline and physical qualities installed per the data collection templates.

Productivity data from an organization’s baseline set of projects and from projects measured in the future can be compared to one another and analyzed for understanding of why relative productivity from one project may be significantly higher or lower than another project, either by discipline or overall. This type of information can be used to begin developing a productivity improvement program. The data analysis (i.e., specific project team actions or systems/processes

used that yielded a lower relative Productivity Index) will provide experience that can be shared across the organization. Engineering productivity improvements resulting from new engineering systems, processes, or other methodologies that are used to execute projects can be validated by comparing the productivity of these projects with productivity numbers from past projects in the database.

If an organization chooses to use the custom-tailored approach, the projects used to establish the customized formulas for measuring productivity are the baseline set of projects described above. The same type of analysis can be applied to these projects to begin establishing a continuous improvement program.

Implementation Resource Purpose and Intent

The two approaches for using the Engineering Productivity Measurement System are:

- “*Off-the-shelf*” approach: Based on analysis of the dataset described in Table 3, a set of equations was developed for calculating basis hours. Users of the “off-the-shelf” system will input the design quantities from their specific projects into the equations developed to obtain basis hours, and compute the productivity index using their actual discipline hours. This approach is relatively easy to deploy. The discipline basis hours are calculated from a small number of design quantities, and the functional forms and coefficients for calculating these basis hours are calculated in advance by the system. The drawback of this approach is that it is less likely that the basis hours will be an accurate estimate of the hours for any given organization or any given industry because the function was developed from a blend of several companies, processes, and industries. The accompanying CD provides a simple interface for entering the individual project data and obtaining the productivity reports for projects. In addition, an historical database is included for producing engineering productivity trends over time.
- “*Custom-tailored*” approach: In this approach, users will develop their own empirical formulas for basis hours based on new data collection representing the work and industrial mix appropriate to them. A much smaller number of variables than those listed in Table 2 needs to be collected. The CD provides a data collection instrument and an option to collect an expanded set of project data for each discipline. Collection of this expanded set of data will allow one to run statistical programs to produce discipline basis hour formulas that are unique to an organization. Detailed descriptions of the required statistical analyses needed to develop basis hour functions are provided in this guide. Those adopting this approach will:
 - Complete data collection (a minimum of 30 projects is recommended, but a larger set will provide more accuracy. Note that at least 30 points must be captured for every design item collected; if there are missing values, more than 30 projects will probably be needed).
 - Follow the statistical analysis procedure described in this guide to develop a custom-tailored basis hour equation.
 - Collect the design quantities required for the resulting equation on future projects, and use those data to obtain basis hour estimates.
 - Divide actual hours by the productivity basis hours for each discipline to obtain the productivity index.

The two approaches are summarized in Figure 1. In the following sections of this guide, detailed implementation steps for each approach will be presented and summarized. The two approaches are expected to be effective in determining the productivity of the engineering effort for a group of projects, but *may not be effective for a single project*.

It is expected that most organizations would begin their implementation using the off-the-shelf approach, given that it is easier to deploy. The organization can begin using the basis hour functions without committing resources to the statistical analysis of historical project information, and can thereby develop confidence and experience with engineering productivity measurement. Note that the use of the off-the-shelf system requires the collection of project data, which will consist primarily of the quantities of several design components appropriate to each discipline. The custom-tailored approach similarly requires the collection of project data, for a somewhat longer list of components, followed by a statistical analysis of these data to develop organization-specific basis hour functions for each discipline. It is this statistical analysis that represents additional effort on the part of the user organization.

The custom-tailored approach may provide more stable productivity ratios, however, because the resulting basis-hour functions will be more “tuned” to the kind of work and the processes used by the organization. Nonetheless, the process cannot even begin without the collection of project data. It is envisioned that some may wish to begin using the off-the-shelf system, but simultaneously to collect the additional design component quantity data “while they are at it.” The application provided on the CD allows the collection of data on the longer list of components for possible future use in the development of organization-specific equations.

