Promoting Power Plant Construction Project Productivity

John Hutcheson, CPM, Duke Energy and Hans Picard, ScD, P+A Innovators

Abstract

Labor productivity on power plant construction and maintenance outage projects can be a big risk to budget and schedule. Recognizing the need to get a measure of control, a pragmatic approach was taken by systematic statistical monitoring and benchmarking of labor utilization. The objective of measurement is two-fold: 1) reduce the time crafts spend on un-productive activities, and 2) create conditions that support efficiency of workflow. Measurement, analysis and improvement of the construction work process can, at relatively low cost, produce over 30 percent increases in productive utilization of the work force resulting in significant cost and time savings. Best practices and results at recently completed Clean Air construction projects are explained.

Introduction

The high costs associated with budget and schedule overruns in the heavy construction industry can often be traced to low worker productivity.[1,2] For decades the trend of construction labor productivity has remained stagnant in comparison to all non-farm productivity[3].

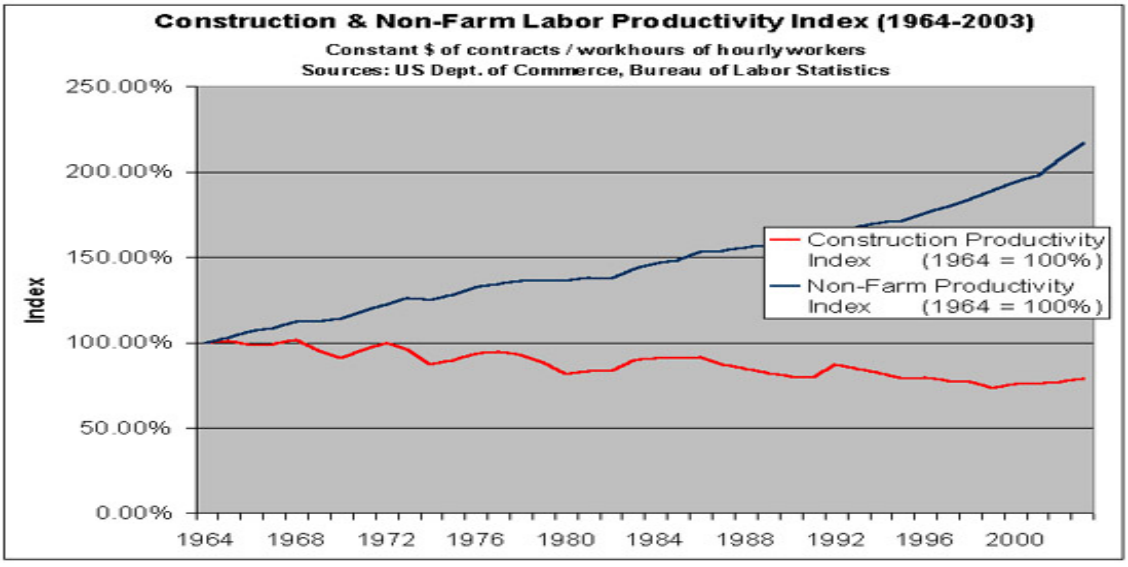


Figure 1. Labor productivity index for US construction industry and non-farm industries 1964 -2003; a growing gap between construction productivity (constant $'s of contracts/craft work hours) and all non-farm productivity.

One of the larger risk factors in heavy construction projects is the cost of labor. Labor cost is less predictable and runs a greater chance of overruns than either equipment or material costs. As labor costs can amount to 50 percent or more of

construction project costs, management of the work process presents the greatest opportunity to reduce project cost.

Improving labor productivity results in reduced labor costs, faster job completion time and direct savings in the bottom line. Increased costs at the bottom line are the result of low productivity, more workers and longer completion times.

The gains to be realized by enabling craft workers to become more efficient, and assisting project managers and field supervision to execute effectively are significant. The downside of ignoring this opportunity is significant as well.

Our approach to improving labor productivity is to look at the work process from the worker's perspective: how to make it easier to get assigned tasks done efficiently, as well as safely. Crafts will spend maximum time working instead of 'walking' or 'waiting' when field management provides all the tools, materials and guidance when and where they are needed by the craft – it's serving the crafts as 'customers' of the management system.

Measuring workforce activity

Seven years ago we determined that useful data about the effectiveness of field management and contract labor productivity would require a system of data collection, storage and information retrieval that measured and assessed the actual work process. A contractor performance measurement system was designed for our specific requirements and implemented on our construction and major maintenance outage projects. Not surprisingly, we found measurable differences between contractors and projects.

