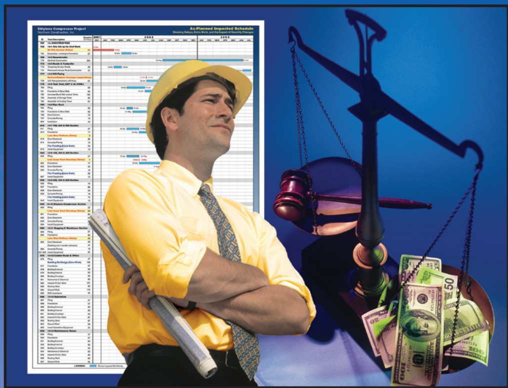

A Reasonable Method to Estimate Loss of Labor Productivity Due to Overtime

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1. INTRODUCTION

In the construction industry, it is largely agreed that overtime work adversely affects labor productivity. However, there is no universally accepted method for estimating the resulting loss of productivity, and many of the studies commonly used to estimate such losses have been subject to criticism by industry experts and the courts.

This article describes a detailed method for estimating productivity losses retrospectively, i.e., after the hours have been incurred. The proposed method uses the productivity losses from an MCAA Bulletin published in 2011, in which the MCAA averaged the results from four well-known overtime studies. Using this method, one applies the MCAA's productivity factors to the actual hours on a week-by-week, worker-by-worker basis to estimate inefficient hours. Among its several advantages, the method a relatively time and cost-effective way of providing detailed results, as it can be used to show the inefficient hours for a given worker or crew, or the inefficient hours in a given week or timeframe.

The Sections below include a brief introduction to the MCAA Bulletin, a description of the proposed method including the steps involved with setting up the Excel model, and the advantages and potential disadvantages of employing this method.

2. THE MCAA BULLETIN

In 2011, the Mechanical Contractors Association of America, Inc. (MCAA) published Bulletin No. OT1 Revised, titled "How to Estimate the Impacts of Overtime on Labor Productivity." In its Bulletin, the MCAA did not provide a study based upon new overtime productivity loss data, but rather it analyzed and summarized the data from four existing studies:[1]

- "Schedule Overtime Effects on Construction Projects," published by the Business Roundtable (BRT) in 1980;
- "Overtime and Productivity in Electrical Construction," published by the National Electrical Contractors Association (NECA) in 1989;
- "Schedule Overtime and Labor Productivity: Quantitative Analysis," published by Dr. H. Randolph Thomas (Thomas), et al, of Penn State University in 1997; and
- "Modification Impact Analysis Guide," Publication No. EP 4150-1-3, published in 1979 by the U.S. Army Corps of Engineers (COE).

[1] See "How to Estimate the Impacts of Overtime on Labor Productivity," MCAA Bulletin No. OT1 Revised, 2011, p. 3.

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Regarding these four studies, the MCAA wrote:

> *"These studies have been in use in the construction industry for many years and have been generally accepted as reliable measures of lost productivity due to unplanned extended overtime. Each has its strengths and weakness, including criticisms ranging from the use of limited data sources to the withdrawal of reports from publication. However, the baseline data in any of these studies have never been proven to be inaccurate. Moreover, the concept that a contractor's work force becomes less efficient as unplanned extended overtime is worked is generally recognized and has never been disproved as an underlying fact."* [2]

The MCAA also cited four cases in which U.S. Courts and Boards acknowledged and/or allowed the studies to be used as a basis for quantifying productivity losses due to overtime.[3]

The MCAA then provided a series of charts for each relevant workweek (50 hours per week, approximately 55 hours per week, 60 hours per week, etc.). Each chart shows the results of the applicable studies in terms of the Productivity Index as a function of the duration of scheduled overtime. Between one and four studies were charted, depending upon the workweek. For example, the chart for the 50-hour workweek includes data from all four studies (BRT, NECA, Thomas, and COE),[4] while the chart for the 84-hour workweek includes data from NECA's study alone,[5] as the other studies did not evaluate the impacts of an 84-hour workweek.

In the balance of its Bulletin, the MCAA provided a table summarizing its results (discussed below), and explained and gave examples of the prospective application and the retrospective application of its PIs to estimate productivity loss. While the method proposed in this article is generally consistent with the simple example of the retrospective application provided in the Bulletin, it is a far more detailed approach.