Finally, even if one does complete the custom tailored process of developing specific basis hour functions, there is still merit in maintaining the data and the ratios as defined in the off-the-shelf version. This is based on the observation that benchmarking activities will, by necessity, be based on a fairly short list of components and a simplified analysis, such as that represented by the off-the-shelf version equations. If the user wishes to participate in benchmarking activities with external units, perhaps facilitated by CII, the off-the-shelf system will be required.

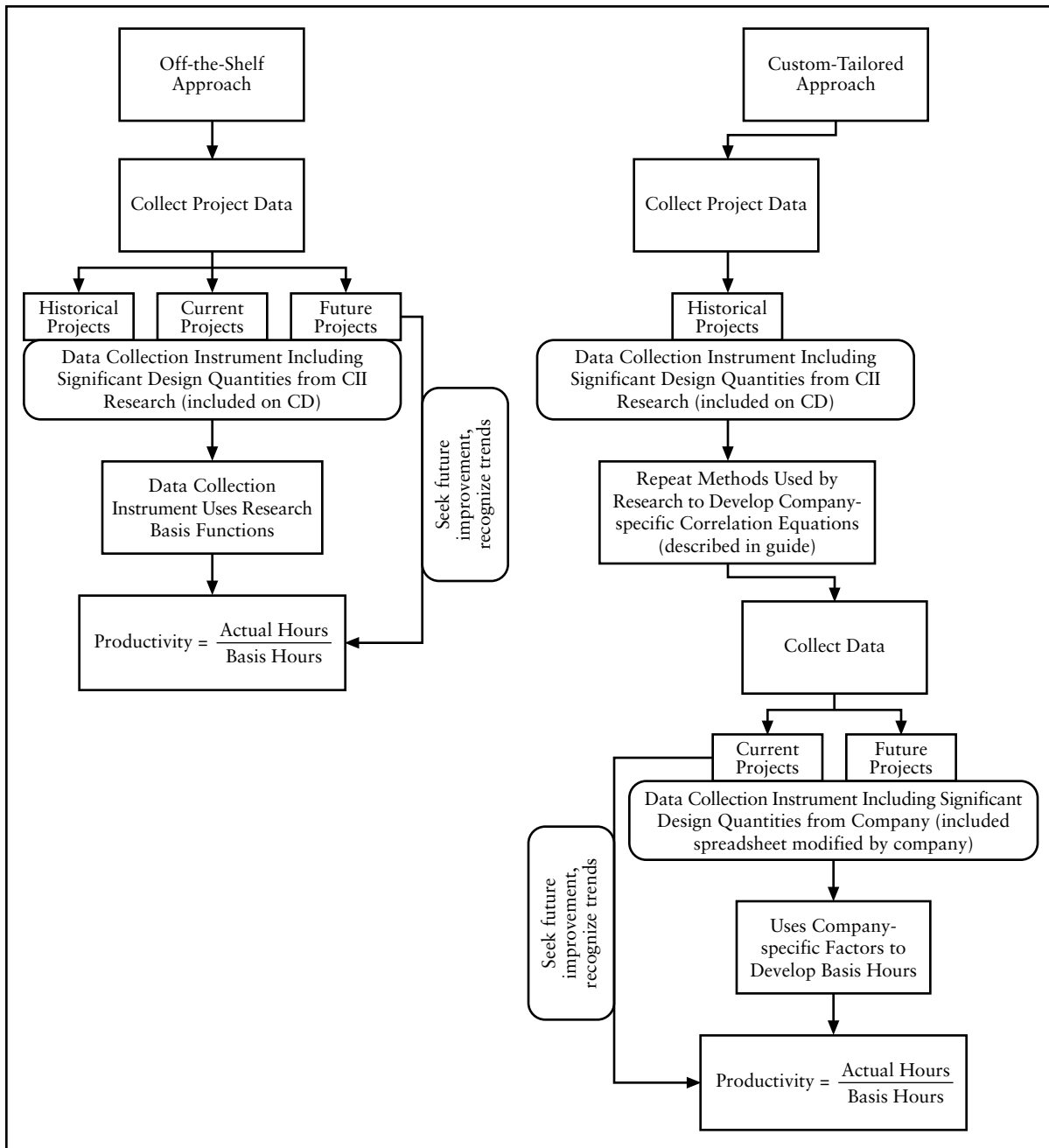


Figure 1. Summary of Two-Stage Implementation Approach

Using the Software: Off-the-Shelf System

This section describes the use and interpretation of the EngineeringProd program on the enclosed CD.

