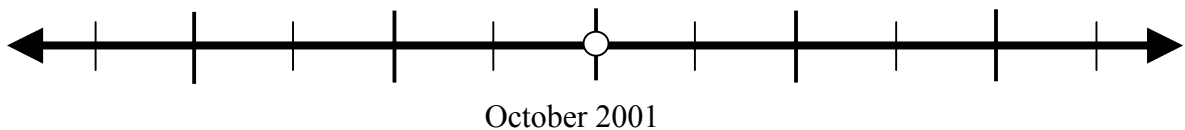


---

# Impacts of Design/Information Technology on Building and Industrial Projects

---



**BMM 2001-10**  
*Reviewed by CII 3Feb04*

© 2001 Construction Industry Institute™.

The University of Texas at Austin.

CII members may reproduce and distribute this work internally in any medium at no cost to internal recipients. CII members are permitted to revise and adapt this work for the internal use provided an informational copy is furnished to CII.

Available to non-members by purchase; however, no copies may be made or distributed and no modifications made without prior written permission from CII. Contact CII at <http://construction-institute.org/catalog.htm> to purchase copies. Volume discounts may be available.

All CII members, current students, and faculty at a college or university are eligible to purchase CII products at member prices. Faculty and students at a college or university may reproduce and distribute this work without modification for educational use.

Printed in the United States of America.

## Abstract

This study, sponsored by the National Institute of Standards and Technology (NIST), represents a collaborative effort by industry, government, and academia to evaluate the use of design/information technology (D/IT) and to relate the degree of D/IT use to project performance.

The study consisted of two tasks. The first was a detailed statistical analysis of 566 projects in the Construction Industry Institute<sup>TM</sup> (CII<sup>TM</sup>) benchmarking database. This analysis produced baseline measures of performance and D/IT use, and then established the correlation between these measures to assess the economic value of using the technologies. This report, which summarizes the findings of the statistical analyses, was the product of the second study task.

The analytic data set included all U.S. domestic and international projects submitted by owners and contractors between 1997 and 1999 using versions 2.0, 3.0, or 4.0 of the CII Benchmarking database. In order to analyze project data that were comparable in scope for owners and contractors, only those projects for which contractors performed both design and construction tasks were included. The resulting data set was again refined to include two industry groups, industrial and buildings. The results were presented in tables under one of four groupings: Owners, Buildings; Owners, Industrial; Contractors, Buildings; Contractors, Industrial.

The results of this study establish that projects benefit from D/IT use. Both owners and contractors can expect overall project cost savings of approximately 2.1 and 1.8 percent, respectively. For owners, there was evidence of construction cost savings of nearly 4 percent by increasing the use of D/IT, as well. For both, there was evidence of construction schedule compression.

## Keywords

Design/information technologies; practice use; performance norms; cost benefits; schedule compression; economic value; project outcomes; technology implementation; bar coding; 3D CAD; EDI; integrated database

## Table of Contents

|                                                                                    |     |
|------------------------------------------------------------------------------------|-----|
| Abstract .....                                                                     | iii |
| List of Tables .....                                                               | v   |
| List of Figures .....                                                              | vi  |
| 1 Introduction.....                                                                | 1   |
| 1.1 Background .....                                                               | 1   |
| 1.2 Purpose.....                                                                   | 1   |
| 1.3 Scope and Approach .....                                                       | 1   |
| 2 Summary of Task 1 - Statistical Analysis .....                                   | 3   |
| 2.1 Description of Data Set.....                                                   | 3   |
| 2.2 Performance Outcomes – All Owners .....                                        | 5   |
| 2.3 Performance Outcomes – Contractors .....                                       | 8   |
| 2.4 Degree of Design/Information Technology (D/IT) Practice Use – Owners .....     | 10  |
| 2.5 Degree of Design/Information Technology (D/IT) Practice Use – Contractors..... | 10  |
| 2.6 Correlation of D/IT Practice Use with Performance Outcomes .....               | 11  |
| 3 Discussion of Task 1 Findings .....                                              | 21  |
| 3.1 Performance Outcomes.....                                                      | 21  |
| 3.2 Implementation of D/IT .....                                                   | 21  |
| 3.3 Relationship Between D/IT Use and Outcomes .....                               | 23  |
| 4 Conclusions and Recommendations .....                                            | 25  |
| Appendix A – Statistical Notes .....                                               | 27  |
| Appendix B – Metric Definitions .....                                              | 29  |
| Appendix C – Project Phase Definitions .....                                       | 33  |
| Appendix D – Calculation of D/IT Use Index.....                                    | 35  |
| Appendix E – References.....                                                       | 39  |

