Crew Cost and Productivity Performance Benchmarking based on Commercial Cost Estimating Databases

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ABSTRACT

Benchmarks of crew cost and productivity performance for commonly-used methods in the construction industry are readily-accessible through industry-wide commercial estimating databases (such as RS Means). The objective of this study is to identify limitations of commercial benchmarking services and further propose a framework for benchmarking crew cost and productivity performance, over several years and in different cities. The proposed framework is applied to a typical open-cut method, illustrated with data retrieved from RS Means online databases. In particular, the data structure of RS Means is explained and the drawback of the underlying productivity benchmarking methodology is revealed. We conclude crew cost data ($/labor-hour) from RS Means can be used to trend the changes of time and location-specific crew and material costs in a reliable way, while productivity (daily or hourly production: unit/hr) accounts for the industry average only, ignoring the variations due to unique attributes of crews, jobs, contractors, or projects.

INTRODUCTION

Performance benchmarking is crucial for estimating, job planning, process control, and productivity improvement in construction. Both owners and contractors benefit greatly from collecting and sharing crew cost and productivity performance data. Performance benchmarking is instrumental in providing the platform to improve communication and coordination among different stakeholders in managing crews or subcontractors in the field.

Many initiatives have been taken to establish construction performance benchmarking systems in different countries, such as the UK (KPI), the USA (CII), Brazil (SISIND) and Chile (CDT) (Marković et al., 2011). One of the main purposes of a performance benchmarking system is to establish a theoretical framework for performance management (Costa et al., 2004).

Over the past 25 years, the Construction Industry Institute (CII) has gained extensive experience in performance benchmarking on projects in the United States, and globally published reports on comparison between local projects and similar projects in the CII database, using project performance metrics. CII has produced a vast array of knowledge by partnering with academia in studying capital projects (COAA Alberta Report, 2008). The deliverables of a typical CII benchmarking system comprise of customized questionnaires and databases and a suite of customized reports. For example, the CII assessment of 2,039 projects, worth over
$133 billion, arrived at the conclusion that owners could gain more Net Present Value (NPV) by choosing the right project (CII performance assessment report, 2012). However, from the perspective of a construction owner or contractor, the resulting deliverables cannot satisfy the needs for benchmarking cost and productivity performance of a specific project or a specific crew.

Best practices, evaluation tools and disciplined processes also play an important role in benchmarking project performance and making investment decisions. Most studies have revolved around analysis of survey data, benchmarking metrics and critical success factors (Hughes, 2004). For instance, a set of five benchmarking metrics were used to measure the project performance of Guyana’s construction industry against the Canadian construction industry based on data collected from approximately 270 projects (Willis, 2011). Previous research also attempted to establish a comprehensive benchmarking model. For instance, a model based on a reliability interval method and a composite performance index was established in Hong Kong, but the model was influenced by subjective understanding of different evaluators (Yeung et al., 2013). No comprehensive model or framework is currently available to guide (1) collecting data, (2) processing data, and (3) comparing collected data with industry benchmarking data (Kim and Bai, 2013).

Considering particular needs of construction companies in terms of estimating construction cost and benchmarking crew performance, the objective of this study is to develop a method framework for crew cost and productivity performance benchmarking and trending analysis. Application of the proposed method is illustrated with a typical open-cut method based on retrieving relevant RS Means data.

Theoretical Foundation

To improve current benchmarking knowledge, for a typical “crew-installing-material” method, traditional benchmarking of unit cost ($/unit) over different projects, cities, and years is not sufficient if the underlying crew cost and productivity benchmarks are not reliably established. Given a certain crew, method, and material, eight ratios pertaining to crew cost and productivity performance are defined as follows:

1. $U_{BC}$ = Unit Cost per unit of the work, Bare Cost only ($/unit)
2. $U_{TC}$ = Unit Cost per unit of the work, Total Cost including overhead and profits ($/unit)
3. $P_{LH}$ = Labor Productivity of the crew, the labor-hours required for each unit (LH/unit)
4. $R_{LH,BC}$ = Labor-Hourly Rate, Bare Cost for each labor-hour ($/LH)
5. $R_{LH,TC}$ = Labor-Hourly Rate, Total Cost including overhead and profits for each labor-hour ($/LH)
6. $P_{HR}$ = Hourly Production Rate of the crew, the units of work finished in a working hour (units/hr)
7. $R_{HR,BC}$ = Crew’s Hourly Rate, Bare Cost for each hour of the crew ($/hr)
8. $R_{HR,TC}$ = Crew’s Hourly Rate, Total Cost including overhead and profits for each hour of the crew ($/hr)
The unit cost based on bare cost can be calculated using either labor-hourly rate in Equation (1) or hourly-rate in Equation (2). Similarly, the unit cost based on total cost including overhead and profits can be calculated by using either labor-hourly rate in Equation (3) or hourly-rate in Equation (4):

\[
U_{RC} = \frac{R_{LH,RC}}{P_{LH}} \times P_{LH} \\
U_{BC} = \frac{R_{LH,BC}}{P_{BC}} \\
U_{TC} = \frac{R_{LH,TC}}{P_{LH}} \times P_{LH} \\
U_{TC} = \frac{R_{LH,TC}}{P_{LH}} \\
\]

(1)  
(2)  
(3)  
(4)

It is observed that the unit cost is derived based on crew cost \( (R) \) and labor productivity \( (P) \). As \( R \) and \( P \) both broadly change over time, location, and job, the unit cost benchmark would not be reliable if benchmarks for \( R \) and \( P \) were not established explicitly. For instance, any increase on unit cost can be attributed to (1) increase on crew resource rate \( (R) \), or (2) increase on labor productivity \( (P) \), or (3) the combined effect. Crew cost data (resource hourly rates) are subject to inflation, exchange rate, supply-demand relationship and overall economic situations. On the other hand, labor productivity is subject to training, motivation, compensation, job complexity, environmental condition, management competency, and equipment conditions. Therefore, crew cost and productivity performance should be independently benchmarked at the crew level.

Due to lack of effective benchmarking methodologies and IT expertise, few construction companies keep their own databases for establishing reliable benchmarks for crew resource rate \( (R) \) and labor productivity \( (P) \). Most practitioners resort to experience, complemented by referencing benchmarks available in industry-wide cost database services. Meanwhile, commercial services like RS Means have continually refined data-collection and analytic methods for cost and productivity performance benchmarking. In this research, we focus on RS Means and identify its major advantages and limitations in benchmarking crew cost and productivity. In the following section, we look into RS Means for related data and apply the proposed methodology to benchmark crew cost and productivity performance for a typical open-cut method for different cities and in different years.

**RS Means Overview**

Robert Snow Means (RS Means) published the first cost book in 1942, containing 1,000 cost line items. RS Means has become one of the most sophisticated and most reliable sources of construction cost data in North America. RS Means publishes more than 120,000 unit prices for different types of projects (residential, commercial, industrial and heavy civil construction) and over 50 different major cities and regions (indexes available for local costs for over 900 zip codes). RS Means classifies methods by MasterFormat 2010 (Construction Specifications Institute) and publishes data including material cost, labor crew rates, equipment rates, productivity and market variations. As a dynamic cost database, all the cost data is kept current by annual and quarterly updates on the cloud (RSMeansOnline.com). In addition to providing a reliable source of data for detailed cost estimate, RS Means also lends an
excellent perspective on how to organize construction-centric data (such as methods, crews, materials, productivity, costs).

As a benchmark, RS Means derives the U.S. National Average—which is an average for material, equipment and labor costs of the construction methods based on 30 major cities in the US. The City Cost Index is established as a “benchmark” ratio to convert the US National Average to time- and location-specific local costs (in US$ or CAN$.) Bare costs of installation crews and materials for common methods applied on building projects of different types are continuously monitored and data collected from contractors, dealers, suppliers, and manufacturers across North America. Thus, crew cost data \(($/\text{labor-hour})\) from RS Means reflect the current status and can be used to trend the changes of time- and location-specific crew and material costs in a reliable way.