Computer Requirements

The following minimum requirements apply. Because the database will handle significant amounts of data, especially as the number of projects included gets large, system performance may be greatly affected by processor speed and memory.

- Pentium II, 233Mhz or higher
- At least 32 MB RAM
- Windows 95/98/ME/2000/XP
- Microsoft Access 98 or higher
- Java Runtime version 1.4.1.02 or later (included with this CD-ROM)

Installation Procedure

To start the installation, insert the CD-ROM into your CD-ROM drive and follow the installation instructions. Alternately, manually access your CD-ROM drive and double-click on the file setup.exe. The InstallShield Wizard will then begin the installation process, as shown in Figure 2 (next page).

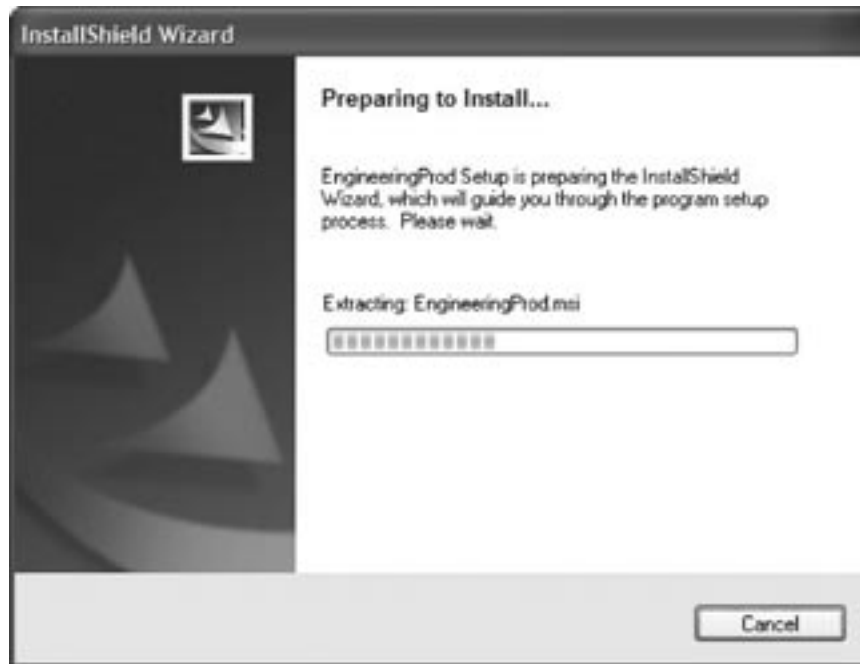


Figure 2. InstallShield Wizard Preparation Screen

InstallShield will trigger Windows Installer to appear to prepare for file copying (Figure 3).



Figure 3. Windows Installer Preparing to Function

Click on the “Cancel” button anytime to cancel the installation (except on the last screen, where it is disabled). When the “Cancel” button is clicked, a dialog window pops up (Figure 4). Click on “Yes” to cancel the installation, or “No” to resume the installation.



Figure 4. Cancellation Dialog Window

The user should wait for the appearance of the InstallShield Welcome screen (Figure 5).



Figure 5. InstallShield Welcome Screen

Click on the “Next” button. This will bring up the Customer Information screen (Figure 6), where user information can be entered.



Figure 6. Customer Information Screen

To allow all users of the computer to use this software, leave the default option as it is. To restrict the application to a particular user, choose “Only for me.” Click “Next” to continue. The next screen is the Ready to Install the Program screen (Figure 7). Click “Install” to confirm your choices and proceed with installation.



