

Measuring the Labor Productivity of Electrical Contractors

University of Washington

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ELECTRI International

The Foundation for Electrical Construction, Inc.

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Executive Summary

This study introduces practical and simple ways of measuring labor productivity in a contractor's organization at different levels of detail. Higher productivity levels allow contractors to simultaneously increase profitability, improve competitiveness and pay higher wages to workers, while completing activities sooner. Once a contractor can measure labor productivity, the effect of any factor or combination of factors can be assessed by comparing labor productivity values before and after the factor was in place. For example, the impact in productivity of a new managerial approach can be determined by measuring labor productivity before and after the new approach is implemented.

To measure labor productivity, we must define the level at which the measurement is going to be implemented. The highest level is the **construction company**, where the intent of measuring labor productivity is to determine the overall performance of a contracting organization. The second level divides **company operations** into two distinctive segments: administration and field operations. Administration is commonly referred to as *home office overhead* and it is considered a necessary but non-value added activity from the owner's viewpoint. The intent of measuring labor productivity at the field level is to determine the level of performance of a contracting organization in the field, independently from the **home office operations**. The third level is the project (e.g. electrical installations for a new semiconductor plant). Measuring labor productivity at the project level determines the level of performance of a contracting organization by project, which is important as many con-

tractors participate in a variety of markets. The fourth level is the **activity**. A construction activity is a physical segment of a project that consumes specific resources and requires a given amount of time for completion (e.g. switchboard installation in building A). The intent of measuring labor productivity at the activity level is to determine the level of performance in greater detail than possible when looking at the company, the field, or even the project level, but still at a high enough level of detail to identify problems with coordination issues. The fifth level is the **construction operation**. A construction operation is a technological—not physical—segment of a project (e.g. installation). Measuring productivity at the operation level captures data in a more amenable unit than is the case at higher levels—such as fixtures/hr or linear feet/hr rather than dollars/hr. The sixth level in this stratification is the **process**. A process is a segment of a construction operation that uses the same resources (e.g. cable pulling and termination). In simple operations when only one process exists, process and operation become synonymous. Finally, the seventh and most basic level is the **task** (e.g. bracing the conductors). A task is an elemental work assignment. The intent of measuring productivity at the task level is to evaluate the skill level and abilities of a worker or a worker/tool or worker/equipment combination.

Contractors may not want to measure labor productivity at all levels. Indeed, it may be more effective if a contractor focuses on properly measuring labor productivity at a few levels, rather than trying to do it all with low reliability and accuracy.

Each contractor should evaluate its particular circumstances and decide which of the tools presented in this report are best suited for its company.

Why Does Labor Productivity Matter?

Labor productivity is considered one of the best indicators of production efficiency. Higher productivity levels usually translate into superior profitability. A sustainable improvement in labor productivity is also associated with economic progress as it generates non-inflationary increases in salaries and wages.

ELECTRI International—The Foundation for Electrical Construction, Inc. and NECA have long recognized the importance of labor productivity in the performance of electrical contractors. ELECTRI International and NECA have commissioned several studies that investigate the effects of a variety of factors on labor productivity. These studies have looked into issues such as overtime, shift work, overmanning, temperature, multi-story construction, change orders, sequencing, stacking of trades, and schedule compression and acceleration among others.

The main goal of this study is to introduce practical and simple ways of measuring labor productivity in a contractor's organization at different levels of detail. Once a contractor is capable of measuring labor productivity, the effect of any factor or combination of factors can be assessed by comparing labor productivity values before and after the factor was in place. For example, the impact in productivity of a new managerial approach can be determined by measuring labor productivity before and after the new approach is implemented. Furthermore, by calculating historical or typical productivity values, contractors can also identify projects under distress. Even though knowing that a project is under distress does not

solve the situation, it allows a contractor to start looking for the root causes of the problem and increases the chances of improving performance by implementing corrective actions early.

The best way to understand the importance of labor productivity is through an example. Let's look at the installation of 200 24" long 2-lamp industrial grade fluorescent fixtures by two crews with different productivity levels.

Table 1 depicts the specifics of this case where Crew B is more productive than Crew A. Crew B's higher productivity could be recognized by the contractor by offering higher hourly wages to those workers. As Table 1 shows, Crew B workers are

Table 1: Productivity, Duration, and Cost

Item	Crew A	Crew B
Scope	200 fixtures	200 fixtures
Productivity	0.85 hrs/fixture	0.70 hrs/fixture
Time Required	170 labor-hours	140 labor-hours
Crew Size	4 workers	4 workers
Activity Duration	42.50 hrs	35.00 hrs
Time Savings		7.5 hrs
Wages	\$35/hr	\$38/hr
Indirect Cost	40%	40%
Labor Cost	\$49.0/hr	\$53.2/hr
Activity Labor Cost	\$8,330	\$7,448
Cost Savings		\$882

paid \$38/hr versus \$35/hr for Crew A workers.

Table 1 also shows that, even with this wage differential, the contractor still achieves savings of more than 10% in total labor costs (\$882). These savings could go directly to the contractor's bottom line to increase its profitability, be fully transferred to the owner in an effort to improve the contractor's competitiveness, or be allocated at will to increase both profits and competitiveness. Table 1 also shows that Crew B would complete the job almost one full day earlier than Crew A. Therefore, the higher productivity of Crew B allows the contractor to simultaneously increase profitability, improve competitiveness, and pay higher wages to workers while completing the activity sooner—a win-win situation for all parties involved.

A Labor Productivity Model For Electrical Construction

The term **labor productivity** is commonly used in a variety of contexts with different meanings. Formally, productivity is defined as “the output produced per unit of time.” All U.S. government data about labor productivity published by the Bureau of Labor Statistics are expressed in this manner. Generally, the U.S. government uses inflation-adjusted dollars to express output and an hour as the unit of time so it is common to find government data where labor productivity is stated as, for example, \$50/hr.

In the construction industry, because of tradition and practical reasons, productivity is usually expressed as the amount of time required to produce a unit of output, where the unit of output varies according to the circumstance. Therefore, it is common to find industry data, such as the *NECA Manual of Labor Units*, where labor productivity is stated as, for example, 1.06 hrs/fixture or 16 hrs/100 linear feet.

These two definitions of labor productivity are equivalent because they both express efficiency. A labor productivity of 1.06 hrs/fixture can be translated into \$/hr if one knows the total cost (material, labor, equipment and indirect costs) of the fixture to the owner. For example, if the total cost of each fixture to the owner is assumed to be \$212, a productivity of \$200/hr is obtained by dividing \$212 by 1.06.

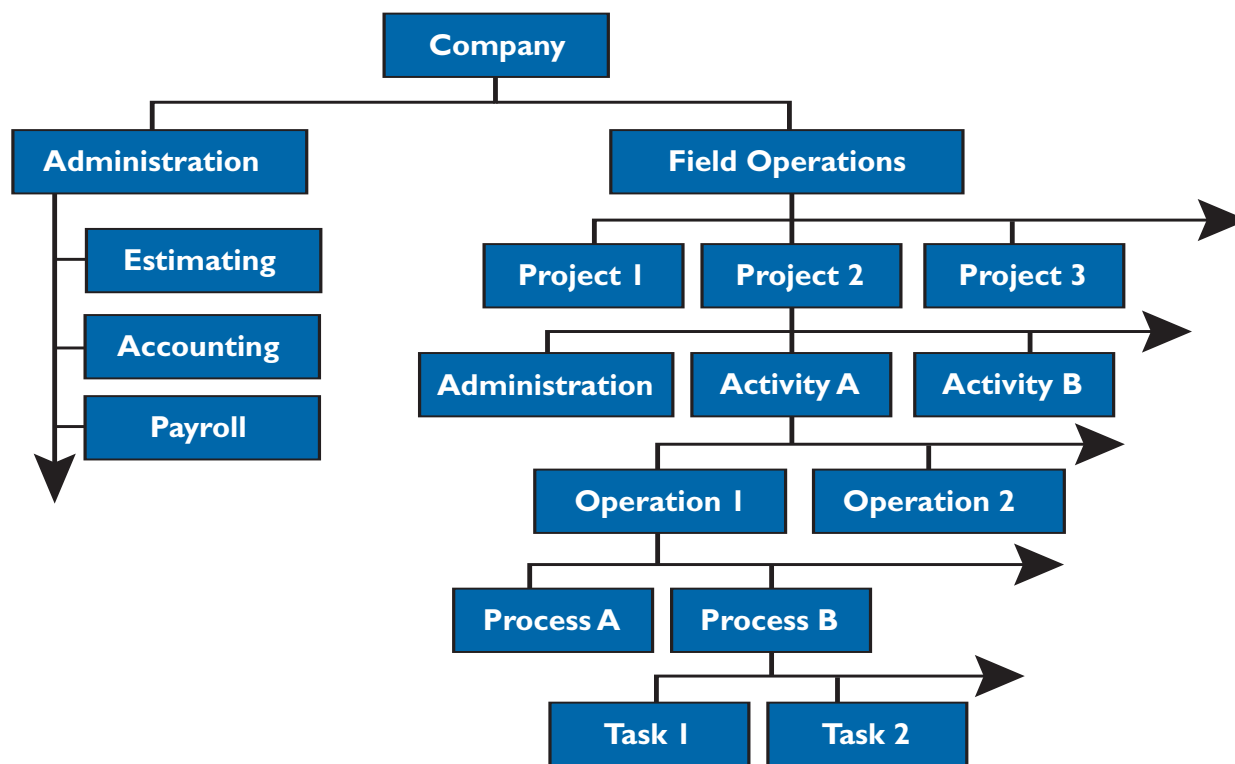
The traditional definition of 1.06 hrs/fixture is more meaningful in the field and more useful during the cost estimating process than the definition of \$200/hr. However, the more formal definition of

\$200/hr is needed to combine field productivity data from different activities to calculate the overall labor productivity for an entire project. Otherwise, how can productivity data such as 1.06 hrs/fixture be combined with 16 hrs/100 linear feet? This illustrates that no universal definition of labor productivity can be applied to all circumstances.