The major limitation with RS Means data is the way crew productivity (daily or hourly production: \(\text{unit/hr}\)) is benchmarked, which accounts for the industry average only, ignoring the variations due to unique attributes of crews, jobs, contractors, and projects.

**Typical Open-Cut Methods**

Despite negative impact on traffic flow and environment, open-cut method is still widely used for installation and maintenance of water and sewer services in most municipalities across North America. The benchmarking for open-cut crew performance in terms of cost and productivity between public agencies and private contractors and among different cities is still a daunting task. As such, benchmarking presents the bottleneck to the application of scheduling research. For instance, the linear regression model was attempted in developing cost functions for open-cut and jacking method in central Taiwan (Yeh et al. 2008), but the cost and productivity data underlying the model would not be relevant for use in other cities.

We applied RS Means for cost and productivity performance benchmarking on a typical open-cut method for different cities in different years. Details of the method studied are as follows: excavating, trench or continuous footing, common earth, 3/4 BCY excavator, 6’ to 10’ deep, excludes sheeting or dewatering. The data structure of RS Means is explained and pros and cons of applying RS Means’ benchmarking methodology are addressed. Table 1 and Table 2 show data collected from the RS Means database representing the National Average, for the year 2012.
Table 1. Data Collected in RS Means for Typical Open Cut Item

<table>
<thead>
<tr>
<th>Line Number</th>
<th>312316130500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Excavating, trench or continuous footing, common earth, 3/4 BCY excavator, 6’ to 10’ deep, excludes sheeting or dewatering</td>
</tr>
<tr>
<td>Crew</td>
<td>B12F</td>
</tr>
<tr>
<td>Daily Output</td>
<td>225.00</td>
</tr>
<tr>
<td>Labor-Hours</td>
<td>0.071</td>
</tr>
<tr>
<td>Unit</td>
<td>B.C.Y. (Bank Cubic Yard)</td>
</tr>
<tr>
<td>Material</td>
<td>$ -</td>
</tr>
<tr>
<td>Labor</td>
<td>$ 2.95</td>
</tr>
<tr>
<td>Equipment</td>
<td>$ 2.88</td>
</tr>
<tr>
<td>Total</td>
<td>$ 5.83</td>
</tr>
<tr>
<td>Total O&amp;P</td>
<td>$ 7.65</td>
</tr>
</tbody>
</table>

Table 2. Crew Information for Typical Item

<table>
<thead>
<tr>
<th>Crew No.</th>
<th>Bare Costs</th>
<th>Incl. Subs O&amp;P</th>
<th>Cost Per Labor-Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hr. Daily</td>
<td>Hr. Daily</td>
<td>Bare Cost</td>
</tr>
<tr>
<td>B12F</td>
<td></td>
<td></td>
<td>Bare Cost</td>
</tr>
<tr>
<td>1 Crane Oper.</td>
<td>$47.80</td>
<td>$382.40</td>
<td>$72.15</td>
</tr>
<tr>
<td>1 Laborer</td>
<td>35.10</td>
<td>280.80</td>
<td>54.00</td>
</tr>
<tr>
<td>1 Hyd.Excavator</td>
<td>647.20</td>
<td>711.92</td>
<td>40.45</td>
</tr>
<tr>
<td>16 L.H., Daily</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>$1,310.40</td>
<td>$1,721.12</td>
<td>$81.90</td>
</tr>
</tbody>
</table>

Overhead and Profit (O & P) add-on percentages are 50.94% for equipment operators; 53.85% for laborers; 10% on tools or equipment; 10% on materials. Note 8 working hours per day; 16 labor-hours of work completed by the crew per day.

