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Calculating Loss of Productivity Due to Overtime Using Published Charts – Fact or Fiction

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INTRODUCTION

In simple terms, productivity is defined as the measure of output (the work produced in units) per unit of input (hours required or cost incurred). Other frequently used productivity measurements include:

$$\frac{\text{\$ revenues}}{\text{hours worked}} \qquad \frac{\text{\$ revenues}}{\text{\$ actual cost}} \qquad \frac{\text{hours earned}}{\text{hours worked}}$$

The most convincing method of measuring loss of productivity is undoubtedly the "measured mile" approach. It compares productivity achieved during unimpacted periods or "normal periods" with the productivity achieved during periods affected by the causes alleged. It is based on actual data and inherently accounts for contractor inefficiencies and/or estimating errors. The damages are calculated based on the difference in productivity rates.

Unfortunately this method is of no help if:

1. the required data for a detailed productivity analysis are not available or are unreliable;
2. several causes contributed to the productivity loss, but only one cause is compensable;
3. the productivity loss has to be included in a change order quantification prior to the execution of the change (forward costing).

Short of "guesstimating", the only alternate method for quantifying a distinct productivity loss may be the use of published studies for the cause in question, but not without the greatest caution.

Contractors and their claims consultants often rely on studies which have very little to do with the specific situation under scrutiny. In fact, they may have never examined the actual study and simply relied on a single chart reproduced in a book or by a trade association.

This article examines the numerous studies available for loss of productivity due to overtime. The objective is to inform the user of their often limited application and the pitfalls of erroneous application.

LOSS OF PRODUCTIVITY DUE TO OVERTIME

Overtime in construction is usually defined as work performed over 40 hours per week, or in some instances, more than eight hours in one day.

The most cited factor affecting productivity during scheduled overtime is physical and mental fatigue. Other factors which may contribute to a productivity loss include:

- absenteeism, accidents;
- reduced supervision effectiveness;
- shortage of materials, consumables or tools due to accelerated pace; and
- tardy processing of engineering questions and requests for clarifications due to greater demand within a given period.

Whenever loss of productivity due to overtime is quantified, the surrounding circumstances must be clearly understood.

Bureau of Labor Statistics

The oldest study on overtime, widely cited as a reliable source, dates back to the 1940s. This study by the Bureau of Labour Statistics of the U.S. Army Department of Labor (BLS) is based on 78 individual cases covering 2,455 men and 1,060 women working in a wide variety of manufacturing industries with the work being mostly highly repetitive, machine paced, performed indoors and requiring little decision making. Moreover, this work was performed by incentive wage employees during wartime, on prolonged overtime schedules. According to the BLS study, average productivity for 50-hour, 60-hour and 70-hour weeks were 92%, 82% and 78% respectively.

Notwithstanding the fact that this study was limited to the manufacturing sector, the Mechanical Contractors Association of America (MCAA) relied on these BLS data when it issued its Bulletins no. 18A and 20 in 1968, to assist contractors in the preparation of claims and change orders relative to loss of productivity due to overtime. In 1994 the MCAA, in its M3 publication entitled "Change Orders, Overtime and Productivity", still included the same BLS information as a reliable source to prove overtime inefficiency. Since the BLS data were gathered in a very specific environment in the manufacturing sector, the BLS results and the MCAA charts are of little use for quantifying loss of productivity in construction.

Foster Wheeler

L.V. O'Connor, Director of Construction of the Foster Wheeler Corporation published a paper in 1969 entitled "Overcoming the problems of Construction Scheduling on Large Central Station

Boilers". The paper describes Foster Wheeler's research conducted from 1963 to 1968. Figure 1 shows Foster Wheeler's overtime inefficiency curves derived from its own data. The paper does not disclose how and under what circumstances the data were obtained. Although not explicitly stated, it is presumed that the findings are based on the boilermaker trade. Average productivity for 5-10 hour days and 6-10 hour days were 87% and 73% respectively.

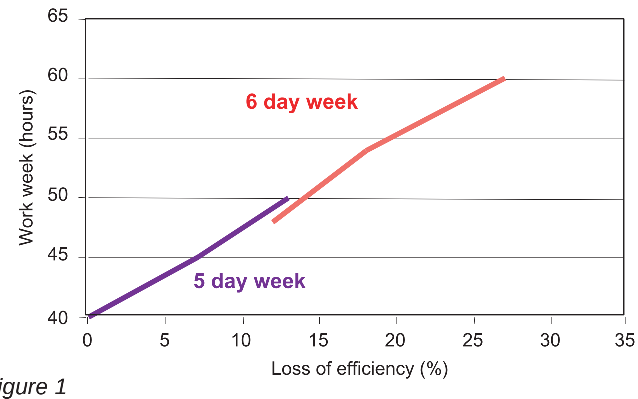

Figure 1

Proctor & Gamble

The Business Roundtable (BRT) issued a task force report in 1980 entitled "Scheduled Overtime Effect on Construction Projects" which was an update of their 1974 report entitled "Effect of Scheduled Overtime on Construction Projects". The original data relied upon were actual project records derived from a series of short jobs over a 10-year period in the 1960s and originated from a single project, namely the Proctor & Gamble Green Bay, Wisconsin process plant. The output was recorded from physical count or measurement, the input was based on actual payroll hours. It is reported that the work was carried out in a tranquil labour climate with excellent field management. The nature of the construction activities and the trades involved are unknown.