There are other issues that also complicate the process of measuring labor productivity. For example, should breaks, walking time, and other so called contributory activities be included or excluded when calculating the time required to install a fixture? Should lost time due to material unavailability, work stoppages, or interference from other trades be included? Should the focus be on measuring productivity at the task level or at the process level when it is known how different activities interact with one another? Should the focus be on measuring direct field productivity only or also the productivity of supervisors? Should the productivity of administrative employees be measured, or only that of field workers? Should historical labor productivity data be developed? And if so, how are baseline values established? To answer these questions, it is necessary to define a labor productivity model for electrical construction that can be used as a guideline to facilitate and simplify the process of measuring labor productivity.

Figure 1 (next page) shows a construction firm stratification diagram. At the top of this stratification is the construction company, which can be defined as an organization whose primary emphasis is to build a facility—or some systems in a facility—in order to satisfy customer’s expectations by

Figure 1: Construction Firm Stratification Diagram



providing quality at a reasonable cost while complying with industry and government standards regarding safety and environmental issues. At the company level, the main focus is on strategic business decisions such as market selection, definition of products and services, definition of growth and profitability targets, selection of personnel, and establishment of a succession plan among others.

The second level divides company operations into two distinctive segments: administration and field operations. Administration is commonly referred as home office overhead and it is considered a necessary but non-value added activity from the owner's viewpoint.

The third level is the project. At the project level the main focus is on scope definition, identification of project requirements and construction activities, development of contractual arrange-

ments, and planning and control of cost, time, and resources.

The fourth level of measurement is the activity. A construction activity is a physical segment of a project that consumes specific resources and requires a given amount of time for completion. Projects are broken down into activities to facilitate scheduling, as well as time and cost control. At this level the main focus is on early and late start and completion dates, activity float, percentage of completion, and resource consumption.

The fifth level is the construction operation. A construction operation is a technological—not a physical—segment of a project, and can span several activities. In other words, the same construction operation could be part of more than one activity. A construction operation is also cyclical or repetitive. At the operation level, the main focus of

measurement is on construction methods and technologies.

The sixth level in this stratification is the process. A process is a segment of a construction operation that uses the same resources. In simple operations when only one process exists, process and operation become synonymous. The main focus at the process level is on technological sequencing and logical collection of tasks.

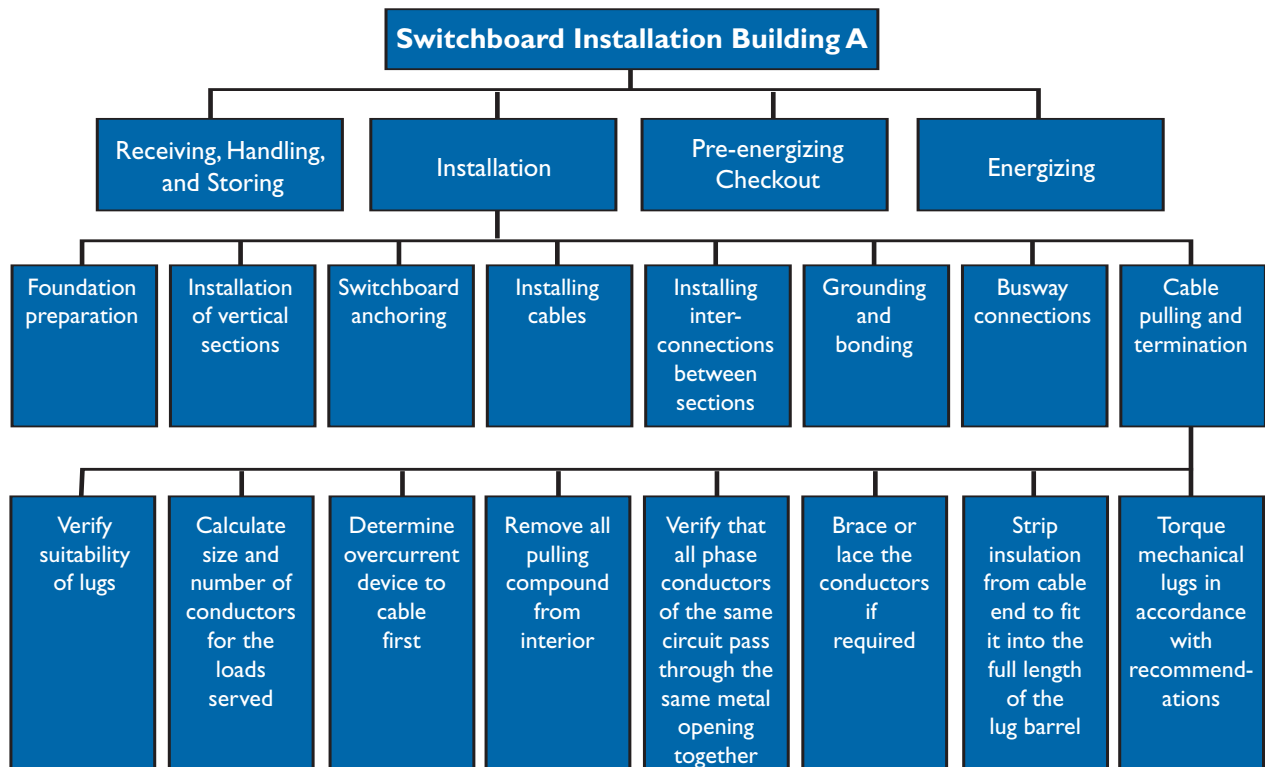
Finally, the seventh and most basic level is the task. A task is an elemental work assignment. The main focus at the task level is on intrinsic knowledge and skills of crew members.

Example

The best way to understand this stratification or hierarchy of construction and the definitions provided above is to analyze an example. An electrical contractor with 200 employees may be work-

ing on several projects simultaneously. For this example, the focus will be on one of those projects: the electrical installations for a new semiconductor plant. For managerial purposes, this project is going to be broken down into a variety of activities, and this example will examine one of these activities closely: Switchboard Installation Building A. This activity identifies a segment of the project in a particular location—building A. Because other switchboards will likely be installed in this project, identifying the particular location is important. This activity will probably be part of the critical path and as such is crucial for the on-time completion of the project. Different accounts will also be created to keep track of all expenses in this activity. For typical project control purposes, this is the lowest level of detail that a construction manager would deal with. However, from a technological perspective we can go further. **Figure 2** shows the stratification of this activity.

Figure 2: Stratification Diagram for the “Switchboard Installation Building A” Activity



The activity **Switchboard Installation Building A** includes four independent construction operations:

- 1) Receiving, handling, and storing
- 2) Installation
- 3) Pre-energizing checkout
- 4) Energizing

These are four separate operations because they use different methods, technologies and labor skills. A detailed examination of one of these operations—installation—shows that it will require eight processes:

- 1) Foundation preparation
- 2) Installation of vertical sections
- 3) Switchboard anchoring
- 4) Installing cables
- 5) Installing interconnections between sections
- 6) Grounding and bonding
- 7) Busway connections
- 8) Cable pulling and termination

In the last one of these processes—cable pulling and termination—eight individual tasks that must be performed in order to complete this process can be identified:

- 1) Verify suitability of lugs
- 2) Calculate size and number of conductors for the loads served
- 3) Determine overcurrent device to cable first
- 4) Remove all pulling compound from interior
- 5) Verify that all phase conductors of the same circuit pass through the same metal opening together
- 6) Brace or lace the conductors if required
- 7) Strip insulation from cable end to fit it into the full length of the lug barrel
- 8) Torque mechanical lugs in accordance with recommendations

As this example shows, the stratification or hierarchy of construction is a useful tool to analyze and break down the construction process at different levels of detail.