Our purpose was, and is, to assist project management achieve their goal of completing their project as early, cost-effectively, and safely as possible.

While the usual project reports can show progress and results versus estimates after the fact, they are often too late to provide timely information that can be used to adjust the work process. Daily measurement reports enable management to drill down and analyze the actual labor activities performed to a granular level. Using this near-real time information, management and supervision can take prompt corrective action, when required. Daily measurement provides the necessary insight into the daily variation in the work process as shown in Figure 2 below.

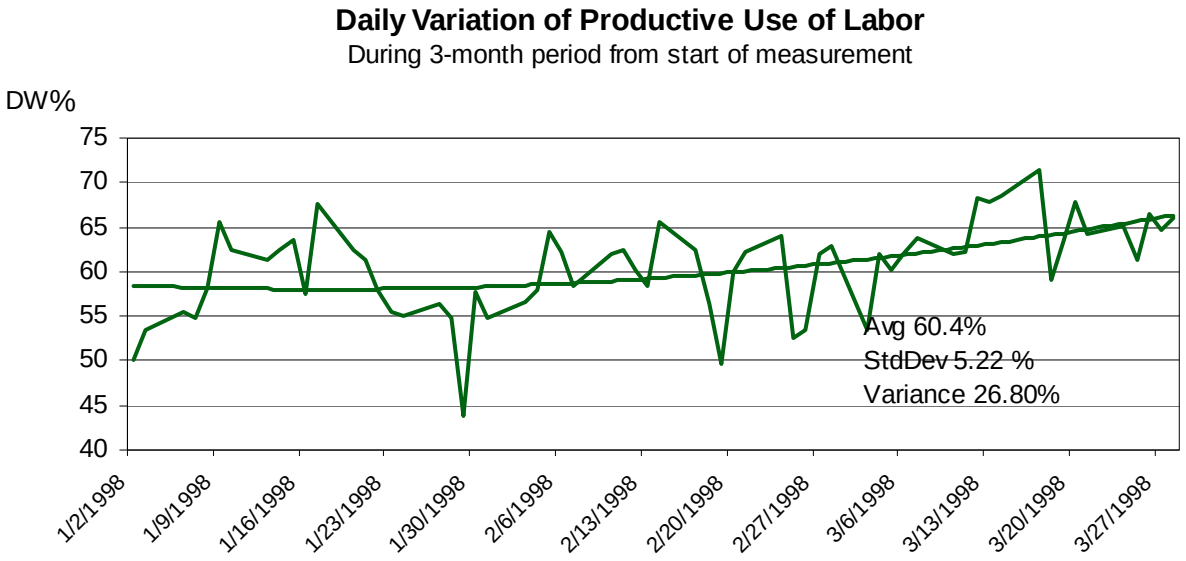


Figure 2. Productive labor utilization (DW%) can vary greatly from day to day, as shown for Clean Air construction project with workforce of over 220 crafts.

Our focus on work process performance measures provides a link between field management's decisions and productive or value-added labor. These highly visible links not only raise awareness, but speak loudly and clearly to indicate opportunities for improvement of the work process.

Our experience has shown that the following key performance measures (KPI's), related to the utilization of the craft workforce, are critical to project success:

- Labor utilization (value-added, non-value-added, or wasted time)
- Field supervision effectiveness (superintendents, foremen)
- Craft accountability (by trade; observed/not observed in assigned work areas)

It has been found that project managers are best supported in their efforts to improve work process management and, therefore productive use of labor, when the following criteria for measurement are applied:

1. All stakeholders understand and support the measurement
2. Measurement is performed by an independent party
3. Measurement is made daily, and results reported daily

4. Results are acted upon promptly by project management

5. Accountability is narrowed to specific craft or work groups

6. Positive change has positive impact on metrics

The consistent implementation of structured measurement by work activity sampling and analysis of the work process meets the need for objective, cost-effective measurement of project execution. Productive labor utilization has, over the past five years, gradually increased some 30 to 40 percent on major power plant Clean Air construction projects.

Realizing construction cost savings requires innovation and new ideas in schedule planning and control[2]. As we show in this paper, we introduce new insight through consistent, shift-to-shift attention to the efficiency of owner/contractors' work processes. Our work measurement program resembles safety programs on our projects. Safety progress results from making safety an important consideration, by setting safety standards and conducting regular safety audits.