## List of Tables

|                                                                                                          |    |
|----------------------------------------------------------------------------------------------------------|----|
| Table 2-1. Summary of Mean Performance Outcomes – Owners .....                                           | 7  |
| Table 2-2. Summary of Mean Performance Outcomes – Contractors .....                                      | 9  |
| Table 2-3. Summary of D/IT Practice Use Scores – Owners.....                                             | 10 |
| Table 2-4. Summary of D/IT Practice Use Scores – Contractors .....                                       | 11 |
| Table 2-5. Correlation of D/IT Practice Use with Performance Outcomes<br>– All Owners .....              | 13 |
| Table 2-5a. Correlation of D/IT Practice Use with Performance Outcomes<br>– Owners, Buildings.....       | 15 |
| Table 2-5b. Correlation of D/IT Practice Use with Performance Outcomes<br>– Owners, Industrial.....      | 16 |
| Table 2-6. Correlation of D/IT Practice Use with Performance Outcomes<br>– All Contractors .....         | 17 |
| Table 2-6a. Correlation of D/IT Practice Use with Performance Outcomes<br>– Contractors, Industrial..... | 19 |
| Table 4-1. Distribution of Current CII Database by Industry Group .....                                  | 25 |

## List of Figures

|                                                                                    |    |
|------------------------------------------------------------------------------------|----|
| Figure 2-1. Database by Respondent Type and Location .....                         | 3  |
| Figure 2-2. Database by Industry Group .....                                       | 4  |
| Figure 2-3. Database by Cost of Project .....                                      | 4  |
| Figure 2-4. Database by Project Nature .....                                       | 5  |
| Figure 2-5. Example D/IT Practice Use versus Performance Outcomes – Owners.....    | 14 |
| Figure 2-6. Example D/IT Practice Use versus Performance Outcomes – Contractors .. | 18 |
| Figure 3-1. D/IT Use .....                                                         | 23 |

# **1 Introduction**

## **1.1 Background**

Although the evolution and deployment of design/information technologies will undoubtedly play an important role in the future of the construction industry, many stakeholders are still unsure of the economic value of using these technologies. A detailed, authoritative, and readily accessible body of information is needed to enable construction industry stakeholders to make cost-effective investment decisions among established, new, and/or innovative design/information technologies. The Construction Industry Institute (CII) Benchmarking and Metrics (BM&M) database, which is composed exclusively of actual project execution experiences, provides a valuable basis for the development of this body of information.

CII is a unique consortium of owners, designers, builders, and universities formed to improve the capital project delivery process. Its research agenda and activities are the result of a collaborative effort between industry and academic researchers. Through this ongoing collaboration, CII has established a database that supports the benchmarking of construction industry performance and practice use metrics. The data in the database have been systematically collected since 1996 to support the benchmarking effort. The database includes over 1,000 projects from 69 member companies and organizations.

## **1.2 Purpose**

The purpose of this research, sponsored by the National Institute of Standards and Technology (NIST), was to measure and evaluate the economic value of using established, as well as new and innovative, design/information technologies (D/IT) within the construction industry. Specifically, this investigation identified and documented the benefits of using design/information technologies from actual project experiences.

## **1.3 Scope and Approach**

This research effort consisted of two tasks specified by NIST. The first was a detailed statistical analysis of a cross-section of projects from the CII Benchmarking and Metrics database. This analysis produced baseline measures of performance and indicators of economic value. Industry norms were identified on five key performance outcome categories: Cost, Schedule, Safety, Changes, and Field Rework. Norms were also established for the use of design/information technology practices. Second, the correlation of design/information technology degree of use with the use of other “best” practices and with each of the five key performance outcomes was determined and documented.