Measuring Labor Productivity at Different Levels

Before analyzing labor productivity at different levels of construction stratification, it is important to remember that construction companies are systems. Since a system is defined as a collection of interrelated components, enhancing the efficiency of a construction company requires looking at the overall picture. Optimizing an individual component in a system may not produce the desired results if that component is not the one causing the problem, or if other necessary components are not also improved concurrently. For example, increasing the productivity of workers may not achieve the desired result of improving efficiency if the procurement processes are not modified to also provide tools, equipment, and materials at the higher rates required. It is easy to imagine a very productive crew having to wait an hour for required materials and not achieving the level of production desired. The analysis that follows, which measures labor productivity at different levels, is not intended to convey the impression that labor productivity can be improved at each level in isolation without regard to what is happening at the other levels. On the contrary, the purpose of looking at different levels is to uncover information that would help diagnose problems and apply solutions to the system. For example, significant problems with availability of materials when measuring the productivity of one activity should be interpreted as a symptom of a potentially bigger administrative problem that may require the redesign of the company-wide procurement system, not only the procurement tasks performed for that particular activity.

Company Productivity

The intent of measuring labor productivity at the company level is to determine the overall performance of a contracting organization. A basic definition of company level productivity is:

$$P_{\text{COMPANY-CURRENT}} = \text{TAVA} / \text{TAL}$$

Where:

$P_{\text{COMPANY-CURRENT}}$: Productivity at the Company Level
(not adjusted for wage inflation)

TAVA: Total Accrued Value Added

TAL: Total Accrued Labor Hours

Equation 1

TAVA is calculated as:

TAVA: Accrued [Income – Materials –
Subcontracts – Owner Paid Overtime Premiums]

Equation 2

The concept of TAVA is paramount in the definition of labor productivity used in this report. At a first glance, it seems that all revenue generated by a contracting organization should be included when calculating labor productivity. However, doing so may prevent a comparison of “apples to apples.” Contractors use different financial and organizational arrangements when delivering projects. In some instances, a contractor may buy all materials and self-perform all activities. In other instances, a contractor may install materials bought and provided by the owner and subcontract some installations.

A project where no materials are provided by the owner would show significantly higher revenues than if materials are provided. However, the number of labor hours required to install those materials is the same regardless of who buys the materials. If the labor productivity calculation does not consider this situation, then the same project would show different labor productivity values depending on who is buying the materials.

A project where all installations are self-performed would require more labor hours than if some of the installations were subcontracted. However, the revenue generated is the same in both instances. If the labor productivity calculation is not corrected to consider this situation, then the same project would show different labor productivity values depending on how much of the scope is subcontracted.

Overtime pay must be considered in a slightly different light. If overtime paid is the result of a contractor's decision to expedite the completion of the project and the labor premium paid is born exclusively by the contractor, then this practice has no bearing in the calculation of labor productivity because it does not directly affect either the revenue or the number of hours worked. However, if the overtime is the result of an owner directive where the owner is compensating the contractor for the additional cost, then this will introduce a distortion in the calculation of labor productivity as the revenue will be higher for the same number of hours.

In order to eliminate all of these distortions, the concept of **value added** is used. Value added is defined as *the additional value given to a set of materials when they are installed in a project*. In other words, a fully assembled electrical system has more value to the owner than the sum of its parts (adding the material value of each component). In addition, the value added by a contractor only includes the self-performed installations. Work on a project by a subcontractor does not add value to the contractor since it is the subcontractor who is actually adding

that value. Furthermore, value is not added to a project when the owner pays an overtime premium.

TAVA includes the term **accrued** in its description because it consists of all income earned by a company for the sale of goods and services in a specific period of time minus material purchases, subcontracts, and owner-paid overtime premiums. The word *earned* is used rather than *collected* because accrued income includes receivables that a company may have for goods and services already rendered and excludes payments made during the period for revenues earned during the previous period. Accountants should be able to compute TAVA for a contracting organization.

The second value required to compute labor productivity at the company level is total accrued labor hours or TAL. TAL includes all labor hours (field workers and home office personnel) that the company has benefited from during a specific period of time whether or not payment has been rendered. Therefore, hours for salaries and wages payables must also be included in this calculation, and wages and salaries paid in this period for work performed in the previous period must be excluded. Once again, accountants should be able to compute TAL for a contracting organization.

Field labor hours can be determined from field records, or in the absence of detailed information, can be approximated. An approximation to the total number of field labor hours can be calculated by dividing total accrued wages of field workers by the average hourly wage. Home office personnel hours can be determined by calculating the number of full-time-equivalent (FTE) positions and multiplying this by the number of working hours for a specific period of time (i.e. 500 hours per quarter or 2,000 hours per year).

The simple measure of productivity at the company level introduced in **Equation 1** presents a problem when comparing productivity over time as it does not consider the effect of wage inflation. Therefore, a better formulation is:

MEASURING LABOR PRODUCTIVITY AT DIFFERENT LEVELS

$$P_{\text{COMPANY-CURRENT}} = (\text{TAVA}/\text{TAL}) \times (\text{WBY}/\text{WCY})$$

Where:

P_{COMPANY} : Productivity at the Company Level

TAVA: Total Accrued Value Added

TAL: Total Accrued Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

Equation 3

The factor (WBY/WCY) shown in **Equation 3** is used to convert current dollars to dollars from a selected base year. Any previous year can be used as a base year. This adjustment for wage inflation allows the comparison of company-level labor productivity values across time, which in turn facilitates the identification of trends.

Company level labor productivity can also be expressed in alternative ways. For example, labor productivity could be expressed as the number of hours required to generate a given amount of value added. **Equation 4** shows the formula required to implement this calculation.

$$P_{\text{COMPANY-HOURS}} = (\text{TAVA}/\text{TAL}) \times (\text{WBY}/\text{WCY}) \times \text{VAM}$$

Where:

$P_{\text{COMPANY-HOURS}}$: Productivity Index at the Company Level

TAVA: Total Accrued Value Added

TAL: Total Accrued Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

VAM: Value Added Multiplier

Equation 4

The VAM term in Equation 4 refers to the given amount of value added used as the basis for the calculation. For example, if \$10,000 is used for the VAM, then Equation 4 would calculate the

number of labor hours required to generate \$10,000 of value added. Therefore, while Equation 3 provides values in dollars per hour, Equation 4 provides values in hours per given amount.

Contractors may also want to create their own company productivity indexes. This can be accomplished by normalizing the value of company level labor productivity for a given year to be equal to 100. This is the function of the IF term shown in **Equation 5**. Then, all other years will be expressed in relation to this base year.

$$P\text{-Index}_{\text{COMPANY}} = (\text{TAVA}/\text{TAL}) \times (\text{WBY}/\text{WCY}) \times \text{IF}$$

Where:

$P\text{-Index}_{\text{COMPANY}}$: Productivity Index at the Company Level

TAVA: Total Accrued Value Added

TAL: Total Accrued Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

IF: Index Factor

Equation 5

The value of IF can be calculated by using a simple formula:

$$\text{IF} = (100) / (P_{\text{COMPANY}} \text{ for the base year})$$

Equation 6

By normalizing labor productivity with the use of a company-specific index, the data can be easily shared with field office personnel without the fear of divulging highly sensitive proprietary data.

Example 1

A small contractor wants to calculate its company level labor productivity for the last five years in order to evaluate its overall performance. As shown in **Table 2** (next page), this contractor did not have complete records for hours worked for the

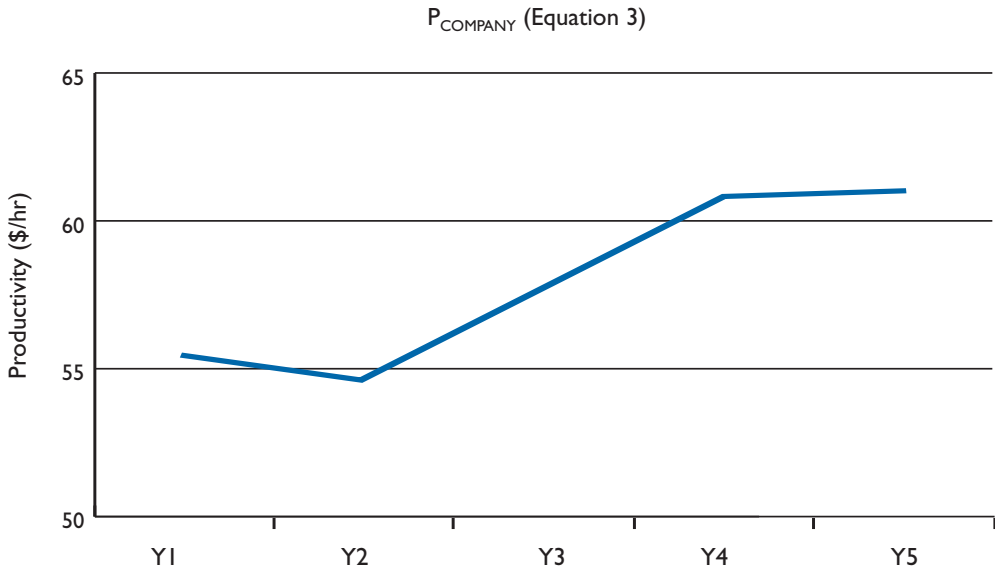
entire five-year period, so for years one and two the number of field labor hours is approximated by dividing total wages by the average field wage paid.