Figure 2 depicts the **cumulative effect of overtime on productivity for 50- and 60-hour work weeks as per the BRT Study.** The measure of productivity is a comparison of actual work hours expended for preplanned operations with a fixed standard base of calculated work hour requirements called a "bogey". The "bogey" standard is for a straight-time schedule. The data are not a comparison of actual straight time with actual overtime productivity.

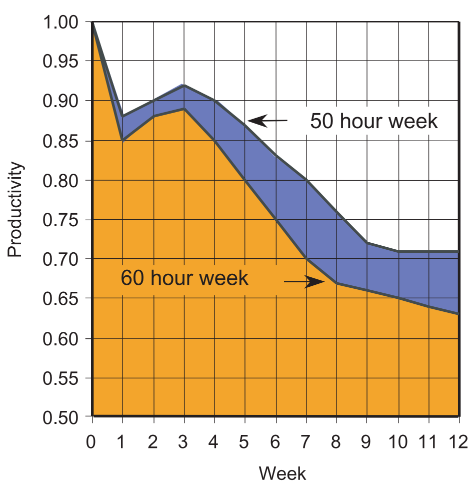

Figure 2

Figures 3a and 3b reflect the **ratios of productive return to overtime hours** for long-term job schedules of overtime operations: the curves reflect the average and the range of expected performance. It is important to note that after several weeks of overtime, the reduced labour productivity reaches the point of no return. The study also suggests that a 45-hour job schedule very quickly becomes nothing more than wage inflation. It is important to note that the effect of reduced labour productivity reaches the point of no productive returns on overtime hours, earlier for a 50 hour schedule than for a 60 hour schedule. However, the inflated cost per hour of productivity effect is greater for the 60 hour schedule.

The study contains the following warning:

"The industrial firm's data on productivity is based on Fixed Standards, and a performance of 1.0 may not be the same as a performance of 1.0 referenced to some other standard of comparison. As a result, a 30% reduction of productivity in one set of data could compare with a 15% reduction reflected in another set of data due to these differences."

In 1973, the American Association of Cost Engineers (AACE) published a report on the "Effects of Scheduled Overtime on Construction Projects" where it relied on the BRT data. Similarly, "The Owner's Guide to Overtime, Construction Costs and Productivity", published in 1979 by the Associated General Contractors, the American Subcontractors Association and the