Figure 7. Ready to Install the Program Screen

The next screen is the Installation Progress screen (Figure 8.) The status indicator bar in the center of this screen will work from left to right across the screen. When the installation is complete, the status indicator bar will reach the right side, and the InstallShield Completion screen will appear (Figure 9).



Figure 8. Installation Progress Screen



Figure 9. Installation Completion Announcement

Now click on the “Finish” button to end the installation. On Windows 95/98/ME, the computer may have to be restarted after installation. The InstallShield application will give the option to restart immediately, which must be done to begin using the software.

Once the installation of the Engineering Productivity Measurement System is completed, the Sun Java Runtime environment version 1.4.1.02 or later will be required. If it is already installed, the following section can be skipped. If an error message about the Java Runtime Environment appears, install that as well.

Installing the Java Runtime Environment

If you are already running the Java Runtime Environment version 1.4.1 or later, it is not necessary to install the version which is packaged with the Engineering Productivity software.

To install the Java Runtime Environment (JRE) go to your Start Menu. You will see an entry for Engineering Productivity. Select that program group and you should see two choices (Figure 10). The second option is the installation program for the JRE. Click this option to begin the installation.



Figure 10. Start Menu Program Group for Engineering Productivity

This will open another InstallShield session in order to complete the JRE installation. A progress screen will appear to show extraction of the necessary files (Figure 11).



Figure 11. Progress Screen for Extraction of JRE Files

The preparation progress screen will then appear (Figure 12).



Figure 12. InstallShield Preparation Screen for JRE

Once the InstallShield is ready to begin the installation, a license agreement for JRE will appear (Figure 13). To reject the terms of the license agreement, click “No.” This action will terminate the JRE installation. The Engineering Productivity Measurement System will not function without the JRE software installed, however. To accept the license agreement for JRE, click “Yes.”

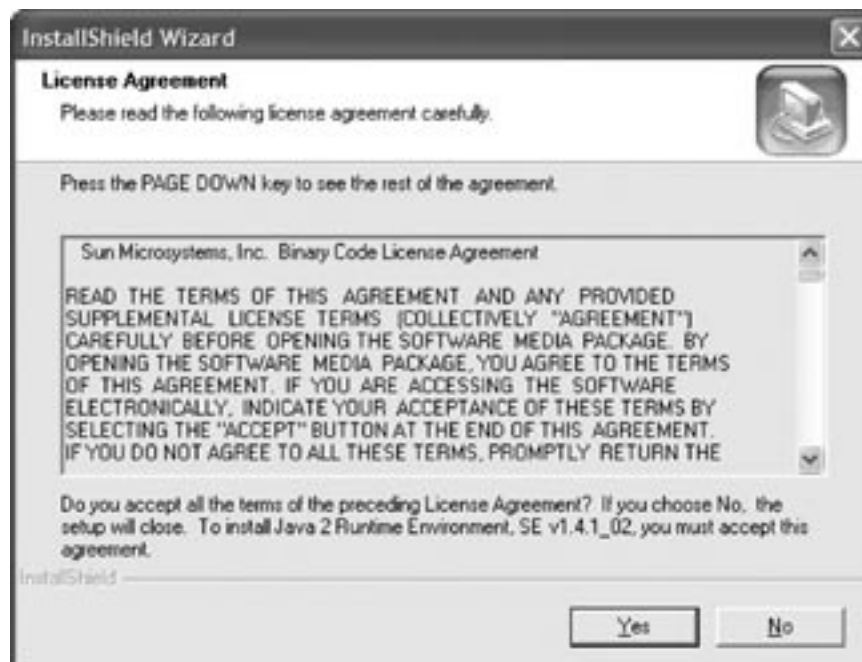


Figure 13. JRE License Agreement Screen

The user will then be asked to select the type of installation (Figure 14).



Figure 14. Selection of Installation Type

The typical installation is appropriate for the Engineering Productivity Measurement System, and will be the default selection on this screen. With the Typical radio button selected, click “Next.” The installation will then proceed with a progress indicator bar visible during the installation (Figure 15). Wait for the completion of this installation and the appearance of the JRE Completion Announcement screen (Figure 16).