The analytic data set was created using owner- and contractor-reported data from U.S. domestic and international projects submitted to the larger CII database between 1997 and 1999. Only data from versions 2.0, 3.0, and 4.0 of the CII benchmarking survey instrument were included in this analysis because the version 1.0 questionnaire did not address design/information technology use. In order to analyze project data that were comparable in scope for owners and contractors, only those projects for which contractors performed both design and construction tasks were included. The data set was further refined to include projects classified under one of two industry groups, industrial and buildings. This resulted in an analytic data set consisting of 566 projects, 346 of which were submitted by owners and 220 by contractors. Analyses and chart types, consistent with the standard chart types produced by the CII BM&M Committee, were specified by NIST. Tables include descriptive and statistical summaries also specified by NIST.

The final task of this research was the development of this report, which summarizes the findings of Task 1. Baseline measures of performance are discussed and key measures of economic value identified.

## 2 Summary of Task 1 - Statistical Analysis

This section provides a summary of the statistical analyses for the 566 projects meeting the criteria specified by NIST. Descriptive statistics are presented followed by tables summarizing average outcomes, degree of D/IT use, and the correlation between D/IT use and performance outcomes.

### 2.1 Description of Data Set

The study included all U.S. domestic and international projects for which data on D/IT use were collected. Owner and contractor data were segregated for analyses, and contractor data were included only if the contractor performed both design and construction tasks. Data were further categorized by Industry Group, Cost, and Project Nature. Two industry groups were analyzed, buildings and industrial. Three cost categories were used, less than \$15 million, \$15-50 million, and greater than \$50 million. Each project was also classified by nature as add-on, grass roots, or modernization. Bar charts showing the number of owner and contractor projects for each category follow.