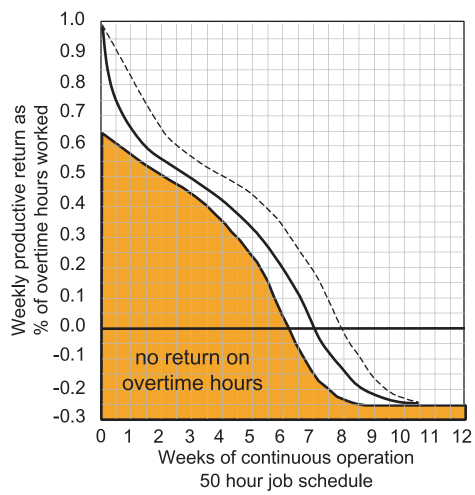

Figure 3a

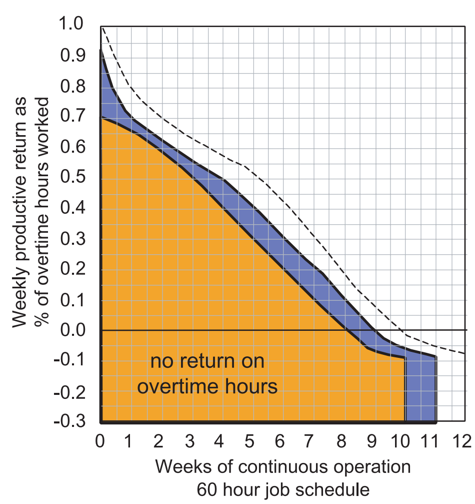

Figure 3b

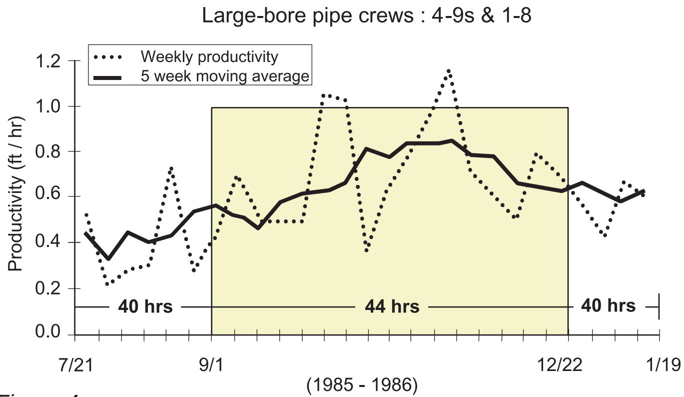

Figure 4a

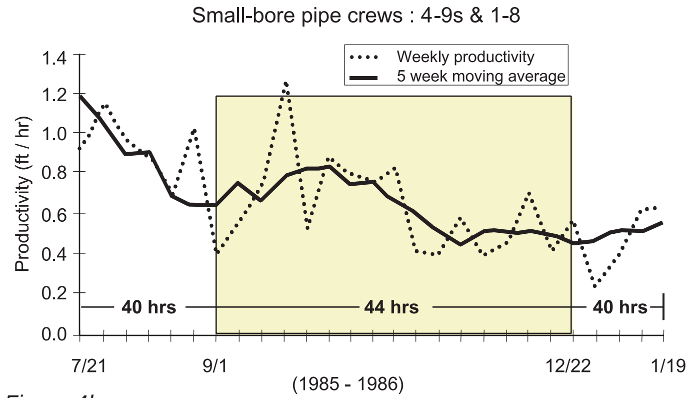

Figure 4b

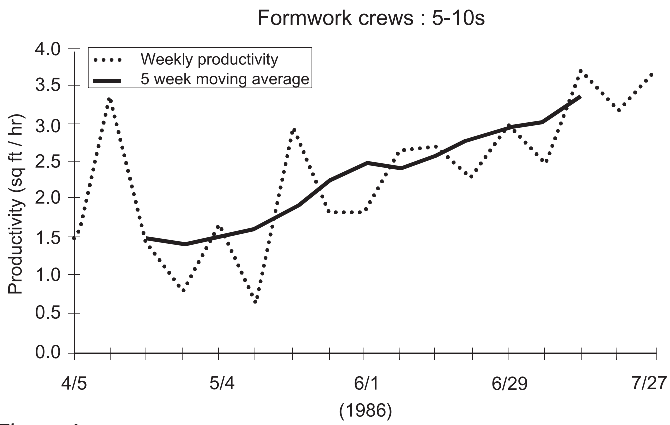

Figure 4c

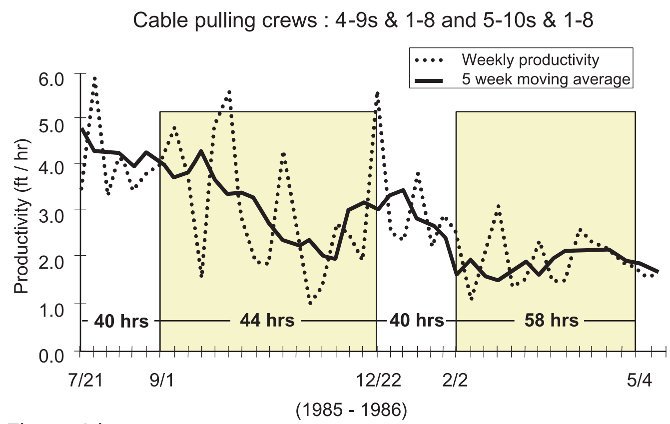

Figure 4d

Associated Specialty Contractors relied on the same BRT data. Finally, the 1994 MCAA publication includes the same BRT data as proof of the relationship between overtime and the increasing ratio of inefficiency during consecutive overtime periods. Thus, all three publications contain no original data and the limitations of the BRT Study are equally applicable.

Construction Industry Institute

In 1988, the Construction Industry Institute (CII) published Source Document 43 on "The Effects of Scheduled Overtime and Shift Schedule on Construction Craft Productivity."

This study contains original data collected between 1984 and 1988 from seven different U.S. heavy industrial projects at various stages of completion, including oil refineries, natural gas recovery plants, a fossil power plant and a chemical processing unit. The focus of the data is on crew performance. Trades involved are primarily electricians, pipefitters and insulators. Two projects include data for concrete crews (labourers) and one project includes formwork and rebar crews (carpenters and ironworkers). Only two projects include data on straight-time as well as on overtime schedules. On the chemical processing unit all tradesmen worked on a rolling 4-10 hour day schedule (two days off); three crews were shifted such that at least two crews were on site every day. Figures 4a to 4d depict the results for selected crews.

Figures 5a and 5b show the curves produced for average normalized productivity against time for various combinations of overtime schedules. They were generated to illustrate overall results of the study.

Based on the inconsistent patterns, no defensible conclusions could be developed with respect to overtime inefficiency. Thus it is not surprising that the study concludes with the following statements:

"1. Previous studies by BLS, the Business Roundtable and others are not consistent predictors of productivity loss during overtime schedules for construction projects in this study.