The productivity benchmark provided by RS Means is given in terms of crews’ “Daily Output,” namely: 225 BCY/d. Therefore, labor productivity and crew hourly production are calculated through Equation (5) and Equation (6) as:

\[
P_{\text{labor}} = \frac{\text{Daily Output}}{\text{Daily Working Hours}} = \frac{225 \text{ BCY/d}}{8 \text{ hrs/d}} = 28.125 \text{ BCY/hr}
\]

\[
P_{\text{ch}} = \frac{\text{Daily Labor Hours}}{\text{Daily Output}} = \frac{16 \text{ LHS/d}}{225 \text{ BCY/d}} = 0.0711 \text{ LH/BCY}
\]

Based on crew composition and hourly rates of different laborers given in Table 2, labor cost per day is calculated through Equation (7) and (8).

\[
1 \text{ Equip. Oper.} \times \frac{\$47.80}{\text{hr}} \times 8\text{ hrs/d} = \$382.40/\text{d}
\]

\[
1 \text{ Laborer} \times \frac{\$35.10}{\text{hr}} \times 8\text{ hrs/d} = \$282.80/\text{d}
\]

Material bare cost per day is zero. Therefore, total bare cost per day is $1,310.40 (labor plus equipment). Then, the crew’s unit bare cost per labor-hour and hour can be obtained through Equation (10) and Equation (11), respectively.

\[
R_{\text{LMBE}} = \frac{\$1,310.40/\text{d}}{16\text{ LHS/d}} = \$81.9/\text{LH}
\]
The crew’s total cost per day including O & P is calculated through Equation (12). Note material total cost per day remains zero.

\[
R_{\text{hr, BC}} = \frac{8131.40/ \text{d}}{8 \text{hrs/d}} = \$163.8/\text{hr}
\]  

(11)

Total cost including O & P per day is \( \$1721.12/\text{d} \). The crew’s unit total cost per labor-hour and hour can be obtained through Equation (10) and Equation (11), respectively:

\[
R_{\text{hr, TC}} = \frac{1721.12/ \text{d}}{160 \text{hrs/d}} = \$107.57/\text{LH}
\]

(13)

\[
R_{\text{hr, FG}} = \frac{1721.12/ \text{d}}{68 \text{hrs/d}} = \$215.14/\text{hr}
\]

(14)

Following the proposed Equations (1), (2), (3) and (4), unit costs can be obtained through Equations (15), (16), (17) and (18).

\[
U_{\text{BC}} = R_{\text{LC, BC}} \times P_{\text{LH}} = \$107.57/\text{LH} \times 0.071 \text{LH/BCY} = \$5.82/\text{BCY}
\]

(15)

\[
U_{\text{FG}} = R_{\text{LC, FG}} \times P_{\text{hr}} = \frac{\$163.8/\text{hr}}{28.17 \text{BCY/hr}} = \$5.82/\text{BCY}
\]

(16)

\[
U_{\text{TC}} = R_{\text{LC, TC}} \times P_{\text{LH}} = \frac{\$107.57/\text{LH}}{28.17 \text{LH/hr}} = \$7.64/\text{BCY}
\]

(17)

\[
U_{\text{FG}} = R_{\text{LC, TC}} \times P_{\text{hr}} = \frac{\$215.14/\text{hr}}{28.17 \text{BCY/hr}} = \$7.64/\text{BCY}
\]

(18)