How to describe labor productivity

Credible productivity data in heavy construction is usually difficult to obtain, and owners typically do not have reliable benchmarks to judge performance on their projects. On the other hand, field managers often believe they have handle on the productivity of their crews. Productivity is sometimes misunderstood; it results not from working harder and faster, but from working smarter.

When all is said and done, to maximize productivity of a given workforce it is important that its productive utilization or 'tool time' be maximized. In our experience, this is made possible by constant efforts to improve the construction work process.

Consider the basic formula (1) for labor productivity (P): 'output' or work performed is divided by the 'input' of labor-hours spent:

$$P = \text{Output} / \text{Input} \quad (1)$$

More specifically, labor productivity can also be expressed as:

$$P = \text{Work Completed} / \text{Labor-Hours Spent} \quad (2)$$

The above formulas are descriptive in a general way, but do not help us understand the variables of labor productivity on construction projects. Therefore, to understand and manage productivity, we observe, measure and analyze labor

utilization in the field. By means of a sampling technique similar to 'Six Sigma', we determine statistically the proportion of craft labor activity that is productive. Measurement of the construction work process provides useful information about its labor productivity. This metric is the 'productive utilization' of the workforce.

As shown in formula 3, productive labor utilization is a major variable in construction labor productivity. Other important variables that effect labor productivity are 'efficiency' and 'quality of work', both of which are linked to craft skills and field supervision's expertise.

$$P = \text{Productive Utilization} \times \text{Efficiency} \times \text{Quality of Work} \qquad (3)$$

The metric 'Productive Utilization' brings to light an important variable of the labor productivity formula. The meaning of formula (3) is that, with a given workforce, the greater the productive utilization, the less labor-hours will be used to complete the project. Work will be accomplished in less time and at lower cost, 'getting more done for less'. Our experience confirms that work process measurement and analysis improves results at relatively low cost. An example result of labor utilization measurement is presented in figure 3, showing the proportions of various labor activities observed and recorded at random intervals over an extended period of project execution.

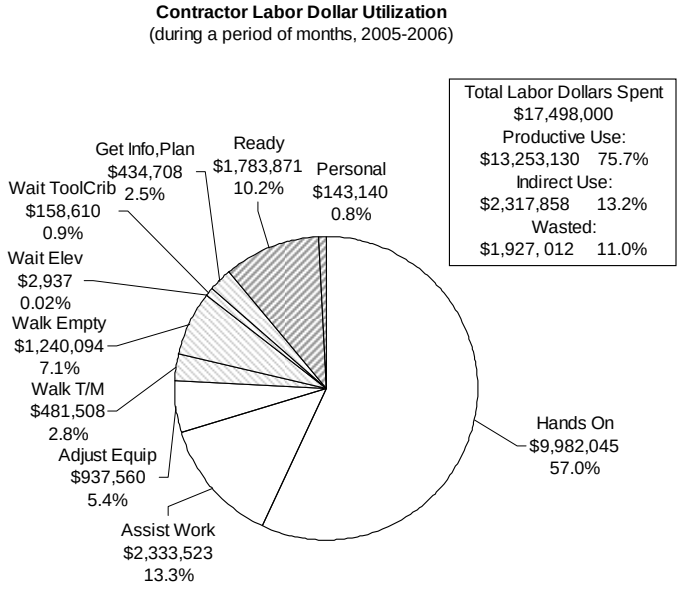


Figure 3. Contract labor dollar spend on power plant Clean Air construction project.

The statistical measurement procedure does not assess whether a crafts person carries out at the assigned task efficiently or 'right the first time'. Efficiency and quality of workmanship are, or should be, monitored by field supervision. In fact,

our measurement method shows how much of the time foremen are actually in the field, with their crews, to assess their individual crafts' performance, ready to assist when needed.

Continuous improvement

As shown in figure 3 above, many labor dollars are spent in non-productive activity due to various delays, interferences or roadblocks. There is, in fact, a 'hidden' cost of labor: the un-productive labor dollars spent. Remember Parkinson's Law? "Work expands so as to fill the time (or: spend the budgeted labor dollars) available for its completion".

The project's payroll shows the amount of labor dollars spent, but not how much value they 'returned on the investment'. Eliminating the hidden cost of labor is a continuous process of gradual improvement. Awareness is raised through continuous assessment of the work process, and depending on the incentive offered, prompt action is taken to improve it.