2. Even on the same project working an overtime schedule, productivity trends of individual crews are not consistent.

3. Productivity does not necessarily decrease with an overtime schedule.

4. Absenteeism and accidents do not necessarily increase under overtime conditions."

In 1994, the Construction Industry Institute (CII) issued Source Document 98 on "Effects of Scheduled Overtime on Labour Productivity: A Quantitative Analysis", the most comprehensive report since the BRT report (1974; 1980). It is based on 151 weeks of data collected from 1989 to 1992 from four active industrial construction projects (papermill, manufacturing, process plant, refinery) without major contract disputes. Each was constructed in a tranquil environment and was well managed. The overtime schedule was used to maintain the schedule, not to attract labour. The manufacturing and papermill projects were existing facilities where old systems and equipment were removed and replaced with new ones. Congestion was a major concern. The refinery involved the rebuilding of an existing facility. The process plant was a spacious, outdoor, grass-roots facility.

The focus of the study was on detailed observation of piping and electrical crews, rather than on various trades. The rationale that only piping and electrical trades were studied is that these trades represented the majority of the work and were most likely to be

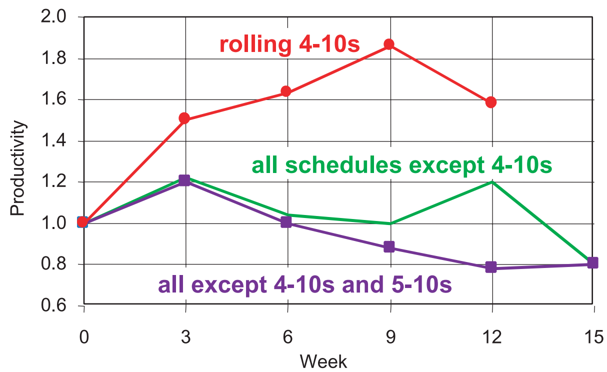

Figure 5a

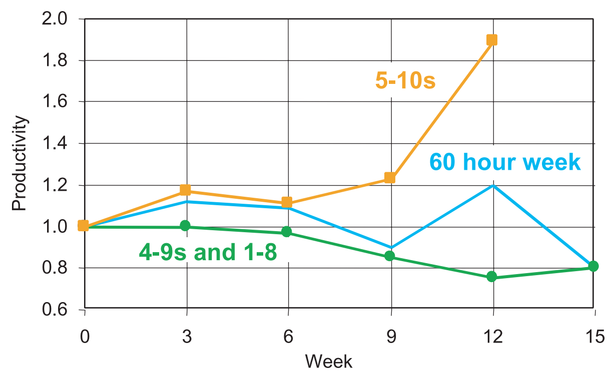

Figure 5b

affected by scheduled overtime. For electricians, the work involved the installation of conduit, cable and wire, terminations and splices, and junction boxes. For piping, work included pipe erection and the installation of supports and valves. The performance of a crew on an overtime schedule was compared to the same crew on a straight-time schedule. There were not data for 5-8 hour days. Therefore a 4-10 hour day schedule was used as the baseline. Work weeks shorter than four days usually were shortened because of weather. There was one 7-day work week which was discarded. Over 90% of the work days were 10-hour days. The study specifically excluded the early phase of the work and the start-up phase.

Figure 6 shows the **overtime efficiency (3-4 week duration) as a function of the number of days worked per week.** It is obvious that 2- and 3-day work weeks were significantly less efficient than the normal 4-day work week, probably because of the effects of adverse weather. The loss of efficiency for the 5- and 6-day work week was in the range of 10 to 15 percent with very little difference between the 5- and 6-day work week.

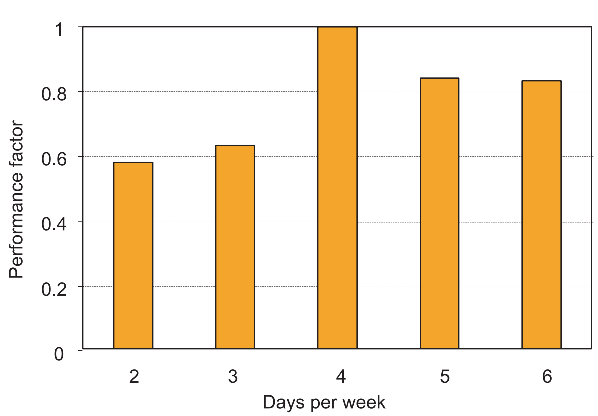

Figure 6

The remaining analyses contained in this study were an effort to support the initial determination that there are productivity losses when working overtime. Figures 7a and 7b show the **efficiency trends for 50-hour and 60-hour weeks as a function of time compared to the curves from the 1980 Business Roundtable Study.** All curves except the BRT curves were normalized about the first week of overtime for better visualization of trends. It is evident that some crews follow the general downward trend established in the BRT Study, while others do not.

