Development of an Industry Level Productivity Metric for the Construction Industry

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ABSTRACT

Construction industry labor productivity is an important metric that provides feedback about task, project, and industry level trends and improvements. However, labor productivity for the construction industry has historically been elusive to define, both qualitatively and quantitatively. Existing research studies and methods have provided different calculation methods at a variety of levels (task, project, industry), but none proved universally satisfying. This study generated a new metric using RS Means Building Construction Cost Data. The metric was derived using labor and cost information from a sample of RS Means construction activities. The sampled data were indexed and combined to generate labor productivity metrics (output per labor hour and output per labor cost). The research findings present a construction industry productivity metric based on RS Means data that is reliable, repeatable, and developed from a consistent and accurate data source. The study results showed a slightly sporadic but consistent decline in both output per labor hour and cost from 1990 through 2012. With this new metric, construction professionals will now be able to analyze industry level productivity by means of a commonly used industry reference manual.

INTRODUCTION

Labor productivity for the construction industry has historically been elusive to define, both qualitatively and quantitatively. “Perceptions of productivity trends vary widely within engineering academia, industry, and economic academia” (Allmon et al, 2000). Construction industry labor productivity (CILP) can have a wide variety of derivations, definitions, and meanings. It can also be applicable to various levels ranging from an individual labor activity to a specific project to the entire construction industry (Song and AbouRizk, 2008). “Understanding productivity in the construction industry is a complex and elusive task, a task made more difficult by the very nature of the industry” (Bernstein, 2003). Although projects may be of a similar type and nature, each one is unique; the site, design, construction methods, and many other project facets are seldom the same.
It is important for the construction industry to have a reliable and consistent measure of productivity data. “It is imperative to generate accurate labor productivity data for the construction industry in order to create the feedback loop required to analyze the effects of different industry-wide initiatives such as the implementation of fully integrated and automated processes” (Rojas 2005).

Establishing a clear metric for CILP allows for the collection of reliable, repeatable data that can be used for industry and academic studies. This is critical because there are a significant number of contradicting viewpoints on productivity trends. Bernstein (2003) notes that “the industry is today building structures of greater complexity and higher quality than in the past and is doing so in shorter periods of time” which could imply increasing productivity. (He additionally mentions that information technology has improved project delivery times but not all resources are experiencing improved inputs or outputs equally thus the net effect on productivity either increasing or decreasing can be deceiving.) Other data indicates that CILP is stagnant or declining (Rojas and Aramvareekul 2003a). At a May 2003 meeting of the ASCE Civil Engineering Research Foundation, “participants at the meeting called particular attention to the need for performance metrics and reliable [productivity] data” (Bernstein 2003).

“There is anecdotal evidence that great strides are being made in certain sectors of the industry, but the lack of widely accepted metrics and credible data makes it difficult to fully understand and evaluate the progress, as well as to devise strategies to extend these advances to other sectors” (Bernstein 2003).

Even when a clear meaning or definition of CILP is established, relevant data are often incomplete or unavailable. During the process of developing an independent skilled labor forecast model for the construction industry, the authors sought out an existing CILP metric to use as an independent variable in the model. The ideal metric would have enough consistent historical values to reveal trends (at least 10 years), have been developed using a reliable and consistent data collection or calculation method, and be able to be constrained to skilled construction labor at the industry level. The industry level condition (as opposed to task or project level) is in line with the scope of the forecast model which is to develop an industry level skilled labor forecast. (Detailed discussion about the development and validation of the forecast model is presented in a separate paper).

The only readily available industry level metric identified was the BLS Multifactor Productivity (MFP) index (discussed in detail in a later section). Other literature presented methods and data collection techniques to develop metrics for CILP, each unique in their approach and results. However, no existing metric was identified as suitable for use in the model. Thus, the objective to develop a new CILP metric for use in the model was initiated. This paper describes the process undertaken to develop the new CILP metric. The result is a repeatable, reliable metric for calculating industry level labor productivity for the construction industry.
Specifically, the productivity data of concern herein is that for the United States construction industry. The time period encompassed by this research extends from 1990 through 2012. The research scope includes data for construction activities performed on projects of all types (e.g. commercial, industrial, etc.).