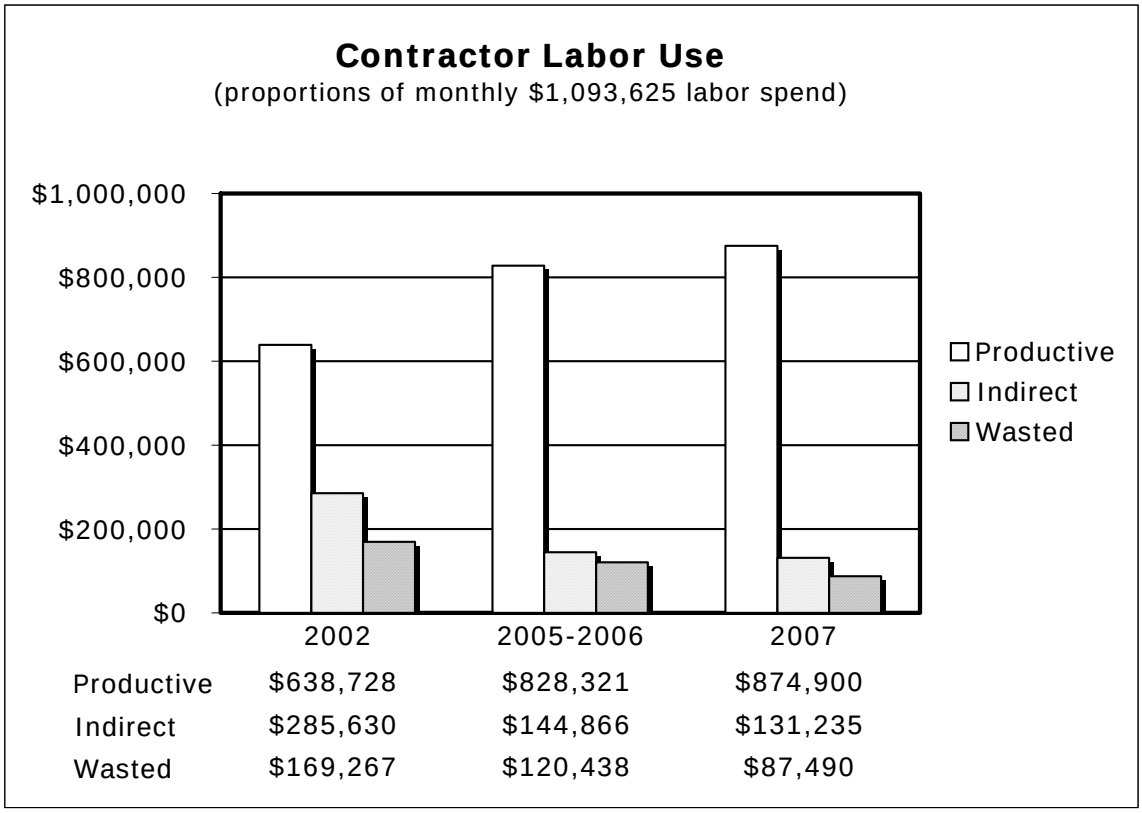
Labor productivity improves gradually as more labor-hours are spent in value-adding activities. Progressive labor-hour reduction is a natural result of an increasingly more efficient construction work process. This in turn results from the growing 'maturity' of field management practices, as suggested in Figure 4.

Maturity Level	Productive Use of Labor	Progressive Maturity of Construction/ Maintenance Work Process Management Practice
4	70%-80^{+}%	Complete, planned work scopes; competitive estimates; lean 'just-in-time' manpower scheduling; 'self-sufficient' work areas; trained, proactive field supervision; craft briefings; project stakeholders fully aligned to targets; continuous improvement
3	60% - 70%	Customer-contractor joint planning and collaboration; labor productivity benchmarking, measurement and incentives; gain-sharing; buy-in by project stakeholders; quick corrective action
2	50% - 60%	Labor productivity improvement is a factor in pre-planning; most tools and materials pre-staged; some improvements made during project execution
1	40%- 50%	Project is managed 'by the contract', just-in-case manpower; if problems, hire more; work process performance/productivity data not considered relevant

Figure 4. Productive labor utilization increases as management practices develop

Figure 5 shows how the productive labor utilization increased at a major mid-West power plant Clean Air projects, first SCR, then FGD scrubbers.

Measurement started early 2002 on the second project with a workforce of over two hundred crafts.



	2002	2005-2006	2007
Productive	$638,728	$828,321	$874,900
Indirect	$285,630	$144,866	$131,235
Wasted	$169,267	$120,438	$87,490

Figure 5. Continuous improvement of productive labor utilization resulting in less non-productive and more productive use of labor dollars on power plant Clean Air construction project.