The calculations show that this company’s labor productivity, according to Equation 3, decreased from \$55.5/hr for the year 1 to \$54.7/hr for year

Table 2: Five Years of Productivity Data for a Small Contractor

	Y1	Y2	Y3	Y4	Y5
Known Variables					
Accrued Income	13,250,000	14,000,000	15,800,000	20,500,000	25,200,000
Accrued Value of Materials	5,300,000	6,300,000	5,530,000	8,200,000	10,584,000
Accrued Value of Subcontracts	550,000	245,000	350,000	750,000	425,000
Field Labor Hours			139,500	150,000	178,000
Field Wages	5,400,000	5,500,000			
Average Field Wage	46	48	50	52	54
Home Office FTE	8	8	9	9	10
Known Variables					
Total Accrued Labor Hours	133,391	130,583	157,500	168,000	198,000
P _{COMPANY} (Equation 3)	55.5	54.7	57.9	60.8	61.1
Value Added Multiplier	10,000				
P _{COMPANY-HOURS} (Eq. 4)	180.3	182.8	172.6	164.4	163.8
P-Index _{COMPANY} (Eq. 5)	100.0	98.6	104.5	109.6	110.1
P-Index _{COMPANY} 3-Yr. Moving Avg.			101.0	104.2	108.0

Figure 3: Five-Year Company Level Productivity Calculated Using Equation 3



(Figure 3). This small variation in labor productivity values is normal and should not raise any red flags. However, for the last three years an upward trend is observed as the company's productivity increased to \$57.9/hr, \$60.8 and \$61.1/hr in years three, four and five respectively.

When productivity is calculated with Equation 4, an inverse relationship is evident: higher productivity as measured in \$/hr is equivalent to fewer

hours required to generate a given amount of value added, \$10,000 in this example. Therefore, Equation 4 provides a different but equivalent way of analyzing the data as compared to Equation 3 (Figure 4). Finally, Equation 5 normalizes the data calculated by Equation 3 to create a company-based productivity index. As shown by the corresponding graphs, the line generated with Equation 3 and the line generated by Equation 5 (Figure 5)

Figure 4: Five-Year Company Level Productivity Calculated Using Equation 4

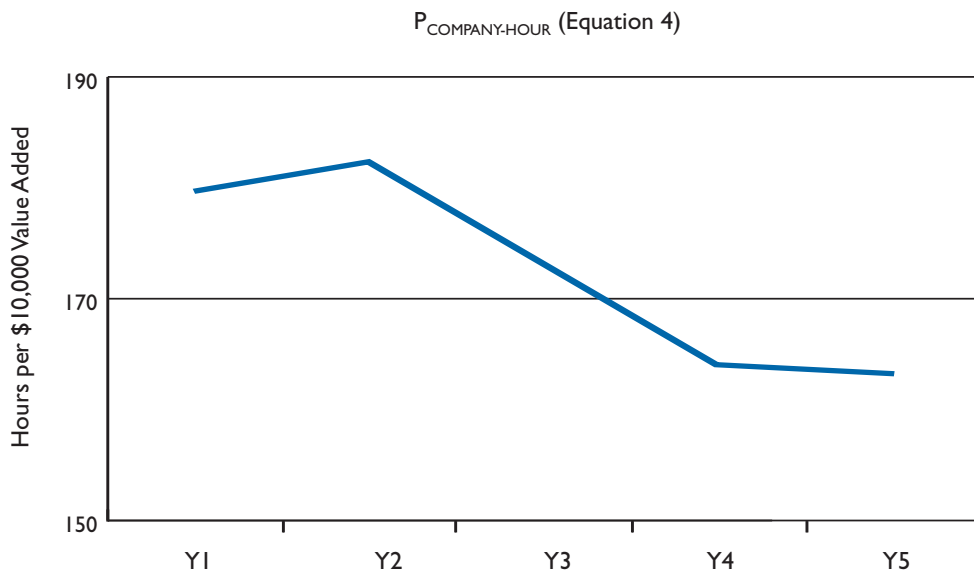
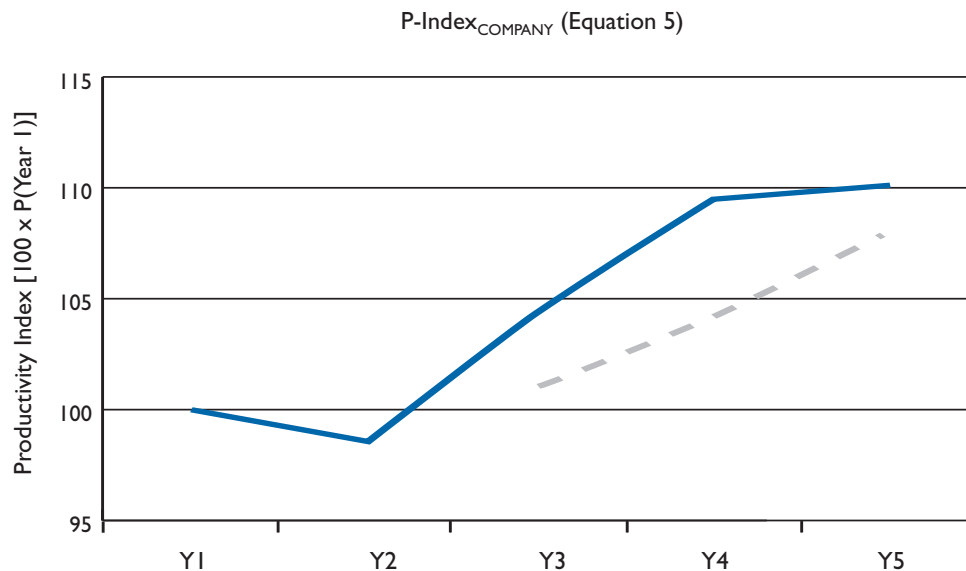


Figure 5: Five-Year Company Level Productivity Calculated Using Equation 5



are equivalent since Equation 5 is only a transformation of scale of Equation 3.

Small variations in productivity values can be expected from year to year. This is absolutely normal and should not be a source of concern, but it may be necessary to smooth out the data in order to facilitate the process of identifying trends. **Table 2** shows the calculation of a 3-year moving average for the values obtained from Equation 5. A 3-year moving average is calculated by adding the productivity value for a given year to the productivity values from the preceding two years and dividing the result by 3. Since three years of data are needed, the 3-year moving average can only be calculated for years three, four and five. The dotted line in **Figure 5** shows the 3-year moving average. An upward trend is a positive finding for a contractor and productivity values above a moving average represent an improvement in productivity beyond the company's historical trend, as is the case in **Figure 5**. On the other hand, productivity values below a moving average show performance below historical trends. A productivity value below a moving average, though, may still represent an improvement in productivity from the previous year. This would be the case for a contractor that has been improving productivity at a given rate, failed to maintain the same pace of improvement for the current year, but still increased productivity.

Field Operations Productivity

Measuring labor productivity at the field level determines the level of performance of a contracting organization in the field, independent from the home office operations. Productivity at the field operation level is computed by:

P_{FIELD} = (TAVA/AFL) × (WBY/WCY)

Where:

P_{FIELD}: Productivity at the Field Level

TAVA: Total Accrued Value Added

AFL: Accrued Field Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

Equation 7

The only difference between Equation 7 and Equation 3 is the number of labor hours considered. Equation 3 considers all labor hours (field plus home office); Equation 7 includes only field labor hours.

Productivity of field operations can also be expressed as the number of hours required to generate a given amount of value added (Value Added Multiplier). Equation 8 shows the formula required to perform this computation.

P_{FIELD-HOURS} = (TAVA/AFL) × (WCY/WBY) × VAM

Where:

P_{FIELD-HOURS}: Productivity at the Field Level
(in hours per given revenue)

TAVA: Total Accrued Value Added

AFL: Accrued Field Labor Hours

WCY: Average Wages Current Year

WBY: Average Wages Base Year

VAM: Value Added Multiplier

Equation 8

Once again, Equation 8 is similar to Equation 4. The only difference is the number of labor hours included in the calculation. Finally, contractors may also want to create their own productivity index for field operations, using Equation 9—a comparable formula to Equation 5.

$$P\text{-Index}_{\text{FIELD}} = (\text{TAVA}/\text{AFL}) \times (\text{WBY}/\text{WCY}) \times \text{IF}$$

Where:

$P\text{-Index}_{\text{FIELD}}$: Productivity at the Field Level

TAVA: Total Accrued Value Added

AFL: Accrued Field Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

IF: Index Factor

Equation 9

Example 2

The small contractor from Example 1 now wants to calculate its 5-year productivity values at the field operations level. The required data for this analysis is in **Table 2** (page 12). After performing the necessary operations, the results are shown in **Table 3**.