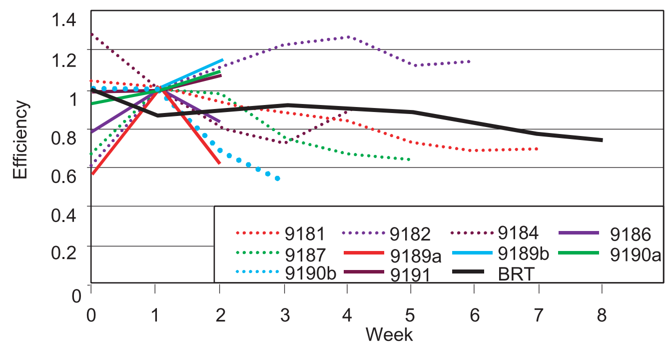

Figure 7a

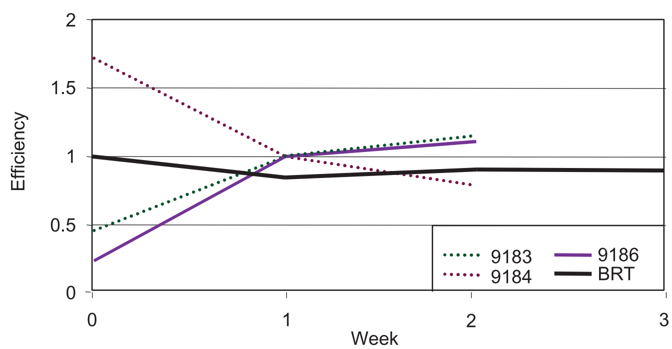

Figure 7b

Figure 8 shows the **average overtime efficiency of all crews working a 50-hour work week, the BRT curve and other references.** The study concluded that the data are consistent with the BRT curve and that the BRT curve is probably a good representation of the industry average but individual work may vary appreciably. Moreover, the study showed that it was possible to work overtime for three to four weeks without losses of productivity which would be consistent with the 1988 CII study.

In the final conclusion, the study states:

- *"The use of short-term overtime **can** cause a loss of labour efficiency. The **average** loss was in the **range of 15%.** When losses were analyzed as a function of time, the averages were consistent with the Business Roundtable curve. However, overtime losses are **not automatic** but can range from **none to 25%** for crews (projects) where there are no other factors affecting productivity. Examples of factors that **can** cause losses greater than 15% are incomplete design, numerous changes, work in an operating environment or labour unrest.*
- *As overtime efficiency decreases, the research found that there was an increase in disruptions. The most consistent increase occurred in the category of resource availability. It is*

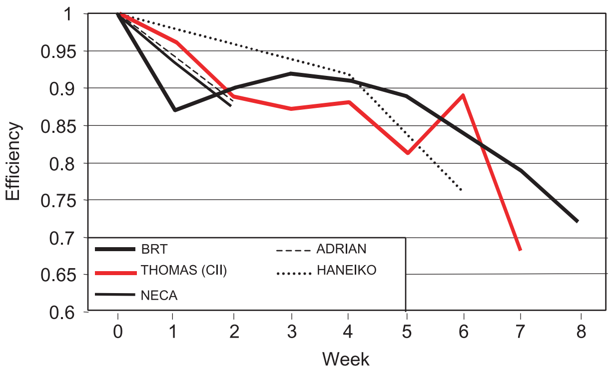

Figure 8

concluded that this increased difficulty in providing resources is the root cause of losses of efficiency.

- *The data collection and analysis methodologies are a sound, reliable way to measure the effects of scheduled overtime. The basis for this conclusion is that the results of the analysis are consistent and in line with what would be reasonable."*

[emphasis added]

Needless to say, the rather vague quantitative conclusions render their application to a loss of productivity calculation highly questionable. However, this study could be construed as a validation of the BRT curves (in spite of the warning expressed in the BRT study) and the apparent contradiction of the CII 1988 conclusions.

National Electrical Contractors Association

The National Electrical Contractors Association (NECA) published several studies on overtime.

In a 1962 survey, 289 members replied to four questions concerning overtime on a sporadic, short-duration basis and two questions concerning continuous overtime over several successive weeks. This is an extremely small sample considering that NECA has thousands of members. The responses yielded the following average values of productivity.

NECA concluded that the observations were close enough to give

FOR SPORADIC EXTENDED DAYS IN AN OTHERWISE NORMAL WEEK

SCHEDULED DAYS	SCHEDULED HOURS	ACTUAL HRS EXTENDED DAY	PRODUCTIVITY EXTENDED DAY
5	8	9	100%
5	8	10	98%
5	8	11	95%
5	8	12	92%

FOR ISOLATED OR SPORADIC EXTENDED WEEKS

SCHEDULED DAYS	SCHEDULED HOURS	PRODUCTIVITY EXTENDED WEEK
6	8	98%
7	8	95%

FOR CONTINUOUS OR PROTRACTED EXTENDED WEEKS

SCHEDULED DAYS	SCHEDULED HOURS	PRODUCTIVITY EXTENDED WEEK
6	10	84%
7	10	78%

substantial confidence in the applicability of BLS values to electrical contracting which provided a more complete coverage.

Notwithstanding NECA's conclusion, it must be reiterated that on one hand the BLS data were collected under very specific conditions in the manufacturing sector and on the other hand NECA data were nothing more than a limited survey, i.e. subjective data which cannot be verified. At best, the coincidental similarity of questionable data can be considered a general indicator.