Cost and Productivity Trending over Different Time Periods and Locations

<table>
<thead>
<tr>
<th>Location</th>
<th>YEAR 2012 Q1</th>
<th>YEAR 2012 Q2</th>
<th>YEAR 2012 Q3</th>
<th>YEAR 2012 Q4</th>
<th>YEAR 2013 Q1</th>
<th>YEAR 2013 Q2</th>
<th>YEAR 2013 Q3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLH (LH/BCY)</td>
<td>0.071</td>
<td>0.071</td>
<td>0.071</td>
<td>0.071</td>
<td>0.071</td>
<td>0.071</td>
<td>0.071</td>
</tr>
<tr>
<td>UBC ($/BCY)</td>
<td>6.14</td>
<td>6.20</td>
<td>6.30</td>
<td>6.42</td>
<td>6.52</td>
<td>6.54</td>
<td>6.45</td>
</tr>
<tr>
<td>UTC ($/BCY)</td>
<td>8.05</td>
<td>8.12</td>
<td>8.29</td>
<td>8.41</td>
<td>8.52</td>
<td>8.53</td>
<td>8.42</td>
</tr>
<tr>
<td>P/hr (BCY/hr)</td>
<td>28.17</td>
<td>28.17</td>
<td>28.17</td>
<td>28.17</td>
<td>28.17</td>
<td>28.17</td>
<td>28.17</td>
</tr>
<tr>
<td>R_{\text{LC, BC}} ($/LH)</td>
<td>86.48</td>
<td>87.32</td>
<td>88.73</td>
<td>90.42</td>
<td>91.83</td>
<td>92.11</td>
<td>90.85</td>
</tr>
<tr>
<td>R_{\text{LC, TC}} ($/LH)</td>
<td>172.96</td>
<td>174.65</td>
<td>177.46</td>
<td>180.85</td>
<td>183.66</td>
<td>184.23</td>
<td>181.69</td>
</tr>
<tr>
<td>R_{\text{LC, BC}} ($/hr)</td>
<td>113.38</td>
<td>114.37</td>
<td>116.76</td>
<td>118.45</td>
<td>120.00</td>
<td>120.14</td>
<td>118.59</td>
</tr>
<tr>
<td>R_{\text{LC, TC}} ($/hr)</td>
<td>226.76</td>
<td>228.73</td>
<td>233.52</td>
<td>236.90</td>
<td>240.00</td>
<td>240.28</td>
<td>237.18</td>
</tr>
</tbody>
</table>
Figure 1. Trending analysis for (a) crew’s labor-hourly rate and (b) crew’s hourly rate

For the current method (excavating, trench or continuous footing, common earth, 3/4 BCY excavator, 6’ to 10’ deep, excludes sheeting or dewatering), the trending analysis of unit costs in Edmonton (Alberta, Canada) from 2012 Quarter 1 to 2013 Quarter 3 is demonstrated in Table 3 and Figure 1. The changes over different quarters can be noted, while crew’s unit costs peak in 2013 Quarter 2. However, the productivity [PLH(LH/BCY), or Phr(BCY/hr)] over different time periods remains unchanged according to Table 3.

The trending analysis of crew’s hourly cost and crew’s labor-hourly cost in different cities during 2013 Quarter 2 is also demonstrated in Table 4 and Figure 2. It can be observed that the crew’s hourly rate and labor-hourly cost in Atlanta (GA, USA) stand as the lowest, as benchmarked against the US National Average, Edmonton/Calgary (AB, Canada), Vancouver (BC, Canada), and Seattle (WA, USA).

Table 4. Comparison of Eight Ratios across Different Cities

<table>
<thead>
<tr>
<th>Location</th>
<th>National Average</th>
<th>Edmonton / Calgary</th>
<th>Vancouver</th>
<th>Seattle</th>
<th>Atlanta</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_LH(LH/BCY)</td>
<td>0.071</td>
<td>0.071</td>
<td>0.071</td>
<td>0.071</td>
<td>0.071</td>
</tr>
<tr>
<td>U_BC($/BCY)</td>
<td>6.09</td>
<td>6.54</td>
<td>6.80</td>
<td>6.50</td>
<td>5.82</td>
</tr>
<tr>
<td>U_TC($/BCY)</td>
<td>7.96</td>
<td>8.53</td>
<td>8.85</td>
<td>8.54</td>
<td>7.60</td>
</tr>
<tr>
<td>P_hr(BCY/hr)</td>
<td>28.17</td>
<td>28.17</td>
<td>28.17</td>
<td>28.17</td>
<td>28.17</td>
</tr>
<tr>
<td>R_LH.BC($/LH)</td>
<td>85.77</td>
<td>92.11</td>
<td>95.77</td>
<td>91.55</td>
<td>81.97</td>
</tr>
<tr>
<td>R_hr.BC($/hr)</td>
<td>171.55</td>
<td>184.23</td>
<td>191.55</td>
<td>183.10</td>
<td>163.69</td>
</tr>
<tr>
<td>R_LH.TC($/LH)</td>
<td>112.11</td>
<td>120.14</td>
<td>124.65</td>
<td>120.28</td>
<td>107.04</td>
</tr>
<tr>
<td>R_hr.TC($/hr)</td>
<td>224.23</td>
<td>240.28</td>
<td>249.30</td>
<td>240.56</td>
<td>213.75</td>
</tr>
</tbody>
</table>
Crew’s labor-hourly rates in terms of total cost over different locations and time periods are contrasted in Table 5 and Figure 3. As shown in Figure 3, the patterns of how crew’s labor-hourly rates in different cities vary over the same time period are almost the same. Obviously, the crew’s labor-hourly rate in Atlanta is considerably lower than the other cities. The crew’s unit cost ($/Labor-Hour) of Canadian Cities (Vancouver/Edmonton/Calgary) is 15-20% higher than that of Atlanta; Seattle’s crew cost is clustered close to Canadian cities. Considering (1) the Canadian dollar has been on par with the US dollar during the time period being studied; and (2) the industry average productivity for applying the same method in different cities in North America is the same, the unit cost in terms of $ per cubic yard of open cut using this particular method in three Canadian cities is 15-20% higher than Atlanta.