A streamlined work process has minimal non-value-added activity, such as 'walking', or waste, such as 'waiting', and enables labor to complete tasks in less time. Comparing labor utilization over the course of the multi-year Clean Air construction project shows the share of direct labor cost that was 'productive'. a Relative labor dollar savings of 27 percent is made available through continuous improvement of the work process. How was this result achieved? Following 'best practices' promote a productive change in the construction work process.

Applying 'best practices'

We suggest project managers apply proven 'best practices' to systematically improve project performance, project control and labor productivity. These practices can be used in areas that both project management and contractors have some or substantial control over. Working together to implement these best practices can significantly reduce project cost and duration.

1. Measure labor resource utilization

Wasted labor-hours and inefficiencies in the maintenance outage or construction work process can today no longer be accepted. It's not rocket science to recognize that it makes a big difference to cost and progress if the labor workforce is used more productively. In fact, the productive utilization of the workforce drives cost-effective completion of a project. Measuring the utilization of labor and removing the productivity blocks pays big dividends.

Measurement is conducted by a trained professional who can monitor hundreds of crafts, depending on site conditions. A productivity analyst assigned to a project to conduct continuous statistical monitoring ('auditing') and analyzing the work process can play an important advisory role to the project controls function.

Similar to 'six sigma' procedures, statistical work process measurement must follow standardized, consistent procedures so the results can be benchmarked and compared contractor to contractor and project to project. Such procedures are detailed in the AACE International Recommended Practice RP-22r.

Data are collected daily each shift by random observation, entered in a database, analyzed and reported the same day. This real-time information enables managers and supervision to take prompt corrective action, and take advantage of opportunities. Analysis of the data provides useful insight in the management system and contractor qualifications.

2. Create 'lean' or self-sufficient work areas

The idea of lean production was introduced decades ago by Toyota in its factories. In a lean production process costs are reduced through elimination of wasteful activities and inefficient procedures. The same idea applies to construction by setting up self-sufficient or lean work areas. In such a lean or self-sufficient work area, the crafts' productive activity is maximal because the need for travel away from the workface, or waiting for foreman support, supplies, tools, or information is eliminated.

From the start, during mobilization and throughout project execution, we work with project management and contractors to plan and set up these self-sufficient work areas and point-of-use logistics to the maximum possible extent. Essential facilities are located as close as possible to the planned work areas.

3. Constantly balance crew size with actual workload

Staffing each job with the 'right' size crew is an ongoing challenge. The goal is to achieve the highest possible level of productive labor utilization and perform each task as soon as possible. Productivities of crews are usually unpredictable, although some cost data is available from commercial databases. It is our experience that contractor staffing is frequently estimated based on long-standing, inefficient field practices. Crew size estimates may include large buffers for 'safety' to cover unforeseen complications. These and other factors can lead

'just-in-case' staffing, meaning 'over-manning', causing lower than acceptable levels of productive utilization. We emphasize 'just-in-time' staffing in order to have just the right numbers of crafts on the job to achieve a target productive level of labor utilization.

4. Maximize foreman availability to crews in their work areas

Many foremen, and higher levels of field supervision, consider such tasks as 'chasing tools' a part of the foreman's job, taking him/her away from the workface. In addition, the foreman may be checking drawings, planning or doing paperwork in a foreman's shack or trailer. Our experience shows, however, that there is a positive correlation between foreman availability and productive activity in the work areas[i], see Figure 3.

Placing a foreman's desk in the work area is one of the practical steps. Another one is the deployment of so-called 'tool-expeditors', two-way radio-equipped crafts who assist foreman and crews by supplying needed tools and materials, thus ensuring foremen plan ahead and anticipate crew needs.