3. DESCRIPTION OF THE METHOD

Table 1 below is a recreated version of the MCAA's results table.[6] The results indicate that the Productivity Index (PI),[7] and therefore actual worker productivity, decreases both as the weekly hours increase and as the duration of overtime work is extended. For example, given a 50-hour workweek, the table indicates that the first week of overtime results in a PI of 0.95, or a 5% loss of productivity, while the tenth consecutive week of overtime results in a PI of 0.72, or a 28% loss of productivity. For a 60-hour workweek, the PIs are 0.91 (9% loss) in first week

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[2] Id.
[3] Id. at p. 16, footnote 6.
[4] Id. at p. 6.
[5] Id. at p. 8.

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and 0.61 (39% loss) in the tenth week, or more extensive losses than the comparable 50-hour workweeks.

Table 1
Productivity Indices from the MCAA's Bulletin No. OT1 Revised

Week of Extended OT	50 hrs/wk	54-56 hrs/wk	60 hrs/wk	63 hrs/wk	70-72 hrs/wk	84 hrs/wk
1	0.95	0.94	0.91	0.89	0.86	0.75
2	0.93	0.90	0.88	0.84	0.80	0.70
3	0.92	0.86	0.85	0.78	0.73	0.65
4	0.91	0.83	0.81	0.73	0.68	0.60
5	0.85	0.79	0.76	0.67	0.63	0.55
6	0.86	0.75	0.72	0.62	0.58	0.50
7	0.76	0.72	0.67	0.58	0.54	0.47
8	0.77	0.70	0.64	0.55	0.51	0.44
9	0.74	0.68	0.62	0.54	0.50	0.43
10	0.72	0.66	0.61	0.52	0.49	0.42
11	0.72	0.65	0.60	0.51	0.48	0.41
12	0.71	0.64	0.59	0.50	0.47	0.40
13	0.69	0.63	0.56	0.49	0.46	0.39
14	0.68	0.62	0.55	0.48	0.45	0.38
15	0.67	0.61	0.54	0.47	0.44	0.37
16	0.66	0.60	0.53	0.46	0.43	0.36

The method described in this Section applies the PIs (and resulting productivity losses) from the MCAA's table, Table 1 above, to the actual hours expended by each worker in each week of a project. Thus, it is a retrospective analysis in which one can quantify not only the total loss of productive time, but also the lost hours for a given person, in a specific week, or over a given timeframe.

[6] Id. at p. 9. The MCAA noted: "*As described herein, the NECA tables list three impact intensity levels for each overtime schedule: 'Low,' 'Average,' and 'High.' For the PI values shown in the following table, the 'Average' values listed in the NECA tables were utilized. Where two different work weeks resulted in the same number of total hours (e.g., a 60-hour work week resulting from a 12-hour per day five-day schedule versus a 10-hour per day six-day schedule), the PI values derived from the source data were averaged between the two working schedules. Further, from weeks 13 through 16, only the NECA PI values were available.*"

[7] Id. at p. 5. The PI is calculated as: (Planned Productivity) / (Actual Productivity), where Productivity is in terms of work hours expended per unit of work installed. Thus, where the actual productivity is the same as the planned productivity, the PI is 1.0. Where the actual productivity is worse than the plan, and more hours are expended to accomplish the same work, the PI is less than 1.0.

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As a preliminary matter, this author has not, in prior analyses, interpolated between the data points provided by the MCAA. One might reasonably argue that in the second consecutive week of overtime, if a worker expended 67 hours, his or her PI may fall between the PI value for the 63-hour workweek (0.84) and the PI value for the 70 to 72-hour workweek (0.80). However, given that (i) the MCAA does not address such interpolation, and (ii) the studies upon which the MCAA's values are based do not provide data for say a 67-hour workweek, an analysis that includes interpolation between data points may (rightly) come under significant criticism. Therefore, the analysis described below uses ranges that are consistent with the data provided by the MCAA, *e.g.*: workweeks between 0 and 49.9 hours are assigned a PI of 1.0 (no productivity loss); workweeks between 50.0 hours and 53.9 hours use the PIs from the "50 hrs/wk" column; workweeks between 54.0 hours and 59.9 hours use the PIs from the "54-56 hrs/wk" column; etc.