Not surprisingly, the field labor productivity of the small contractor follows the same trend as the company's labor productivity. For trade contractors that self-perform most or all of their work, field labor hours will represent the majority of labor hours and will dictate the trends at both the company and the field level. General contractors or trade contractors that subcontract a significant amount of work may experience a greater divergence between labor productivity trends at the

company and the field levels.

Going back to the example, it may be difficult to compare the labor productivity at the company level to the labor productivity at the field level. The best way to do so is to look at the Productivity Indexes calculated for both cases (same base year required). A review of the data in Tables 2 and 3 shows that the Productivity Index at the company level is slightly higher than the Productivity Index at the field level. This implies that home office personnel have increased their labor productivity at a higher rate than field workers over the past four years. This is a typical result, as it is easier to increase the productivity of home office personal than the productivity of field workers—it is possible to handle one more project per year with the same home office personnel, but not with the same number of field workers (hours).

Table 3: Five Years of Field Productivity Calculations for a Small Contractor

	Y1	Y2	Y3	Y4	Y5
Calculated Variables					
Total Field Labor Hours	117,391	114,583	139,500	150,000	178,000
P_{FIELD} (Equation 7)	63.0	62.4	65.4	68.1	67.9
Value Added Multiplier	10,000				
$P_{\text{FIELD-HOURS}}$ (Equation 8)	158.6	160.4	152.9	146.8	147.2
$P\text{-Index}_{\text{FIELD}}$ (Equation 9)	100.0	98.9	103.8	108.1	107.7
$P\text{-Index}_{\text{FIELD}}$ 3-Year Moving Avg.			100.9	103.6	106.5

Figure 6: Five-Year Field Operations Productivity Calculated Using Equation 7

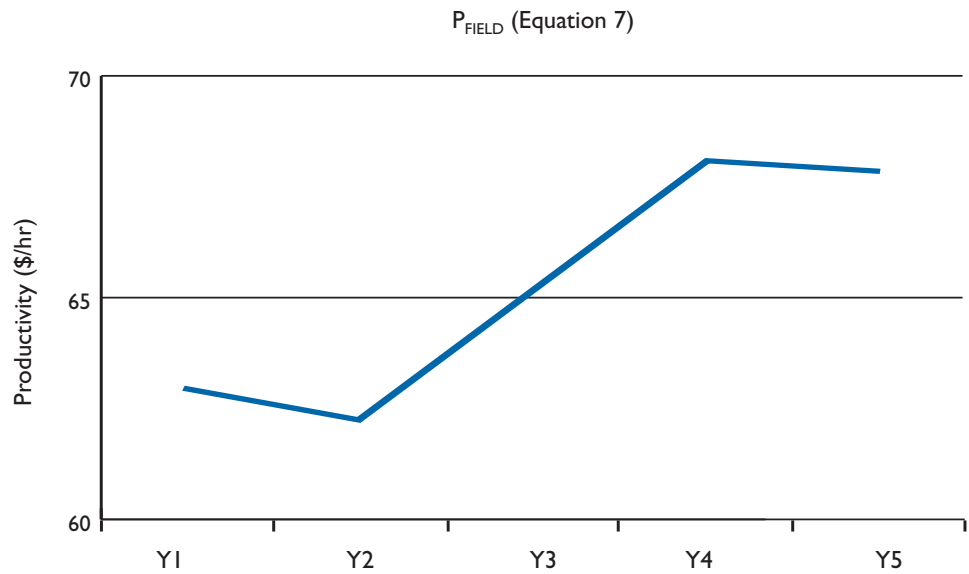
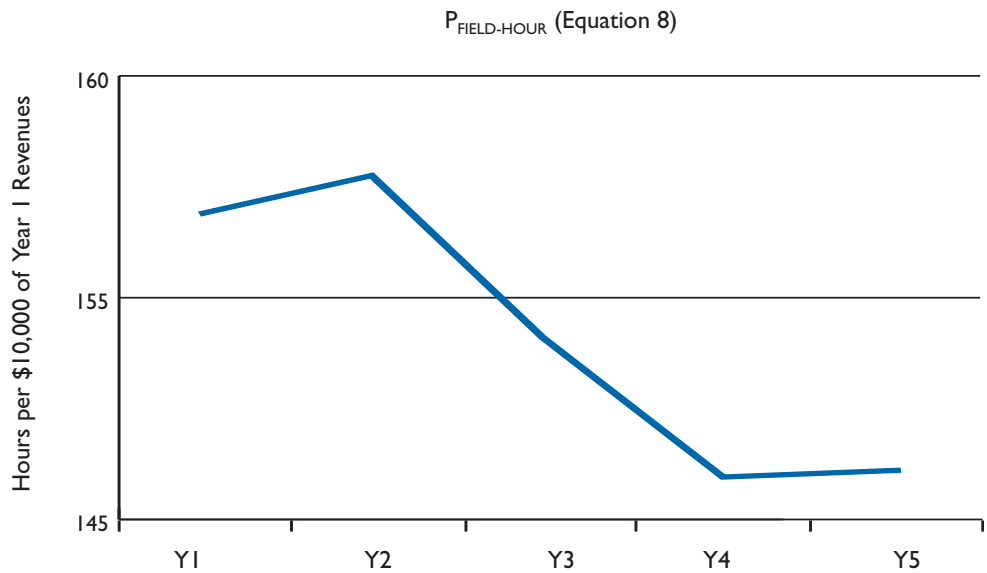


Figure 4: Five-Year Field Operations Productivity Calculated Using Equation 8

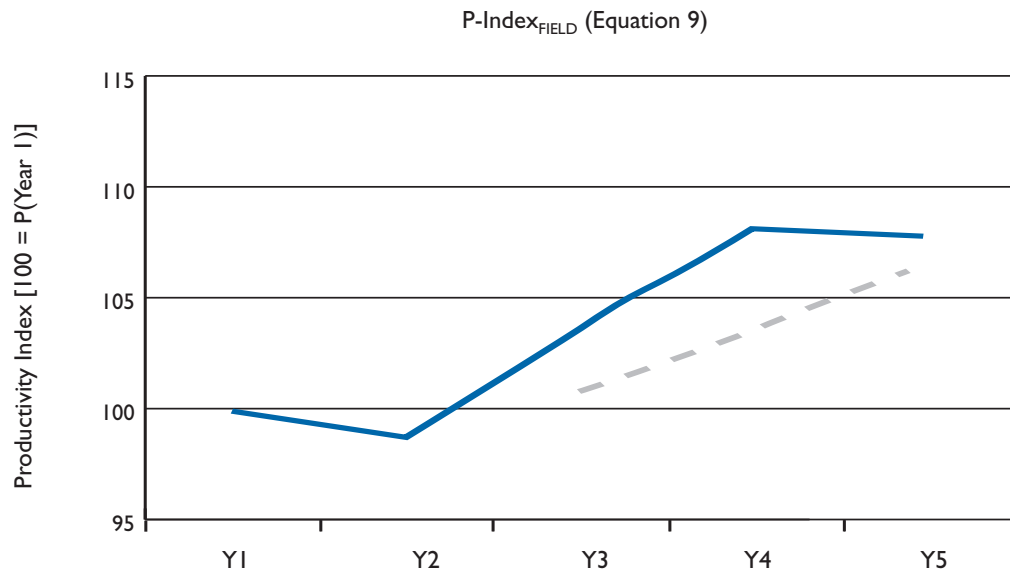


Project Productivity

Labor productivity at the project level is measured to determine the level of performance of a contracting organization by project, which may uncover patterns or correlations. For example, an electrical contractor may realize that its productivity tends to be 10 percent lower when working with a given general contractor (GC). In light of this, the electrical contractor may choose not to work with that particular GC in the future; alternatively, it may choose to

increase the amount budgeted for labor by 10 percent when sending bids to this GC. Contractors may also find patterns related to project managers. A project manager that consistently achieves the lowest labor productivity values within the company may have to be let go in order to enhance the company's efficiency. Furthermore, contractors may also be able to find patterns related to market segments. Contractors that work in several markets may not be as efficient in all of them. Knowing the areas in

Figure 5: Five-Year Field Operations Productivity Calculated Using Equation 9



which a contractor has a competitive advantage (through higher labor productivity values) may prove valuable when making strategic decisions about areas of expansion for the company.