**Definition of construction industry labor productivity**

There are two primary types of productivity measurement. A single factor productivity metric expresses output as a function of one input, such as labor. A multifactor productivity metric expresses output as a function of multiple inputs, such as equipment size and materials used. “A change in labor productivity reflects the change in output that cannot be accounted for by the change in hours worked of all persons. A change in multifactor productivity reflects the change in output that cannot be accounted for by the change in combined inputs” such as improvements in efficiency and technological advances (BLS 2013). Some common measures of labor productivity are summarized in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Common Measures of Labor Productivity</th>
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<tbody>
<tr>
<td><strong>Input – Output Relationship</strong></td>
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<tr>
<td><strong>Measure</strong></td>
</tr>
<tr>
<td>Time / Unit</td>
</tr>
<tr>
<td>0.1 hour / SF (SM) brick</td>
</tr>
<tr>
<td>Cost / Unit</td>
</tr>
<tr>
<td>$12 / SF (SM) brick</td>
</tr>
<tr>
<td>Output / Input</td>
</tr>
<tr>
<td>Unit / Time</td>
</tr>
<tr>
<td>10 SF (0.929 SM) of brick / hour</td>
</tr>
<tr>
<td>Unit / Cost</td>
</tr>
<tr>
<td>10 SF (0.929 SM) of brick / $120</td>
</tr>
<tr>
<td>Output / Multiple Inputs</td>
</tr>
<tr>
<td>Multifactor Ratio</td>
</tr>
</tbody>
</table>

A time per unit measure such as 0.1 hour per brick or a unit per time measure such as 10 SF (0.929 SM) of brick per hour, measures the efficiency of labor on the job site (Allmon et al 2000). A cost per unit measure such as $12 per square foot of brick, or unit per cost measure, such as 10 square feet of brick per $120, relates productivity to capital. A multifactor ratio is a relation of output to a combined set of one or more inputs. For this study, we focused on the measure of output divided by input, either output per labor hour or output per labor cost in constant dollars.

**LITERATURE REVIEW**

This literature review focuses on literature about U.S. construction labor productivity trends, definitions, and research that used existing data sources, such as RS Means, to quantify productivity metrics. Rojas and Aramvareekul (2003) sought to challenge the perception that CILP had been declining, specifically for the period 1979 to 1998. They determined that “to calculate productivity values for an industry, three pieces of information are required: the industry’s output, the industry’s employment data, and the average number of hours worked.” Rojas and Aramvareekul observed problems in their data analysis including “deficiencies in data collection, data processing, and interpretation of results” as well as “the inability
to differentiate between the diverse sectors of the construction industry in a changing output mix environment may have created misinterpretations of labor productivity values, as sectors with low productivity have increased their share of the market” (2003). Their conclusion was that the challenges and uncertainty with the data could not reliably lead to a determination of an increasing, decreasing, or constant trend in construction productivity. However, their data indicated that labor productivity in 1998 was below that of 1979 which could be interpreted as an overall decrease.

A 2005 study by the Design Build Institute of America (DBIA) used an output (unit costs of buildings) approach and an input (cost of capital and material) approach to analyze trends in construction industry productivity from 1966 to 2003. The DBIA study used data sources that included the ENR Material Price Index, the BLS Produce Price Index, cost records from The Haskell Company (a design-build firm based in Jacksonville, FL), and the authors’ industry experience. The analysis concluded that industry productivity had actually increased on the order of 33 percent over the 37 years, approximately 1 percent per year (Haskell 2005).

**BLS multifactor productivity index for construction**

The BLS Division of Major Sector Productivity compiles a multifactor productivity (MFP) index for the construction industry (Allmon et al 2000, BLS 2013). Data for the construction industry are categorized under the North American Industrial Classification (NAICS) Sector 23. MFP is based on output divided by combined inputs. The output data are based on gross output estimates published by the Bureau of Economic Analysis (BEA). The input data are based on a weighted average of labor (employee hours), capital services (services from assets such as equipment), and intermediate purchases (energy, material, and purchased services such as equipment rental and repair), also referred to as combined inputs. The input data come from a variety of government agencies including the BLS and BEA. The overall trend of the MFP has been decreasing. However, following the recession beginning in December 2007, the MFP experienced a slight increase.

**Literature that used RS Means**

Allmon et al (2000) studied productivity by looking at unit labor costs, unit output figures published in RS Means’ building construction cost data, and the amount of time spent on productivity activity, referred to as direct work rate. Six specific construction activities were chosen to evaluate and compare the effect of technological advances on the productivity of those activities. Their results indicated increased productivity for all of the activities studied and for construction in general for the 20-year period preceding the research. The increases were attributed to a combination of technological advances and depressed real wages. The authors indicate that using unit labor costs, unit output figures, and direct work rates is a good approach to studying broad productivity but “does not comprehensively deal with productivity within the construction industry” because productivity for activities and trades not included in the study may exhibit different trends.

Goodrum, Haas, and Glover (2002) used RS Means to examine the problems of using aggregate level data to measure construction productivity and then to look at changes in construction productivity using activity level data. They collected data for
1976 and 1998 from RS Means and other manuals for 200 construction activities to obtain cost, physical output, and work hour data. Goodrum, Haas, and Glover note that there is a weakness in using just two points in time, but their overall objective was to examine the changes in productivity over a 22-year time period. Three criteria were outlined for data selection by Goodrum, Haas, and Glover (2002): activities had to appear in both 1976 and 1998 manuals, activities had to experience a diverse range of technical change, and activities should represent different Construction Specifications Institute (CSI) divisions.