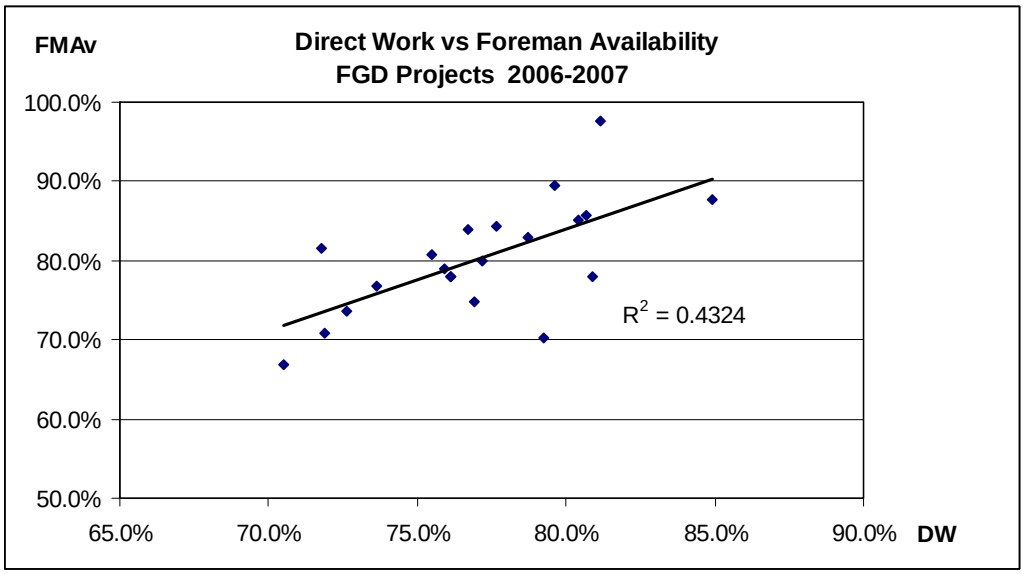


Figure 6. Productive labor utilization generally increases with FM Availability

5. Provide foremen with look-ahead schedules

Foremen must be able to anticipate and continually look ahead for next steps and any roadblocks that could cause delays. The look-ahead schedule is prepared by the contractor for the next three to five work days. Foremen need a daily schedule that shows in detail the tasks they and their crew are expected to work on. It also should include 'plan B' tasks for situations that prevent the scheduled task from being worked, enabling the crew to relocate to the new task without much lost productive time.

6. Institute continuous improvement

Labor utilization targets are set prior to project start, in agreement with contractor management. Targets are realistic yet demanding. Raising the bar on each next project emphasizes looking for ways to work ‘smarter’. As field management of the work process improves or ‘matures’, the measurement results will show progressively greater productive utilization of the work force.

7. Management support is essential

The contract must include language that provides the owner with the right to audit and observe workforce activity. In a cooperative relationship, the information resulting from measurement and analysis are used for a ‘win-win-win’ purpose, such as sharing the cost savings and making the jobs easier to do, and more efficient. Measurement must not be used as ‘policing’. It is an objective data collection method, the results of which benefit contractor, crafts and owner.

In conclusion

To promote labor productivity on heavy construction projects and save time and money, improve the work process. Use ‘best practices’ based on these ideas:

Approach construction project execution as a production work process

- Distinguish what craft activities add value to the work process, and what activity is un-productive or wasteful
- Define what we need to get better at to improve efficiency of the work process
- Institute continuous improvement of the work process

Collect real-time labor utilization data at the points where the work is done

- Use statistical methods to analyze level and variation of labor performance
- Identify and quantify labor productivity constraints and areas of opportunity
- Determine lean workforce size, in balance with actual workloads

Introduce new visibility and accountability in project performance management and field supervision

- Provide daily contractor/craft reports and trend labor utilization data
- Monitor productive labor utilization against estimate-independent benchmarks
- Present real-time data that enable project managers and field supervision to proactively ‘deal with it now’

The bottom line is this: with relatively little, but consistent effort, construction projects can be completed using less labor than conventionally estimated by minimizing wasted resources and maximizing benefits in the process.

References

[1] More Construction for the Money, The Business Roundtable, reprinted October 1991
[2] Broken Buildings, Busted Budgets, Barry B. LePatner, The University of Chicago Press, 2007
[3] Paul Teicholz, Ph.D., Professor (Research) Emeritus, Dept. of Civil and Environmental Engineering, Stanford University, "Labor Productivity Declines in the Construction Industry, Causes and Remedies", AECbytes Viewpoint #4 April 14, 2004
[4] Picard, Hans E, Sc.D. Field data
[5] Jyh-Bin Yang, "How the critical chain scheduling method is working for construction", Cost Engineering Vol. 49, No. 4, April 2007
6 James L Jenkins; Daryl L Orth, Productivity improvement through work sampling, AACE International Transactions 2003; pg CS51, 20037
7. AACEI Recommended Practice RP-22r, 2002
8. U.S. Dept of Labor

John Hutcheson can be contacted at john.hutcheson@duke-energy.com;
Hans Picard at info@boostconstructionproductivity.com

***