**Figure 2-1. Database by Respondent Type and Location**

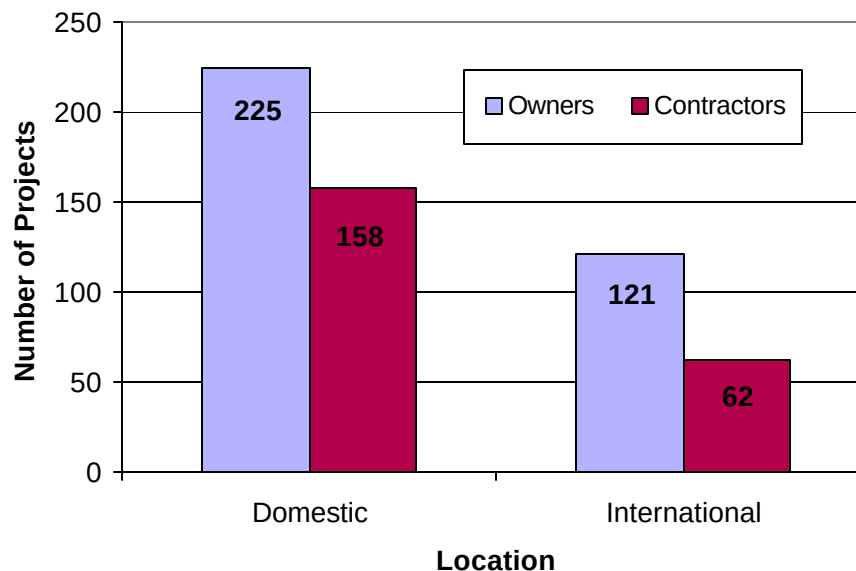


**Figure 2-2. Database by Industry Group**

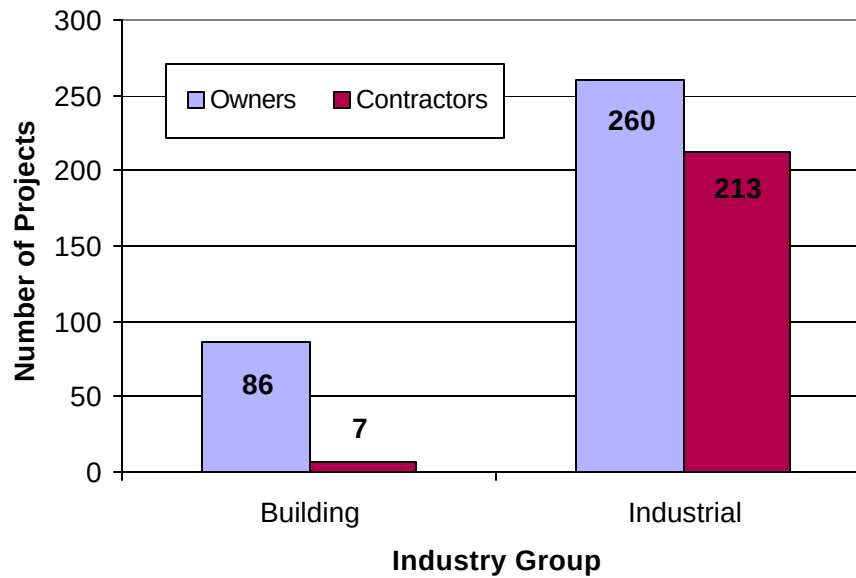


**Figure 2-3. Database by Cost of Project**

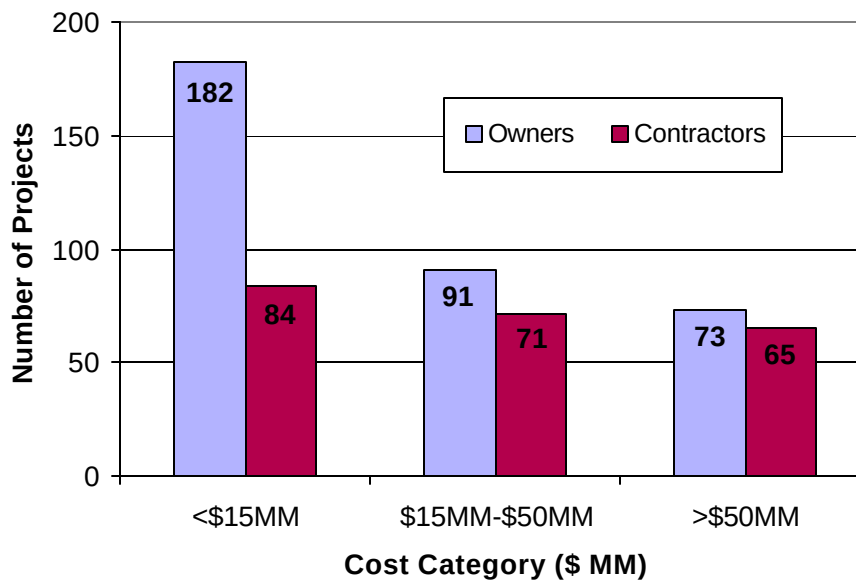
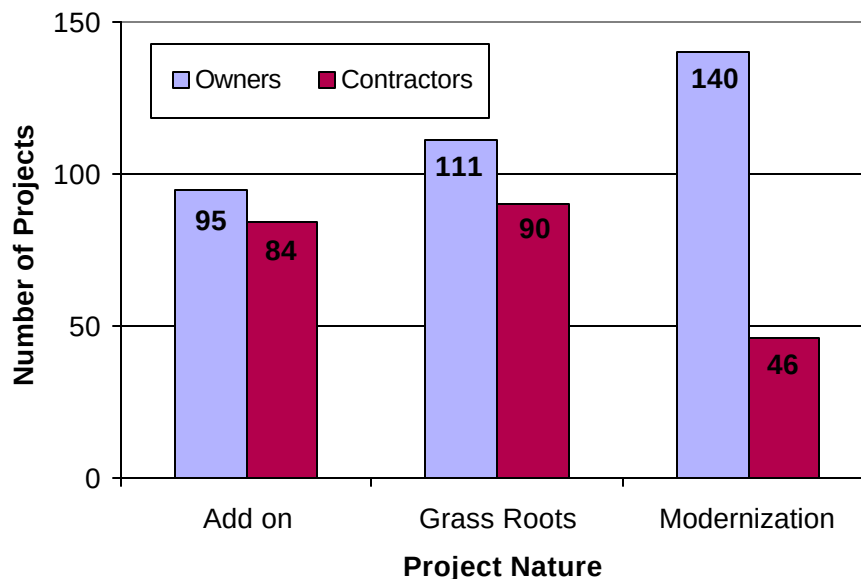


**Figure 2-4. Database by Project Nature**



Subject to the selection criteria discussed above, all projects in the CII database were eligible for inclusion in this analysis. In some cases, however, item responses were excluded from the detailed analyses that follow because they were deemed to be statistical outliers based on the decision rule described in Appendix A. Also, the number of projects represented in the tables was reduced by item nonresponse and confidentiality rules. Thus, while the data in Figures 2-1 through 2-4 above represent all the projects included in the analytic data set, the data included in Tables 2-1 through 2-6a represent only those data values that are more typical values throughout the entire distribution of projects.