Productivity at the project level is given by:

$$P_{\text{PROJECT}} = (\text{TAVAP}/\text{ALH}) \times (\text{WBY}/\text{WCY})$$

Where:

P_{PROJECT} : Productivity at the Project Level

TAVAP: Total Accrued Value Added of Project

ALH: Accrued Labor Hours for the Project

WBY: Average Wages Base Year

TAL: Average Wages Current Year

Equation 10

The TAVAP term includes all value added for work invoiced or to be invoiced in a project, including change orders. The ALH term includes all direct labor consumed by the project, accounting for both craftsmen and supervisory employees. Only supervisory employees that work full-time for the project should be included. Part-time supervisory employees, such as project managers that oversee multiple

projects, are considered part of the home office personnel. Average wages are used as wage inflation indexes so that data from projects performed in different years can be compared.

Finally, contractors may also want to create their own productivity index for projects, using a comparable formula to Equation 5:

$$\text{P-Index}_{\text{PROJECT}} = (\text{TAVAP}/\text{ALH}) \times (\text{WBY}/\text{WCY}) \times \text{IF}$$

Where:

$\text{P-Index}_{\text{PROJECT}}$: Productivity Index at the Project Level

TAVAP: Total Accrued Value Added of Project

ALH: Accrued Labor Hours for the Project

WBY: Average Wages Base Year

WCY: Average Wages Current Year

IF: Index Factor

Equation 11

Contractors may select any project as the base project for the index calculation. Once again, by normalizing labor productivity with the use of a project-specific index, the data can be easily shared with field

Table 4: Labor Productivity for Three Projects

	Project 1	Project 2	Project 3
Known Variables			
Project Value Added	1,650,000	2,475,000	3,712,500
Labor Hours	25,756	38,345	49,897
Average Wages	37	37	38
Calculated Variables			
P _{PROJECT} (Equation 10)	64.1	64.5	72.4
P-Index _{PROJECT} (Equation 11)	100.0	100.8	113.1

office personnel without the fear of divulging highly sensitive proprietary data.

Example 3

A contractor wants to calculate the labor productivity values for three of his projects. The required data for this analysis, as well as the results of the calculations, are shown in Table 4.

Project 1 and Project 2 show similar values for labor productivity, at around \$64/hr. Project 3, on the other hand, shows a significantly higher value at \$72.4/hr. This difference may be explainable if Project 3 belongs to a different market than the other projects or because it has some unique features. However, if these three projects belong to the same market and are similar in nature, then Project 3 represents an outstanding performance when compared to the other two projects. If this is the case, then the contractor should investigate further and verify the validity of the data. If the data is correct, this would represent a significant finding for the company. Further analysis of Project 3 would be warranted to learn what possible factors could have contributed to this outstanding performance and evaluate the possibility of transferring lessons learned to future projects. Also notice that Projects 1 and 2 have the same average wages, while Project 3 has a different one. This may indicate that Projects 1 and 2 were built in the same year, but Project 3 was built in a different year. Alternatively, this could also indicate that

Project 3 was built in a different jurisdiction than projects 1 and 2. Therefore, the adjustment for wage inflation can also be used to compare projects built during the same year at different jurisdictions (locations with different average wage values).

Activity Productivity

The intent of measuring labor productivity at the activity level is to determine the level of performance at a greater detail than possible when looking at the company, the field, or even the project level, but still at a high enough level of detail to identify problems with coordination issues.

Productivity at the activity level is given by:

P_{ACTIVITY} = (TAVAA/ALHA) × (WBY/WCY)

Where:

P_{ACTIVITY}: Productivity at the Activity Level

TAVAA: Total Accrued Value Added of the Activity

ALHA: Accrued Labor Hours for the Activity

WBY: Average Wages Base Year

TAL: Average Wages Current Year

Equation 12

The TAVAA term includes all value added for work invoiced or to be invoiced for the activity, including change orders. The ALHA term includes

only direct labor consumed by the activity. No supervisory employees should be included in this calculation. Notice that average wage rates are used so that data from similar activities performed in different years (or different jurisdictions) can be compared.

Example 4

A contractor wants to calculate the labor productivity values for two critical activities. The required data for this analysis, as well as the results of the calculations, are shown in **Table 5**.

The calculation of the labor productivity values for the two activities shown in Table 5 follows the same basic procedure used before. A Productivity Index for Activities can also be calculated, if desired, following an comparable procedure to the one followed at the company, field, and project levels, with a significant difference in how the “known” variables are obtained. Calculating labor productivity at the company, field, or project level can be accomplished by processing data that most accounting departments already have as a result of their regular operations. However, calculating labor productivity at the activity level requires information from the field that is usually not captured during the performance of regular company business.

Figuring out the value added of an activity is not as simple as getting the value added for an entire project to calculate project productivity. First, the scope of the activity must be clearly defined. Second, the procurement process most likely does not keep

track of the amount or cost of the materials on an activity by activity basis. Third, the appropriate indirect cost items must be selected as part of the value of the activity. These indirect cost items can include, for example, profits, contingency, financial charges, bonding and insurance, equipment, and supervision. Perhaps the simplest way to accomplish this task is to develop a detailed estimate of the activity as if the work were to be performed by a change order, and use this amount as the total value of the activity from which materials, subcontracts, and owner-paid overtime premiums are to be subtracted.

Figuring out labor hours is not simple either, as workers usually work on several activities during the same week, or even during the same day. Properly allocating labor hours to an activity may require additional record keeping in the form of timesheets for each employee who works on the activity.

Because additional information must be collected, it is impractical to calculate labor productivity for all activities in a given project. Furthermore, not all activities are equally important. Activities that are repetitive, belong to the critical path, or involve a great deal of uncertainty regarding labor consumption are prime candidates for measuring productivity. An electrical contractor who wants to measure the productivity of key construction activities in a project should begin by inviting field personnel to actively participate in the process. A simple data collection system could consist of forms to be filled out by electricians and foremen, and should be designed to ensure minimum disruption of the activity and reduce the amount of additional effort required to collect the data.

It is imperative that those in the field understand that the objective of measuring activity productivity is to evaluate the efficiency of the activity and not the performance of the workers. Studies have shown that the majority of the unproductive time for construction workers is caused by problems with the process rather than by worker inefficiencies or laziness. Some examples of this include lack of proper

Table 5: Labor Productivity for Two Activities

	Activity 1	Activity 2
Known Variables		
Activity Value Added	175,000	262,500
Labor Hours	2,863	3,486
Average Wages	37	37
Calculated Variables		
P_{ACTIVITY} (Equation 12)	61.2	75.3

directions, tools, or materials; requests to go to workstations that are not ready or are already occupied, requests for rework because of changes, and requests to work in unreasonable sequences or using inefficient methods.

In addition to obtaining quantitative information about construction activities, contractors should take advantage of the participation of field personnel to capture some qualitative data that can be as valuable as the numerical results. Often, the individuals who actually perform the work are in the best position to provide feedback about what is and is not working properly. Surveys and interviews should be used to gather this qualitative data since traditional channels of communication, which require the information to go through several levels, can be unreliable. Since people at each level tend to filter the information for a variety of reasons, significant problems may never be uncovered. Questionnaires and interviews, when used properly, are great tools to uncover problems and gather the opinions of workers in an unbiased fashion.

Questionnaires must be carefully designed to ensure that they will uncover problems. There are many ways to ask a question, from multiple-choice to open-ended written statements. Multiple-choice questions are appropriate when there are only a few options available, but should be avoided when no one knows exactly how many different answers there may be for a question. Open-ended questions do not want to limit the respondents to a pre-selected number of options, but most people will not spend a lot of time answering open-ended questions. A proper combination of open-ended with other type of questions may be best. “Yes or no” questions force respondents to take a position since there is no “middle” choice. For example, workers can either say that the instructions provided are the best for the job or not, but cannot state that they are just OK. Another option is to ask people to grade the level of a problem or the frequency of occurrence of specific situations. For example, for a list of issues respon-

dants can choose whether they are “very important,” “important,” or “not really important,” or if they occur “very frequently,” “frequently,” “sometimes,” or “almost never.”

Contractors should make clear that answering the questionnaire or participating in an interview is voluntary and that anyone who feels uncomfortable can be excused. Common topics covered in questionnaires and interviews include

- availability and appropriateness of materials, tools, and equipment,
- suitability of instructions and other information,
- availability and suitability of safety equipment,
- sequencing of tasks,
- frequency and reasons for rework,
- frequency and reasons for interference with other crafts or activities, and
- problems with overmanning, overtime, turnover, and absenteeism.

Finally, it is imperative to keep in mind that information obtained from interviews or questionnaires is basically useless unless lessons learned are extracted by carefully studying the answers given and determining the root causes of problems. The answers will only reveal symptoms of problems rather than the problems themselves. Once the root causes of the problems are identified (i.e., lessons are learned), corrective actions must be implemented company-wide to improve the processes involved.