In 1969, NECA published "Overtime and Productivity in Electrical Construction", a study conducted by the NECA Southeastern Michigan Chapter. Data are from jobs worked during 1964, presumably for electricians. The origin of the data and the work environment are unknown. Figure 9 shows the **decline of productivity over periods of one to four successive weeks.** What happens beyond is, as indicated, a question mark. What is striking about the four weeks of data is that weeks 2, 3 and 4 are multipliers of 1.5, 2.0 and 2.5 respectively of the first week data. This raises some serious concerns with respect to the originality of the data.

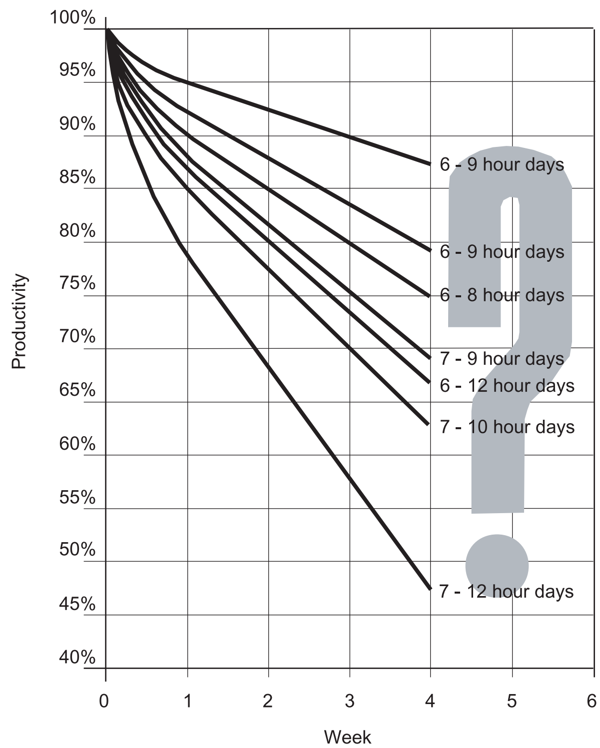

Figure 9

The findings for the **number of work hours per day** and the **number of work days per week** are depicted in Figures 10a and 10b. They are consistent with expectations.

In 1989, NECA published a second edition of "Overtime and Productivity in Electrical Construction".

The study provides information on low, average and high productivity loss for 5-, 6- and 7-day work weeks and 9, 10 and 12 hours per day for sixteen successive work weeks, based on data gathered by NECA since 1969 for journeymen electricians. The origin of the data and the work environment are unknown. Figure 11 summarizes **the data for average productivity for successive weeks of overtime.**

Miscellaneous Studies

In 1969 James Howerton published statistics on an overtime study conducted in 1964. The project, its location and the trades involved are unknown. Figure 12 shows **productivity as a function of successive weeks of overtime.**