All data were presented as aggregates to ensure that no individual project could be identified in any of the charts or tables. When the risk of identifying any project in any subcategory was increased due to the small number of projects in any subcategory, the data for that subcategory were suppressed to ensure confidentiality. This was particularly true for analyses of contractor projects classified in the Buildings Industry Group. See Appendix A for an explanation of the CII confidentiality policy and its application.

## **2.2 Performance Outcomes – All Owners**

Table 2-1 summarizes owner project performance for each analysis category. In this summary only mean values are shown. The table reveals a number of important characteristics of these projects. First, the average cost, schedule, and safety performance among all owner projects was relatively good. Overall, the projects experienced cost growth of -3.2 percent and schedule growth of 4.5 percent. The recordable incident rate (RIR) of 3.132 and lost workday case rate (LWCIR) of 0.671 were well below industry

averages for similar projects<sup>1</sup>. Forty-two percent of the projects reported no recordable incidents at all, and slightly more than 73 percent reported no lost workday cases.

By Industry Group, industrial projects generally experienced better cost, schedule, and change performance than building projects as indicated by table cell shading. Building projects claimed the best overall safety performance.

Results by Cost Category were mixed. It was the larger projects, those costing over \$50 million, that reported somewhat better performance in the Cost, Changes, and Rework categories, and in the Safety-related LWCIR. Smaller projects, those costing less than \$15 million, reported better rates of zero recordables and lost workdays. Midsize projects, with costs ranging between \$15 and \$50 million, reported better schedule performance, but the small difference is not likely to be significant.

By Project Nature, add-ons and modernization projects exhibited stronger overall performance than did grass roots. Both add-ons and modernization projects performed better in the Cost performance category. Add-ons exhibited better performance in project schedule growth and construction schedule growth. Modernization projects experienced better Safety performance.

---

<sup>1</sup> OSHA Website, September, 2001.