Operation and Process Productivity

One of the disadvantages of calculating productivity at the activity level is that the unit of measurement is dollars per hour. Dollars per hour is used because an activity, by definition, involves several operations which have their own units of measurement. The only way to combine productivities of operations measured in different units (i.e. fixtures/hr vs. linear feet/hr) is to use dollars per

hour. However, dollars per hour is not a very amenable unit to evaluate field productivity. Therefore, in many cases, contractors may want to use questionnaires and interviews to collect only qualitative information at the activity level and leave the measurement of productivity at the operation or the process level. This section deals with measuring the productivity of operations and processes because in many cases an operation has only one process, so these two concepts become synonymous. Furthermore, even when an operation has several processes, the techniques used to measure the productivity of operations are basically the same as those used to determine the productivity of processes.

A variety of tools are available to measure labor productivity at the operation or process level, among them:

- time studies,
- photographic and video studies, and
- activity sampling.

Time Studies

Time studies are used to collect information about the duration of the different tasks that make up a construction operation or process. These studies are task-based rather than worker-based. Specific data-gathering forms for each construction operation or process must be prepared in advance to collect the information. Traditional time studies require a significant amount of resources as one observer needs to be assigned to each worker. Traditional time studies have some limitations due to their nature. For example, in a time study the observer must make a determination about the instantaneous point in time when one task finishes and the next one begins. For some construction operations or processes, such a point may be more obvious than for others. This is not usually a problem when the same person is collecting all data, but it could be a major concern when different observers are collecting data on the same operation or process and the data is to be combined later. Additionally, most observers usually do not

collect explanatory data that could shed some light on why a particular task or set of tasks is taking significantly more time than expected. This happens because of the large amount of data that is often collected and the time and physical effort required.

A modified version of a time study can be applied, however, if workers are recruited to collect their own data. Obviously, the main reason that companies have observers collect the data is a lack of trust of workers. Once again, it is imperative to communicate to those in the field that the objective of measuring productivity is to evaluate the efficiency of the operation—*not* the performance of the workers. Worker trust and cooperation is indispensable if modified time studies are to be performed. Furthermore, workers can add information of great value to their time annotations by including notes and comments that help put the information into context. Notes detailing why productivity was negatively or positively affected during a particular operation can be invaluable to management. Forms must be designed to allow workers to collect their own data. These forms should capture amounts of materials or equipment installed, time invested in every task, and contextual information to explain deviation from expected performance. Management can then combine the data from these forms and calculate productivity values in meaningful units such as fixtures/hr or liner feet/hr.

Photographic and Video Studies

Photographic and video studies can be very useful tools when studying construction operations and processes. They can capture at least the same information as with time studies without requiring the expense of observers.

Photographic studies use a camera or video camera to capture time-lapse pictures of a construction operation. Time-lapse refers to the process of taking still pictures at selected intervals; in general, one to ten seconds. The shorter the interval, of course, the greater the amount of detail that can be gathered.

Intervals of one second are usually used to keep track of hand movements. Intervals of four seconds are commonly used to study overall body or equipment movements. Intervals greater than four seconds are used only as a general reference on how the operation is proceeding.

Video studies use a video camera to capture real-time video of a construction operation. With the availability of digital video cameras and video processing software, it is possible to use a digital video camera to record real-time video and also to extract time-lapse pictures from the same event. Some of the advantages of photographic and video studies include:

- The creation of a permanent record of the operation that can be studied from several perspectives by a variety of individuals.
- By using time-lapse photography, operations or processes that take hours can be studied in minutes.
- The video can be shown to craftsmen, foremen, and supervisors to gather their opinions regarding improvement in productivity, quality, and safety.
- Inefficiencies and imbalances—such as interferences between crew members, lack of materials or tools, and changes in procedures—can be uncovered.
- The detailed records provided by these studies can help resolve disputes in the project.
- The photographic/video record can provide excellent support for or refutation of claims.
- They can be excellent training and teaching aids.
- They can be used to capture and support lessons learned.

Some issues of attention when performing photographic and video studies:

- Make sure the camera is positioned well. Try to position the camera above the level of the operation or process to be recorded. If it is too low, there may be significant obstructions in the foreground

and/or a loss of information from workers that cannot be seen in the frame. Some users recommend at least 15 feet above operation level for optimal observations. Cameras can be mounted on buildings, rooftops, slopes, tower cranes, or specially erected small scaffolds.

- Take advantage of the camera's zooming capabilities to capture the entire area of interest.
- The camera should be placed in a waterproof box with a window designed to minimize reflections.
- Sometimes it may be difficult to identify the workers to be observed in a congested area where several crews are co-located. It may be a good idea to ask the workers to wear special colored hats or another distinctive mark for easy identification.
- To frame the recording in its proper context, record a panoramic view of the entire project first, and then zoom in to the area of interest.
- The camera should have the capability of imprinting each frame with a number and the time.
- Information including the project's name and location, operation's name and date, and time of the recording should be added to the video using the editing software.
- Special conditions and other information relevant to the study should be added to the recording using the editing software.

The detailed analysis of photographic and video studies still requires time, and this is one of the main reasons some managers favor a more informal review of the recordings. However, a detailed analysis is indispensable to obtain the maximum benefits possible. The recording should be viewed at least three to five times to identify all the interferences, waste motions, lost time, duplicated efforts, and other inefficiencies. The activities of each crew member or piece of equipment should be studied independently.

Activity Sampling

There is no doubt that the best way to evaluate the effectiveness of a worker, a crew, or an entire construction operation or process would be to capture continuous data about the work being carried out and duplicate the operation on a computer simulation—an undertaking that would probably be more expensive than the construction operation or process itself. In the future, information technologies may provide a way to accomplish this inexpensively, but today such capabilities are not available. However, statistical principles can be used to make inferences about a population using data from samples.

The principles of statistics and probability required to scientifically perform activity sampling—calculating statistical sample sizes or determining if differences in performance are statistically significant—are beyond the scope of this study. However, it is possible to take advantage of rules of thumb based on past studies where rigorous statistical principles have been applied. This approach is valid when the main objective is to identify *potential* problems. Since construction is a system of interrelated components, activity sampling can help identify symptoms of potential company-wide problems. When performing sampling studies of construction operations,

- have the capability to easily identify those who belong to the sampling group and those who do not. This is especially relevant if the construction operation or process is performed in an area where members working on different operations or processes tend to be co-located. Requiring workers to wear special shirts or hard hats may be extremely helpful in such a situation.

- perform no less than 400 observations in total. This could mean 40 observations per worker for a crew of ten workers or four observations per worker for a group of 100 workers. This requirement guarantees that a reasonable level of confidence is achieved regarding population representation.

- have the same likelihood of observing every worker. If some workers are blocked by obstructions or topographic limitations, then the sample may not be representative of the population and the conclusions of the study may not be valid.

- avoid observations with a sequential relationship. Collect the observations at random times and in different sequences. A portable computer or a personal digital assistant (PDA) may be used to generate random times and gather observations.

- annotate the first impression received when observing a worker. Be careful not to pay attention to what the worker was doing immediately before or will do immediately after the observation. The objective of first impressions is to avoid biases.

- make sure that the basic characteristics of the work situation are the same throughout the observation period. For example, do not mix data captured on a sunny day with those obtained on a rainy day.

- avoid identification by those performing the work. It is a well-known fact that people tend to alter their behavior when they know that they are being observed. Therefore, have the observer be as inconspicuous as possible, perhaps performing duties at the site that requires his or her presence at unpredictable times. This strategy will make it more difficult for workers to realize that they are under observation for data collection.

There are three major methods for activity sampling: field ratings, productivity ratings, and 5-minute ratings.

Field Ratings

Field ratings classify workers only as “working” or “non-working” at the time of the observations. Working is defined as any engagement in a useful activity. Some issues to consider when performing field ratings are:

- Use mechanical counters to record observations. One counter can be used to record people “working” and another one can be used to record all observations.

■ Counting requires full undivided attention. Concentrate while performing counts and avoid any distractions.

■ It is not advisable to perform field ratings during the first or last half-hour of a work day or just before or after lunch time, unless the goal is to evaluate how an operation behaves at these particular times.

■ For an employee to be counted as “working,” he or she must be carrying materials, holding or supporting materials, or participating in active physical work (measuring, reading blueprints, writing orders, giving instructions, receiving instructions, operating a machine, etc.).

■ An employee should be counted as “non-working” when he or she is waiting for another task to finish, talking without actively working, walking around empty-handed, and attending self-operating machines, among other examples.

Productivity Ratings

Productivity ratings go beyond field ratings in the definition of the activities that the workers are performing at the time of the observations. Three main categories are used for classifying work: *effective*, *contributory*, and *not-useful*. To properly apply productivity ratings, one must first classify activities into each one of those categories for the construction operation under study. Different construction operations will have different lists of *effective*, *contributory*, and *not-useful* work activities.