Table 2 below is excerpted from a larger table in which productivity losses were calculated for all workers over the entire duration of a project. It shows only John Smith's time over a six-week period, from the week ending 21 September 2014 (Week 62 of the project) through the week ending 26 October 2014 (Week 67 of the project).

Table 2
Example Table – Inefficient Hours for One Worker in a Six-Week Period

Personnel Name / Description	21-Sep-14 62	28-Sep-14 63	5-Oct-14 64	12-Oct-14 65	19-Oct-14 66	26-Oct-14 67	Subtotal
SMITH, JOHN							
Actual Hours	50	54.5	58	60	42	69	**333.5**
Consecutive Weeks Working 50+ hours	1	2	3	4	0	1	
Code (Workweek)	50to54	54to60	54to60	60to63	LT50	63to70	
Code (Workweek - Consecutive Weeks)	50to54-1	54to60-2	54to60-3	60to63-4	LT50-0	63to70-1	
PI Compared to 40-hr Workweek	0.95	0.90	0.86	0.81	1.00	0.89	
Productivity Loss	5.00%	10.00%	14.00%	19.00%	0.00%	11.00%	
Inefficient Hours	**2.4**	**5.0**	**7.1**	**9.6**	**0.0**	**6.8**	**30.9**

Table 2 is a straight-forward Excel model that includes formulas (not shown) which calculate the consecutive overtime workweeks and workweek ranges, "look up" the applicable PIs from the MCAA's table, and calculate the resulting productivity loss and inefficient hours. An analyst with knowledge of Excel functions (such as 'IF' and 'VLOOKUP') can produce such a table relatively quickly. The purpose of the formulas, of course, is to avoid manually entering PIs for hundreds of workers over dozens or hundreds of working weeks. Once the formulas in Rows 5 through 10 are set up, along with the referenced lookup tables, the rows can simply be copied and pasted to align with each worker's actual hours, and to ultimately calculate the inefficient hours for all of the project's workers.[8]

The data and formulas contained in Rows 4 through 10 are described below:

- Actual Hours (Row 4): This row contains the actual hours expended as sourced from the contractor's time-recording system. Contractors typically record actual hours for each worker on a weekly basis, and most time-recording/job cost software allows for an export of the actual weekly hours by worker into Excel. The highlighting in Table 2 denotes workweeks in which 50 hours or more were worked, and is provided for presentation purposes only.
- Consecutive Week Working 50+ Hours (Row 5): This row shows the number of consecutive weeks in which overtime was worked. It is accomplished using a formula with an 'IF' statement: if overtime was worked in the week, add "1" to the prior week's number, otherwise record "0". For example, in Cell C5, more than 50 hours were worked in Week 63 (per Cell C4), thus the formula added "1" to the prior week's value of "1" (in Cell B5), which resulted in "2".
- Code (Workweek) (Row 6): This row includes a code denoting the range of hours worked in a given week. As addressed above, the ranges are consistent with the MCAA's table. The formula includes a 'VLOOKUP' function, which in turn references a lookup table. The lookup table includes all the hours that could be worked (including half hour or tenth of hour increments, depending upon the actual labor hour data) and the corresponding codes. For example, any actual hours (Row 4) between 54.0 and 59.9 are coding as "54 to 60."
- Code (Workweek - Consecutive Weeks) (Row 7): This row includes another code, which is a combination of the Workweek (from Row 6) and the Consecutive Weeks of overtime work (from Row 5). To combine these cells, one can use the 'CONCATENATE' function or '&' in the Excel formula. This code is used to lookup the relevant PI value from the MCAA's table.
- PI Compared to 40-hr Workweek (Row 8): This row includes the PI from the MCAA's table for a given "Workweek - Consecutive Weeks" code. The formula includes a 'VLOOKUP' function which contains a reference to a lookup table. A portion of the lookup table is shown in Table 3 below.

[8] In projects with many thousands of workers, the copy-paste exercise may become overly burdensome. A more sophisticated Excel model can be created for such projects, but the description of such modeling is beyond the scope of this article.