Table 5. Labor-hourly Total Cost over Different Cities and Time Periods

<table>
<thead>
<tr>
<th>RLH TC ($/LH)</th>
<th>Edmonton/Calgary</th>
<th>Vancouver</th>
<th>Seattle</th>
<th>Atlanta</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAR 2012 Q1</td>
<td>113.38</td>
<td>118.03</td>
<td>115.92</td>
<td>99.86</td>
</tr>
<tr>
<td>YEAR 2012 Q2</td>
<td>114.37</td>
<td>119.15</td>
<td>117.61</td>
<td>99.86</td>
</tr>
<tr>
<td>YEAR 2012 Q3</td>
<td>116.76</td>
<td>120.85</td>
<td>116.90</td>
<td>103.80</td>
</tr>
<tr>
<td>YEAR 2012 Q4</td>
<td>118.45</td>
<td>122.82</td>
<td>118.45</td>
<td>104.65</td>
</tr>
<tr>
<td>YEAR 2013 Q1</td>
<td>120.00</td>
<td>124.37</td>
<td>120.00</td>
<td>107.32</td>
</tr>
<tr>
<td>YEAR 2013 Q2</td>
<td>120.14</td>
<td>124.65</td>
<td>120.28</td>
<td>107.04</td>
</tr>
<tr>
<td>YEAR 2013 Q3</td>
<td>118.59</td>
<td>122.96</td>
<td>118.59</td>
<td>105.77</td>
</tr>
</tbody>
</table>
CONCLUSION

The proposed benchmarking framework is ready to be used for internal data collection and processing. The crew’s labor-hourly rates and crew’s hourly rates can serve as important criteria for benchmarking against commercial data of a specific local area or in-house collected internal data of a particular company. Implementing such a framework by an individual company requires substantial commitment of resources. Nonetheless, benefits from effective cost benchmarking would potentially far outweigh the investment of resources. If crew productivity benchmarks were not available or reliable, then critical construction management functions such as cost estimate, project planning and performance control would all become inaccurate.

In conclusion, the labor cost benchmark data in terms of crew’s hourly rate and crew’s labor-hour rate can be readily derived from RS Means over different time periods and cities, which provides a reliable source of information to benchmark crew’s cost performance given a commonly applied construction method. However, productivity benchmark data in RS Means only represent average crew performance without sufficiently accounting for broad productivity variations due to field constraints specific to jobs, contractors and projects. This is analogous to describing a wide ranging distribution with only the central tendency (average), without presenting the spread of data (the variance or standard deviation). Thus, cost estimate and job schedule generated based on RS Means should be interpreted with caution in reality.

An organization is recommended to take the RS Means data structure, crew classification and cost benchmarking methods, and standardized work breakdown structures as an effective basis in order to build customized crew performance benchmarking systems. In particular, crew productivity benchmarking should be performed in a more reliable way by defining crew productivity as a variable, which is dependent on not only time and location, but also job complexity, human factors, trades’ competencies, and equipment conditions.

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