In general, *effective* work should include activities which are directly involved in the operation and are usually carried out in the immediate vicinity of the work. Some examples include installing conduit, pulling cable, energizing a piece of equipment, unpacking materials and equipment, and testing equipment. *Contributory* work includes activities that, while not directly adding to the process of putting together a facility, are still essential for the operation. Examples include handling materials, measuring, reading drawings, building a scaffold, cleanup,

giving or receiving instructions, and necessary movements around the work area. *Not-useful* work includes all other activities. Some examples include walking empty-handed, taking a coffee break, waiting for materials, waiting for equipment, or waiting for instructions. The difference between contributory work and not-useful work may require close attention in some instances. For example, a worker who is waiting for another crew member to pass a piece of material is in a *contributory* stage. However, if there are two workers waiting, then only one of them could be considered in a *contributory* stage. Rework is generally classified as *not-useful* work.

Productivity studies have found that most construction workers spend from 30 to 45 percent of their time doing *effective* work and another 25 to 35 percent doing *contributory* work. Therefore, *not-useful* work is experienced between 20 and 45 percent of the time. This implies that the productivity of a typical construction operation which is not running at optimal levels can probably be improved by at least 25 percent if proper procedures and techniques are applied. Keep in mind that in addition to reducing *not-useful* work, proper planning and technologies can also reduce *contributory* work to a certain extent. Productivity ratings are very useful as benchmarks to determine the improved performance of a construction operation when different technologies, construction methods, or planning techniques are applied.

As with field ratings, productivity ratings require undivided attention and should not be performed on the first or last half-hour of a work day or close to a lunch break.

5-Minute Ratings

5-minute ratings are not considered as statistically valid as field or productivity ratings, and are used more as a short-cut to determine if further evaluation of a particular construction operation is required. The name is a reminder that a crew should not be observed for less than 5 minutes. One recom-

mendation is to add a minute for each worker in the crew under observation. Therefore, a crew of six workers should be observed for at least 11 minutes (5 minutes + 1 minute x 6). The observation period is then broken down into arbitrary but equal sub-periods. For example, the 11-minute observation could be broken down into 1-minute sub-periods. Workers are observed and classified as *working* or *non-working* (as in field studies) in each sub-period. The key difference here is that the observations are not instantaneous as in field and productivity ratings. Workers are observed for the full duration of the sub-period and would be classified as *working* only if the observer judges that they were working during more than 50 percent of the sub-period.

To get a proper reading on a crew's effectiveness, the recommendation is to perform at least four separate 5-minute rating studies in a day.

Notice that productivity ratings do not strictly measure productivity. They do, however, determine the ratio between productive and unproductive time. This is a very valuable piece of information that can be used to evaluate the effectiveness of productivity improvement efforts.

Task Productivity

Task productivity is probably the easiest—but the least effective—measure to obtain in the field. In determining the productivity of a task, the measurement is really of the abilities and proficiency of the worker. Determining how many linear feet of cable a worker can install per hour is useful only as the upper limit of achievable productivity. Projects do not suffer low productivity because workers are not producing or working “hard enough,” but because of:

- Poor planning of construction operations: for example, incomplete or incorrect instructions given to workers, overmanning, staking of trades, inefficient sequencing, lack of coordination among trades, and shortages of materials, tools, and equipment.

- Design issues: for example, inconsistencies

among design documents, incomplete designs, and erroneous designs, and

- Lack of motivation: for example, worker suggestions are dismissed, superior performance is not adequately rewarded, and high turnover.

Nonetheless, measuring task productivity may be very useful when new construction tools or technologies are being implemented as a way to compare the achievable productivity offered by the new methods with that of the traditional approach.



Conclusions and Recommendations

Improving labor productivity is recognized as an important goal by most contractors. However, some are reluctant to try new construction methods, techniques, managerial approaches, or incentive systems because they do not know how to validate their effectiveness. This report discusses practical and simple ways of measuring labor productivity at different levels, ranging from the company to the individual task. Measuring labor productivity before and after applying a new approach can provide valuable information to validate its effectiveness. Furthermore, the ability to measure labor productivity over time allows contractors to establish a continuous improvement program within an organization with the aim of enhancing productivity and profitability.

Contractors may not want to measure labor productivity at all levels. Indeed, it may be more effective if a contractor focuses on properly measuring labor productivity reliably at a few levels, rather than trying to do it at all with low accuracy. Each contractor should evaluate its particular circumstances and decide which of the tools presented in this report are best suited for the company. Furthermore, contractors may also decide to follow a sequential approach, measuring labor productivity at one level, then moving to the next one. No matter which approach is adopted, just thinking about productivity improvement and collecting data to evaluate performance is a step in the right direction. The process itself will likely uncover inefficiencies in company-wide procedures that, when fixed, may yield significant rewards.



Appendix A: Labor Productivity Formulas

$$P_{\text{COMPANY-CURRENT}} = \text{TAVA/TAL}$$

Where:

$P_{\text{COMPANY-CURRENT}}$: Productivity at the Company Level (not adjusted for wage inflation)

TAVA: Total Accrued Value Added

TAL: Total Accrued Labor Hours

Equation 1

TAVA: Accrued [Income – Materials – Subcontracts – Owner Paid Overtime Premiums]

Equation 2

$$P_{\text{COMPANY-CURRENT}} = (\text{TAVA/TAL}) \times (\text{WBY/WCY})$$

Where:

P_{COMPANY} : Productivity at the Company Level

TAVA: Total Accrued Value Added

TAL: Total Accrued Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

Equation 3

$$P_{\text{COMPANY-HOURS}} = (TAVA/TAL) \times (WBY/WCY) \times VAM$$

Where:

$P_{\text{COMPANY-HOURS}}$: Productivity Index at the Company Level

TAVA: Total Accrued Value Added

TAL: Total Accrued Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

VAM: Value Added Multiplier

Equation 4

$$P\text{-Index}_{\text{COMPANY}} = (TAVA/TAL) \times (WBY/WCY) \times IF$$

Where:

$P\text{-Index}_{\text{COMPANY}}$: Productivity Index at the Company Level

TAVA: Total Accrued Value Added

TAL: Total Accrued Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

IF: Index Factor

Equation 5

$$IF = (100) / (P_{\text{COMPANY}} \text{ for the base year})$$

Equation 6

LABOR PRODUCTIVITY FORMULAS

$$P_{\text{FIELD}} = (\text{TAVA}/\text{AFL}) \times (\text{WBY}/\text{WCY})$$

Where:

P_{FIELD} : Productivity at the Field Level

TAVA: Total Accrued Value Added

AFL: Accrued Field Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

Equation 7

$$P_{\text{FIELD-HOURS}} = (\text{TAVA}/\text{AFL}) \times (\text{WCY}/\text{WBY}) \times \text{VAM}$$

Where:

$P_{\text{FIELD-HOURS}}$: Productivity at the Field Level (in hours per given revenue)

TAVA: Total Accrued Value Added

AFL: Accrued Field Labor Hours

WCY: Average Wages Current Year

WBY: Average Wages Base Year

VAM: Value Added Multiplier

Equation 8

$$P\text{-Index}_{\text{FIELD}} = (\text{TAVA}/\text{AFL}) \times (\text{WBY}/\text{WCY}) \times \text{IF}$$

Where:

$P\text{-Index}_{\text{FIELD}}$: Productivity at the Field Level

TAVA: Total Accrued Value Added

AFL: Accrued Field Labor Hours

WBY: Average Wages Base Year

WCY: Average Wages Current Year

IF: Index Factor

Equation 9

$$P_{\text{PROJECT}} = (\text{TAVAP}/\text{ALH}) \times (\text{WBY}/\text{WCY})$$

Where:

P_{PROJECT} : Productivity at the Project Level

TAVAP: Total Accrued Value Added of Project

ALH: Accrued Labor Hours for the Project

WBY: Average Wages Base Year

TAL: Average Wages Current Year

Equation 10

$$P\text{-Index}_{\text{PROJECT}} = (\text{TAVAP}/\text{ALH}) \times (\text{WBY}/\text{WCY}) \times \text{IF}$$

Where:

$P\text{-Index}_{\text{PROJECT}}$: Productivity Index at the Project Level

TAVAP: Total Accrued Value Added of Project

ALH: Accrued Labor Hours for the Project

WBY: Average Wages Base Year

WCY: Average Wages Current Year

IF: Index Factor

Equation 11

$$P_{\text{ACTIVITY}} = (\text{TAVAA}/\text{ALHA}) \times (\text{WBY}/\text{WCY})$$

Where:

P_{ACTIVITY} : Productivity at the Activity Level

TAVAA: Total Accrued Value Added of the Activity

ALHA: Accrued Labor Hours for the Activity

WBY: Average Wages Base Year

TAL: Average Wages Current Year

Equation 12



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