They calculated labor productivity using output (units) divided by work hour requirements (hours). They also calculated a multifactor productivity using output (units) divided by labor cost and equipment cost (adjusted to 1990 constant dollars). The mean increase in labor and multifactor productivity between 1976 and 1998 for 200 activities was 30.9% and 36.2%, respectively. These values represented an overall increase but some of the activities experienced an increase while others experienced a decrease or no change. The Goodrum results correlate well with the results of the DBIA (2005).

A method similar to that of Goodrum, Haas, and Glover (2002) was utilized later by Goodrum, Zhai, and Yasin (2009) to calculate percentage change of construction productivity in the United States. They sampled 100 different construction activities from the RS Means Building Cost Estimation Manual from 1977 and 2004. They calculated a partial (labor and material) and total (labor, material, and equipment) percentage change in labor productivity from 1977 to 2004. The average percentage change was calculated as 13.5% for total productivity and 15.5% for partial factor productivity. Their conclusions included demonstration of a positive relationship between productivity and improvements in material technology during this time period.

Several researchers have defined and quantified CILP using different methods with varying results. Multifactor metrics include interactions with variables other than labor and the aggregate effect is sometimes difficult to interpret. Other metrics developed have provided varying labor productivity trends. Still others used RS Means, a reliable and consistent data source, yet only analyzed intermittent data. Of the existing metrics, none adequately satisfied all of the previously listed constraints for use as an independent variable in a skilled labor demand forecast model. Thus, we embarked on the development of a new metric based on an existing, reliable data source and focused on labor productivity for consecutive years.

DEVELOPMENT OF A CILP METRIC USING RS MEANS

The objective of this study was to create a new CILP metric. Based on the availability of the data and verification that other productivity studies had been completed using such data, the researchers developed a new productivity metric using RS Means data. RS Means is a common industry standard used for determining the cost of construction projects of all building type and size (RS Means 1990 – 2010). Allmon et al (2000) noted that “such manuals are not intended for productivity studies, but they provide one of the best sources of time-series data on productivity that is publicly available” and “using this type of data source provided consistency in data collection and simplified output comparisons across [activities].”
RS Means *Building Construction Cost Data* manuals are published annually and provide detailed cost data for over 20,000 construction activities. RS Means publishes productivity data for most activities listed in the cost data manuals. The productivity data include *daily output* and *labor hours* for each activity. “The daily output represents the typical number of units the designated crew will install in a normal 8-hour workday. The labor hours figure represents the number of labor-hours required to install one unit of work” (RS Means 2012). RS Means uses the following sources to determine the daily output for each activity: information provided by vendors, information provided by contractors, RS Means staff engineers’ experience, trade labor productivity publications, and actual time and motion study observations (Reed 2013, Mewis 2013).

Daily output and subsequently labor hours will change if one of more of the following conditions is met: the size of the crew changes, some new procedure or process involved in the installation changes the amount of work the crew can perform in one day, a new tool or item of equipment changes the installation process, or a safety or health requirement changes the installation process (Mewis 2013).

**Data collection from RS Means**

The first task in a labor productivity metric derivation was to identify a representative sample of activities from the RS Means manuals. The objective was to select 100 activities from RS Means to comprise a sample data set to develop the metric. Activities were randomly selected from RS Means. The randomly-selected activities had to meet one or more of the following criteria, based on similar criteria used by Goodrum et al (2009) and Allmon et al (2000), before they could join the sample on which the new metric was based. The activities would: be found on most typical projects (e.g. concrete footings and cast iron pipe), have published daily output and labor hours data, be both meaningful and complex, and be from different divisions of the Construction Specifications Institute (CSI) MasterFormat.

If a randomly-selected activity did not meet all of the criteria listed above it was not included in the sample data set. It was anticipated that some of the selected activities may still need to be eliminated from the sample data set therefore 10 additional activities were initially selected for a total of 110. A preliminary collection of data, such as daily output and labor hours, was made for the 110 sampled activities in 1993, 1999, and 2008. Exactly 11 of the 110 activities either did not appear or did not have consistent and complete data in all three years and were thus removed from the preliminary sample.