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Table 3
Excerpt from the Lookup Table

Code	PI
50to54-1	0.95
50to54-2	0.93
50to54-3	0.92
50to54-4	0.91
50to54-5	0.85
54to60-1	0.94
54to60-2	0.90
54to60-3	0.86
54to60-4	0.83
54to60-5	0.79

For example, in Week 63, the formula in Cell C8 looks up the value "54to60-2" (from Cell C7) in the lookup table shown above, and retrieves the corresponding PI of 0.90.

- Productivity Loss (Row 9): As explained in the MCAA Bulletin, the productivity loss is calculated as 1.00 less the PI.[9] In Week 62, for example, the PI of 0.95 corresponds to a 5% productivity loss, (1.00 – 0.95) x 100.

- Inefficient Hours (Row 10): In a retrospective application (i.e., when the hours have already been incurred), the MCAA provided the following formula:

  "*Inefficient MHs = Actual MHs – [Actual MHs / (1 + Inefficiency Factor)]*"[10]

  Applying the MCAA's formula for Week 62, for example, results in:

  Inefficient MHs = 50 – [50 / (1 + 0.05)] = 50 – 47.62 = 2.38 hours, which is shown rounded to 2.4 hours in Table 2 above.

[9] See "How to Estimate the Impacts of Overtime on Labor Productivity," MCAA Bulletin No. OT1 Revised, 2011, p. 9.
[10] Id. at p. 12.

In sum, John Smith worked 333.5 hours in the six-week period shown in Table 2 above, and the analysis shows a loss of 30.9 hours due to the effects of overtime work. Notably, the largest productivity loss of 19% occurred in Week 65 during Mr. Smith's fourth consecutive week of overtime work. While he worked more hours in Week 67, the productivity loss was less in this week (11%) because he did not work overtime in Week 66, which "reset" the count on the consecutive weeks of overtime worked.[11]

4. ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages of the proposed method must be weighed against other studies and methods available to estimate productivity loss due to overtime. A review of every such study and method is beyond the scope of this article. However, after conducting a review of the available alternatives, one finds that all studies and methods have either (i) been criticized in some manner by industry experts or the courts, or (ii) have not been frequently used or studied, and therefore have not come under significant scrutiny.

Thus, while the proposed approach has potential weaknesses, such as a lack of data underlying the studies used by the MCAA or the fact that the calculated inefficient hours are estimated and not exact, other approaches may have similar weaknesses.

The extensive calculations and details provided with this approach can be a potential disadvantage, as there is simply more information subject to critique. Moreover, there will likely be examples where the results can be shown to be inconsistent with the MCAA's productivities. Such an inconsistency is shown in the data from Table 2 above. Mr. Smith worked consecutive weeks of 50, 54.5, 58, and 60 hours between Weeks 62 and 65. The analysis shows that Mr. Smith suffered a productivity loss of 19% in Week 65. This loss is based upon him working four consecutive weeks of between 60 and 63 hours, but he worked less than 60 hours in Weeks 62 through 64. Therefore, in Week 65, the productivity loss is somewhat inconsistent with the MCAA's table and is likely slightly overstated. On the other hand, the overstated hours in this particular week are minor in the context of the overall analysis. Moreover, one should be able to show examples in which the hours are understated, as would be the case if the hours were reversed (i.e., 60, 58, 54.5, and 50 hours).

On balance, the advantages of the proposed approach should outweigh the potential disadvantages. One advantage is that the studies used by the MCAA are relatively well known and frequently used in the construction industry. As noted previously, the MCAA cited four cases in which U.S. Courts and Boards acknowledged and/or allowed the studies to be used as a

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[11] Id. at p. 3. The MCAA wrote: "*Experience indicates that a return to a normal 40-hour schedule tends to 'reset' the productivity of a crew, such that if the crew returns to an overtime schedule after a week or two of a normal schedule, the productivity loss would 'reset' to that of the first week of overtime.*"

basis for quantifying productivity losses due to overtime.[12] Furthermore, industry groups such as the Association for the Advancement of Cost Engineering (AACE) International acknowledge the studies. For example, all four studies used in the MCAA Bulletin are listed by the AACE in its Recommended Practice 25R-03, "Estimating Lost Labor Productivity in Construction Claims," albeit without commentary.[13]

Second, using average productivity losses from several studies, the results of which are similar,[14] has the advantage of decreasing the possibility that the results are rejected due to the uncertainties associated with any one study alone.