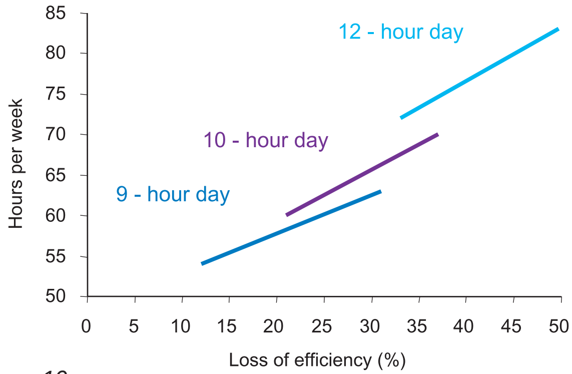

Figure 10a

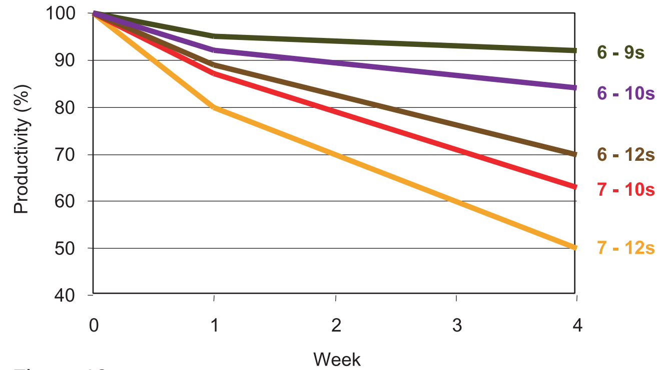

Figure 12

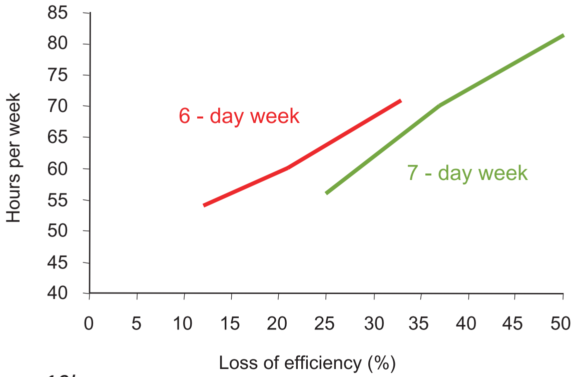

Figure 10b

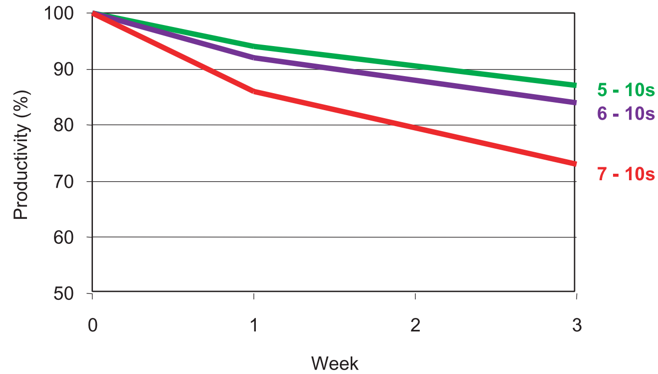

Figure 13

In 1987 J.J. Adrian reported loss of productivity as part of an analysis of a contractor's claim. The data originate from concrete activities in Chicago in 1982. The work was performed under ideal weather conditions (60°-80°F). Figure 13 shows the **productivity losses reported for successive weeks of overtime.**

In 1991 Haneiko and Henry published statistics on the impact of overtime on concrete placement. The data were collected in 1986 on a backfit project in Texas. Overtime for concrete placement averaged 20 hours/week (60 hours/week) for an eight-week period. Productivity during this period was 35% less compared with the eight-week straight time period (40 hours/week), namely 6.78 hrs/cy vs. 5.01 hrs/cy. The only concrete work account that continued throughout the overtime period was the footings and grade beams. Straight time productivity was 4.68 hrs/cy. Figure 14 shows **productivity over eight weeks of overtime for the concrete placement of footings and grade beams.**

U.S. Army

In 1979, the Corps of Engineers published the "Modification Impact Evaluation Guide" for the purpose of evaluating impacts due to changes. With respect to overtime, the guide recognizes:

"Working more hours per day or more days per week introduces premium pay rates and efficiency losses. Workers tend to pace themselves for longer shifts and more days per week...

When modifications make it necessary for the contractor to resort to overtime work, some of the labour costs produce no return because of inefficiency...

if overtime is necessary to accomplish modification work, the government must recognize its liability for introducing efficiency losses...

... data are included merely as information on trends rather than firm rules which might apply to any project...

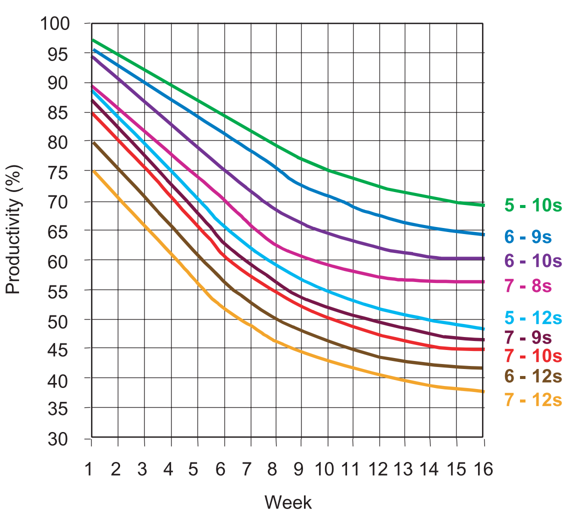

Figure 11

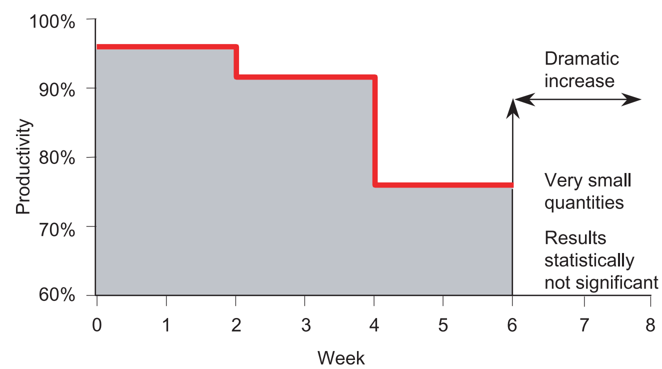

Figure 14

... data do not extend beyond the fourth week, it is assumed that the curves would flatten to a constant efficiency level."

Figure 15 depicts the curves published by the Corps on the **effect of the overtime work schedule on efficiency.** The origin of the data relied upon is unknown. However, it appears that the Corps accepted the NECA (1969) average data for 6-9s, 6-10s, 6-12s, 7-8s, 7-9s and 7-10s since they are identical, and added some of their own lines.