Whereas previous studies that used RS Means evaluated only the beginning and end years of a time span, the goal of this study was to obtain every year of data for the selected sample of activities. From the 99 activities that had complete information in the three selected years, a final sample of the most commonly used 20 activities was selected on which we collected data for every year from 1990 through 2012. The sample of 20 activities included activities from a diverse set of CSI divisions. The activities included in the final sample are shown in Table 2. The final sample of 20 activities had 6 activities (30%) that experienced changes in daily output, labor hours, or crew size at one or more times during the years examined.
Metric Development

Daily output values for the final 20 activities were weighted to ensure that the wide ranges of magnitudes of the values are evaluated on a comparable scale. Weighting was achieved by setting the output for each activity to a unitless benchmark value of 100 in 2003. The output values for all other years were calculated as a relative percentage to the benchmark value. For example, RS Means may publish the output of one activity as 4 each per day and a different activity as 15,000 per day. Adjusting daily output values to a comparable scale by weighting allows for annual changes in the values to be accounted for comparably.

To calculate the new CILP, the weighted daily output values from all 20 activities in each year were summed. Labor hours and labor cost (adjusted to constant 1999 dollars using the Consumer Price Index (CPI)) were also summed. The metric itself was then calculated by dividing output by labor hours or by labor cost. The resulting metric values are shown in Figure 1. Different activities had different output units (i.e. linear feet, each, square yard) so the metric represents a unitless index of the compiled quantitative values.

As Figure 1 shows, according to the new metric labor hours had very little variability across the sampled activities as seen in the relatively stagnant period of no change in labor hour productivity for most of the 2000’s. Specifically, from 1999 – 2007 output per labor hour experienced no change for the 20 activities in the sample. That would mean there were no changes in the amount of time or the number of workers needed to complete the sampled activities. The fluctuation in the mid 1990’s is due primarily to sporadic changes in a few activities. Overall, labor cost productivity shows a generally decreasing trend, indicating that workers were being paid more to produce the same amount of output.

Figure 1. Construction industry labor productivity
CONCLUSIONS

Assessing construction labor productivity at the industry level is difficult. Deriving industry level productivity depends on what the industry is most interested in gleaning from the data. The newly developed RS Means based CILP metric presented here was found to be a viable method for determining industry level productivity in the US construction industry. Whereas other studies using RS means developed metrics that compared two individual points in time, the new metric provides a continuous annual analysis of CILP. The annual frequency of the new metric is more suitable for the intended use of the data as an independent variable in a labor demand forecast model. Its biggest advantage lies in being suitable for identifying micro level changes in individual activities while aggregating them to the industry level. The method presented here, using RS Means, is reasonable for determining labor productivity data for use in a labor demand forecast model. The logic of the new approach was sound and the results can be replicated and expanded easily in the future.

One of the most difficult trends to capture in a productivity metric is a change in the quality of work over time. “If the same amount of work results in a higher-quality product, then the work has become more productive” (Hendriksen 2005). Whether it does or does not, quality cannot be isolated in the Means data set any more than technological advances can. This influence on productivity was not addressed herein, because no data were found that could support its inclusion. This remains an area of valuable research that would be beneficial to the construction industry.

<table>
<thead>
<tr>
<th>2010 RS MEANS Activity ID</th>
<th>Activity</th>
<th>Table 2. Sample Set of RS Means Construction Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 02 65 10.30 0110</td>
<td>Removal of underground petroleum storage tanks, non-leaking, 3000 – 5000 gallons</td>
<td></td>
</tr>
<tr>
<td>2 03 11 13.20 2000</td>
<td>Cast in place concrete forms, interior beam, job-built plywood, 12” wide, 1 use</td>
<td></td>
</tr>
<tr>
<td>3 03 11 13.85 2000</td>
<td>Cast in place concrete forms, walls, job built plywood, to 8’ high, 1 use</td>
<td></td>
</tr>
<tr>
<td>4 03 30 53.40 3800</td>
<td>Concrete footings, spread under 1 CY</td>
<td></td>
</tr>
<tr>
<td>5 03 41 05.15 00501</td>
<td>Precast concrete columns, rectangular to 12’ high, large columns</td>
<td></td>
</tr>
<tr>
<td>6 04 05 13.30 0100</td>
<td>Mortar with masonry cement, M 1:1:6 mix</td>
<td></td>
</tr>
<tr>
<td>7 05 12 23.17 0800</td>
<td>Structural steel columns, concrete filled, extra strong pipe, 3-1/2” diameter</td>
<td></td>
</tr>
<tr>
<td>8 06 11 10.10 3680</td>
<td>Wood framing, beam and girder, single 4”x8”</td>
<td></td>
</tr>
<tr>
<td>9 07 11 13.10 0600</td>
<td>Bituminous asphalt coating with fibers, troweled on, 1/16” thick</td>
<td></td>
</tr>
</tbody>
</table>
The existence and maintenance of a reliable labor productivity metric to track changes and trends over time is critical to the success of the US construction industry. A key finding of this research was the lack of consistent and repeatable labor productivity metrics. These simply are not maintained and established by any one organization (other than the BLS which publishes MFP but not single factor CILP). Academic researchers and industry organizations should be charged with defining and maintaining consistent CILP metrics.

REFERENCES