**Table 2-1. Summary of Mean Performance Outcomes – Owners**

| Performance Metric <sup>1</sup>             | All Owners | By Industry Group      |                         | By Cost Category (millions) |           |        | By Project Nature |        |        |
|---------------------------------------------|------------|------------------------|-------------------------|-----------------------------|-----------|--------|-------------------|--------|--------|
|                                             |            | Buildings <sup>3</sup> | Industrial <sup>4</sup> | <\$15                       | \$15-\$50 | >\$50  | Add               | Grass  | Modern |
| <b><u>COST</u></b>                          |            |                        |                         |                             |           |        |                   |        |        |
| Project Cost Growth                         | -0.032     | -0.004                 | -0.042                  | -0.034                      | -0.028    | -0.034 | -0.035            | -0.026 | -0.035 |
| Construction Cost Growth <sup>2</sup>       | -0.012     | 0.036                  | -0.027                  | -0.012                      | -0.018    | -0.003 | -0.015            | -0.005 | -0.015 |
| Startup Cost Growth <sup>2</sup>            | -0.086     | -0.030*                | -0.092                  | -0.140                      | -0.039    | -0.066 | -0.144            | -0.034 | -0.091 |
| Construction Phase Cost Factor <sup>2</sup> | 0.579      | 0.846                  | 0.495                   | 0.621                       | 0.534     | 0.532  | 0.535             | 0.638  | 0.562  |
| Startup Phase Cost Factor <sup>2</sup>      | 0.040      | 0.052*                 | 0.039                   | 0.039                       | 0.040     | 0.044  | 0.036             | 0.046  | 0.040  |
| <b><u>SCHEDULE</u></b>                      |            |                        |                         |                             |           |        |                   |        |        |
| Project Schedule Growth                     | 0.045      | 0.087                  | 0.032                   | 0.069                       | -0.001    | 0.038  | 0.027             | 0.052  | 0.051  |
| Construction Schedule Growth <sup>2</sup>   | 0.073      | 0.109                  | 0.063                   | 0.070                       | 0.067     | 0.086  | 0.054             | 0.085  | 0.076  |
| Startup Schedule Growth <sup>2</sup>        | -0.050     | -0.018                 | -0.055                  | -0.035                      | -0.060    | -0.062 | -0.068            | -0.140 | 0.027  |
| Actual Overall Project Duration             | 133        | 154                    | 126                     | 116                         | 133       | 180    | 117               | 161    | 123    |
| Actual Total Project Duration               | 100        | 128                    | 91                      | 87                          | 100       | 133    | 90                | 122    | 89     |
| Construction Phase Duration <sup>2</sup>    | 60         | 79                     | 54                      | 49                          | 62        | 87     | 54                | 75     | 52     |
| Startup Phase Duration <sup>2</sup>         | 9.15       | 11.55                  | 8.79                    | 8.00                        | 8.52      | 12.50  | 9.41              | 11.40  | 7.53   |
| Const. Phase Duration Factor <sup>2</sup>   | 0.468      | 0.541                  | 0.443                   | 0.431                       | 0.489     | 0.538  | 0.484             | 0.500  | 0.433  |
| Startup Phase Duration Factor <sup>2</sup>  | 0.098      | 0.113                  | 0.096                   | 0.086                       | 0.084     | 0.136  | 0.102             | 0.116  | 0.085  |
| <b><u>SAFETY</u></b>                        |            |                        |                         |                             |           |        |                   |        |        |
| R.I.R.                                      | 3.132      | 2.617                  | 3.223                   | 3.166                       | 2.685     | 3.586  | 3.042             | 3.353  | 3.036  |
| L.W.C.I.R.                                  | 0.671      | 0.779                  | 0.652                   | 0.566                       | 1.060     | 0.443  | 0.809             | 1.070  | 0.299  |
| Zero Recordables                            | 42.0%      | 59.4%                  | 38.9%                   | 62.6%                       | 29.8%     | 10.4%  | 37.9%             | 27.0%  | 54.9%  |
| Zero Lost Workdays                          | 73.1%      | 75.8%                  | 72.6%                   | 88.6%                       | 68.3%     | 48.1%  | 68.3%             | 60.6%  | 84.9%  |
| <b><u>CHANGES</u></b>                       |            |                        |                         |                             |           |        |                   |        |        |
| Change Cost Factor                          | 0.054      | 0.060                  | 0.051                   | 0.058                       | 0.053     | 0.044  | 0.055             | 0.047  | 0.058  |
| Change Schedule Factor                      | 0.044      | 0.062                  | 0.036                   | 0.042                       | 0.062     | 0.029  | 0.034             | 0.056  | 0.042  |
| <b><u>REWORK</u></b>                        |            |                        |                         |                             |           |        |                   |        |        |
| Field Rework Cost Factor                    | 0.051      | 0.049                  | 0.052                   | 0.051                       | 0.059     | 0.033* | 0.045             | 0.037  | 0.064  |
| Field Rework Schedule Factor                | 0.013      | 0.023*                 | 0.009                   | 0.011                       | 0.019*    | C.T.   | 0.012*            | 0.024* | 0.007  |

<sup>1</sup> Metric definitions are provided in Appendix B.

<sup>2</sup> Phase definitions are provided in Appendix C.

<sup>3</sup> n=76

<sup>4</sup> n=240

Shading indicates best performance within category.

\*= Statistical warning indicator. See Appendix A.

C.T.= Data withheld per CII Confidentiality Policy. See Appendix A.

## 2.3 Performance Outcomes – Contractors

Table 2-2 contains the outcome summary for contractor projects. Again, only mean performance values are shown, and the best performances under Cost and Project Nature are shaded. Due to the small number of cases included under the Buildings Industry Group, data were suppressed for confidentiality reasons.

Overall, contractors reported better schedule performance than owners, especially in the areas of project and construction schedule growth. Cost performance for contractors was generally worse than that of owners, but contractors led owners in safety performance with a somewhat lower RIR (2.107 v. 3.132) and a much lower LWCIR (0.134 v. 0.671).

By Cost Category, smaller projects performed better than midsize or larger projects in cost performance. Smaller projects were also the best performers in the Safety performance category, with the rates of zero recordables at 57.6% and zero lost workdays at 96.9% far surpassing the rates of midsize or larger projects. The best schedule performance was achieved by midsize projects. Large projects performed best in the Changes category.

By Project Nature, patterns similar to owners were observed with modernization projects generally achieving the best performance. Unlike the pattern observed for owners, grass roots projects appeared to perform better than add-ons.