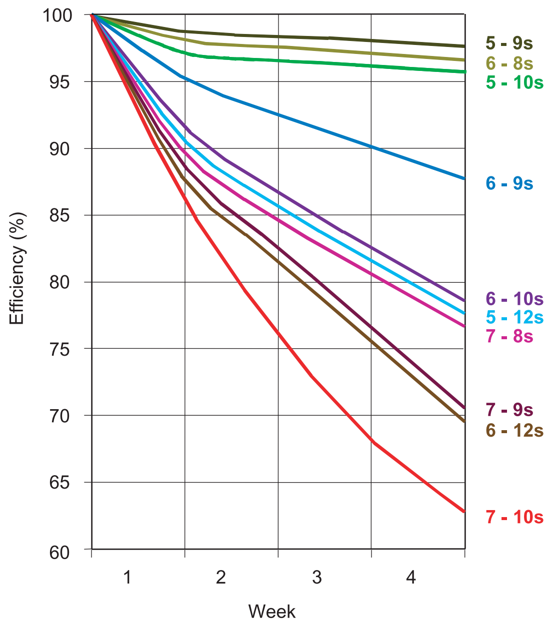

Figure 15

Synopsis

Based on the foregoing overview of available studies it is evident that only a few are based on original data. Moreover, less than reliable data have been published and republished over and over giving a false appearance of originality. Finally, data are available for a limited number of trades only. Figure 16 compares the reported efficiency from various studies for the 50-hour, 60-hour and 70-hour work weeks with the majority based on 10-hour workdays and an overtime schedule of four consecutive weeks. Subject to the qualifications already expressed, there is a certain consistency in that there is a definite, but not necessarily linear, decrease in productivity for each additional 10 hours per week.

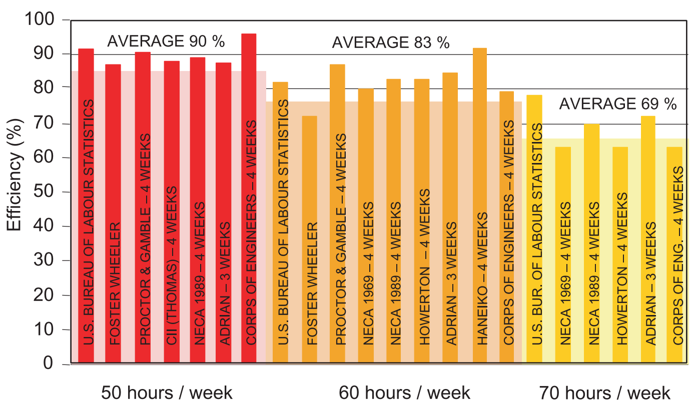

Figure 16

CONCLUSIONS

At the outset of this article it was clearly stated that published charts should only be used with the greatest caution and, more importantly, only when no other practical method is available to calculate productivity losses from the actual project records.

The inherent limitations of published charts have best been summarized by the U.S. Army Corps of Engineers:

"... data are included merely as information on trends rather than firm rules which might apply to any project."

Notwithstanding these limitations, appropriate application of published data for the purpose of forward costing of a change or accelerated schedule, i.e. before execution of the work, is considered advantageous to all parties involved. The owner will know the cost prior to embarking on a change or accelerated schedule and the contractor will get paid for the cost of the agreed upon productivity loss during the execution of the work. With this approach both parties share some risk but can avoid the costly after-the-fact dispute resolution process.

The use of published charts in an after-the-fact claim situation is more problematic. Each of the studies containing original data applies to a very specific project environment for specific trades only. It is, therefore, of the utmost importance to understand and document the surrounding circumstances of a claim situation. It is then up to the experienced analyst to compare the claim scenario to the published study which resembles it most and introduce adjustments if deemed necessary. Published data can therefore be helpful in quantifying loss of productivity in overtime situations but the result will always remain an approximation, although it may be the best one under certain circumstances.

For many types of projects no published data are available. Such projects include roadwork, pipelines, transmission lines or extensive cut and fill operations, just to name a few. However, the absence of such data is not surprising. On these types of projects contractors typically record actual quantities and hours of work, allowing for a loss of productivity calculation based on actual data. Thus, an attempt to rely on undated published data on these types of projects will invariably be treated with suspicion. Moreover, these projects are often planned from the outset with 10-hour shifts and/or 6-day week schedules to take advantage of daylight or to attract labour to remote work sites. The latter aspect is particularly relevant in cases where the labour force is housed in camps, thus eliminating daily commuting time to the work site. The fatigue resulting from a daily two-hour commute is considered similar to a daily increase of two working hours. Reliance on published charts on such type of project is therefore highly questionable.

In claim situations where the loss of productivity is a result of extended overtime and other parallel causes, none of the published charts offer any help in calculating cumulative losses. Conversely, relying on published charts for the isolation of one specific cause such as overtime may yield unreliable results. However, if there is no other practical way to calculate such loss, the analyst may have no choice but to rely on a study which best fits the project situation under scrutiny, to calculate an approximate loss.

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