Third, the productivity losses in the MCAA Bulletin can be shown to be reasonable, or even conservative from a contractor's perspective, as compared to other measures. For example, in its "Process Plant Construction Estimating Standards," Richardson provided percentages to increase its standard unit manhours for workweeks in excess of 40 hours.[15] A contractor would use these percentages to increase its labor hours in its prospective estimates to account for overtime work. Richardson recommended adding: 5% to 10% for 41 to 48 hours per week; 11% to 15% for 49 to 50 hours per week; 16% to 20% for 51 to 54 hours per week; 21% to 25% for 55 to 59 hours per week; etc.[16] Comparing these percentages with those in Table 2 above, one finds that the MCAA's percentages are often much lower than Richardson's percentages, especially for weeks in which less than 50 hours are worked and when there are less than five consecutive weeks of overtime.

Fourth, the week-by-week, worker-by-worker analysis provides extensive details of the lost productivity by worker and timeframe, while requiring little or no additional time to prepare as compared to other methods.

Finally, the detailed method has the additional benefit of accounting for high variability in the weekly hours expended by a worker, a crew, or the workforce in general. In the relatively simple example that the MCAA provided in its Bulletin, it showed certain mechanics working exactly 40-hour weeks or exactly 50-hour workweeks.[17] Labor hours are typically much more variable,

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[12] Id. at p. 16, footnote 6.

[13] See "Estimating Lost Labor Productivity in Construction Claims," AACE RP 25R-03, 13 April 2004, Appendix D: Specialized Studies Related to Overtime and Shift Work. On p. 5, the AACE wrote: "*The effect of continued overtime work on labor productivity is, perhaps, one of the most studied productivity loss factors in the construction industry. The large number of studies contained in Appendix D is testimony to this fact.*"

[14] See "How to Estimate the Impacts of Overtime on Labor Productivity," MCAA Bulletin No. OT1 Revised, 2011, p. 4. The MCAA wrote: "*The four studies presented in this chapter as a basis for estimating a contractor's loss of labor productivity show striking similarities in their results.*"

[15] See Richardson "Process Plant Construction Estimating Standards," 2003 edition, Aspen Technologies, Inc., Volume I, p. 8.

[16] Id.

[17] See "How to Estimate the Impacts of Overtime on Labor Productivity," MCAA Bulletin No. OT1 Revised, 2011, p. 4.

as workers take sick days and vacations, and contractors may assign more overtime work to its most productive crews or crews that are working in critical disciplines or areas. In a given week, a contractor may have crews working 40 hours, 50 hours, 55 hours, and 60 hours. And within a given crew, it would be uncommon for each person to work exactly the same amount of time. The proposed method calculates productivity losses regardless of the variability in hours.

About the Author

Rod C. Carter, CCP, PSP, *is President of Long International, Inc. He has over 20 years of experience in construction project controls, contract disputes and resolution, mediation/arbitration support, and litigation support for expert testimony. He has experience in entitlement, schedule, and damages analyses on over 30 construction disputes ranging in value from US$100,000 to US$7 billion, related to oil and gas, heavy civil, nuclear, environmental, chemical, power, industrial, commercial, and residential construction projects. He is proficient in the use of Primavera Project Planner software and has extensive experience in assessing the schedule impact of RFIs, change orders, and other events to engineering and construction works. Mr. Carter specializes in loss of productivity, cumulative impact, and quantum calculations, and has held a lead role in assessing damages on more than a dozen major disputes. In addition, Mr. Carter has developed cost and schedule risk analysis models using Monte Carlo simulations to address the uncertainty of estimates and claims. He has testified as an expert in construction scheduling and damages and has presented expert findings to an international arbitral tribunal. Mr. Carter earned a B.S. in Civil Engineering from the University of Colorado at Boulder in 1996, with an emphasis in Structural Engineering and Construction Management. Mr. Carter is based in Littleton, Colorado, and can be contacted at rcarter@long-intl.com and (303) 463-5587.*