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Utilizing Industry Studies in Preparing and Presenting Loss of Labor Productivity Claims

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I. Setting the Stage for Reliance on Industry Studies (Instead of Utilizing Project Specific Empirical Studies)

We have sometimes seen the term *amorphous* applied to the subject of loss of labor productivity, or more particularly, cumulative impacts.[1] The American Heritage Dictionary defines amorphous as follows: **1.** Lacking definite form; shapeless. **2.** Of no particular type; anomalous. **3.** Lacking organization; formless. [From Greek *amorphos* : *a*-, without; see A-[1] + *morph*¶, shape.]

Of course, the use of this descriptor applied to the loss of labor productivity, or cumulative impacts, does not suggest that labor inefficiency is not a real and tangible phenomenon. However, it does suggest that labor inefficiency is hard to see – that it can be all but invisible to the eye as it is occurring. It can also be very difficult to measure and to link a cause with an effect.

Fortunately, the courts and boards of contract appeals have held that the absence of scientific proofs, or exact calculations supported by books and records, are not required in order to perfect a loss of labor productivity claim.[2] In many cases, labor inefficiency can be subtle; deteriorating the contractor's profit margin slowly but in the end, amounting to a substantial financial loss. In some cases, such as on projects with extensive overtime schedules or where chaos prevails on the jobsite – evidenced by rampant stacking of trades, lack of site access, a pervasive out-of-sequence work flow – the assumption that a significant loss of labor productivity is occurring is the only logical conclusion. However, even in the cases of rampant site mismanagement and project mayhem, discrete loss of labor productivity can still be difficult to see as it is occurring (i.e. *amorphous*).

It is precisely this amorphous quality of labor inefficiency that causes many contractors to wait until a project is virtually complete before preparing a loss of productivity claim. The other factor that may delay, or deter a contractor from timely preparing a claim is the quality and reliability of the contractor's contemporaneous labor tracking records. It is surprising in this day of computer proliferation that many labor intensive contractors do not routinely track their labor productivity on a weekly or monthly basis using readily available software programs. Many contractors do not see their labor productivity results until the project is complete and at a time when their bid labor hours can be compared with their actual labor hours. Often, the timing requirements contained in the contractual notice provisions have, at that point, expired.

Perhaps the single most problematic issue when evaluating a contractor's loss of labor productivity is the lack of detailed and reliable contemporaneous labor tracking records. **The decision by the claimant not to maintain useable contemporaneous labor and production**

records sets the stage for the necessity to utilize industry studies and not empirical project specific evaluations, to estimate the claimant's loss of labor productivity.

Such labor tracking records usually divide the planned and actual labor hours by discrete elements of work using charge codes, such as by building area, floor, major mechanical or electrical room, system or other definable feature of work. From this data and from the progress data (i.e. percent complete), an earned value analysis can be performed on a regular basis. While the contemporaneous comparisons of the planned and actual labor hours expended by week or month is still a "modified total labor" method[3], it allows the claimant to focus on potential problem areas in order to review the original plan and to evaluate the actual hour expenditures. Where such record keeping exists, a contractor can reasonably quickly identify the labor codes which appear to be inefficient and can physically evaluate the work areas to determine if the apparent loss of productivity is real, a labor reporting error or a bid error.

As noted however, many labor intensive contractors do not attempt to keep such records, or abandon these recording keeping efforts as the project decays into mayhem. Several reasons for the lack of record keeping include: i) the time it takes in the planning stage to divide the bid hours into definable elements of work; ii) the substantial effort it takes to record and input actual labor hours by element of work; iii) the propensity for field managers to improperly (through accident or on purpose) code hours to the labor codes; and iv) the inability properly and timely to adjust labor codes for scope change or other types of labor hour adjustments to produce reliable results.

There is another important factor that results in the absence of contemporaneous labor tracking records. Some contractors believe that a project fraught with changes in scope automatically equates to a project with increasing profit over and above that which was originally forecasted. Thus, with the expected increase in profitability resulting from the portent of many change orders, the contractor loses the sense of urgency to maintain accurate labor records. In fact, some contractors on public works projects believe that maintaining detailed labor and cost records for change orders is not to their advantage, particularly if a DCAA or other public audit agency may inspect the contractor's books and records seeking to prove windfall profits or mischarges on change order accounts.[4] In other cases, the contractor may simply believe through unfounded optimism, inexperience or hubris that, at the end of the day, losses in labor productivity will be overcome by the substantial profits that the contractor assumes will come as a result of multiple changes in scope. This is usually *not* the case.

The fact that reliable contemporaneous labor tracking records are not maintained on many construction projects leaves the contractor in a predicament when preparing a loss of productivity claim. How best to quantify the losses with some degree of specificity and to connect the cause with the effect? That is oftentimes the claimant's dilemma and it is a serious one at that. Generalized and vague assertions by contractors of cost overruns resulting from "loss of labor productivity" are easy for owners or prime contractors to deny on the grounds that the claimant has not carried its burden of proof; has failed to demonstrate that the losses were caused by the acts or omissions of another party and has otherwise failed to provide any specificity as to the bases of its claims.

Assuming that the contractor has not attempted to keep particularized labor records or has abandoned its labor tracking process as the job progressed, the contractor has three choices: i) to file a modified total labor hour claim; ii) to attempt to perform a measured mile by relying on various other types of project records; or iii) to apply industry studies. This discussion does not touch on filing modified labor hour claims. That process is generally self-evident and usually does not require expert testimony, except perhaps for an opinion that no other more particularized quantification method was possible. The measured mile approach often requires an expert to extract and collate labor and material data from sources such as payroll reports, purchase orders, photographs and other contemporaneous data. In the final analysis, the claimant and/or its expert must arrive at a ratio of labor hours expended to install a known quantity of material or equipment in order to perfect a measured mile analysis. In addition to the difficulties in obtaining reliable and usable labor records by which a measured mile analysis can be performed, on some projects there is no time period or area that represents non- or less-impacted segments of the work. Thus, the measured mile is offered as the basis of claim on relatively few construction projects. The third option – the application of industry studies – is the one most frequently utilized to prepare a loss of labor productivity claim.

II. Assessing Quantitative Loss of Productivity Studies

II.a Inventorying Reliable Industry Studies to Quantify the Loss of Productivity

There are dozens of studies on the subject of the quantitative loss of productivity, as illustrated by Figure 1. They fall into two general categories: discrete and cumulative. Discrete studies focus exclusively on one variable and its impact on labor productivity – overtime or weather, for instance – and exclude the impact of any other variable. Their advantage is that the studied variable can be explored in considerable detail, and the resulting model be applied with singular focus to the disrupted project.

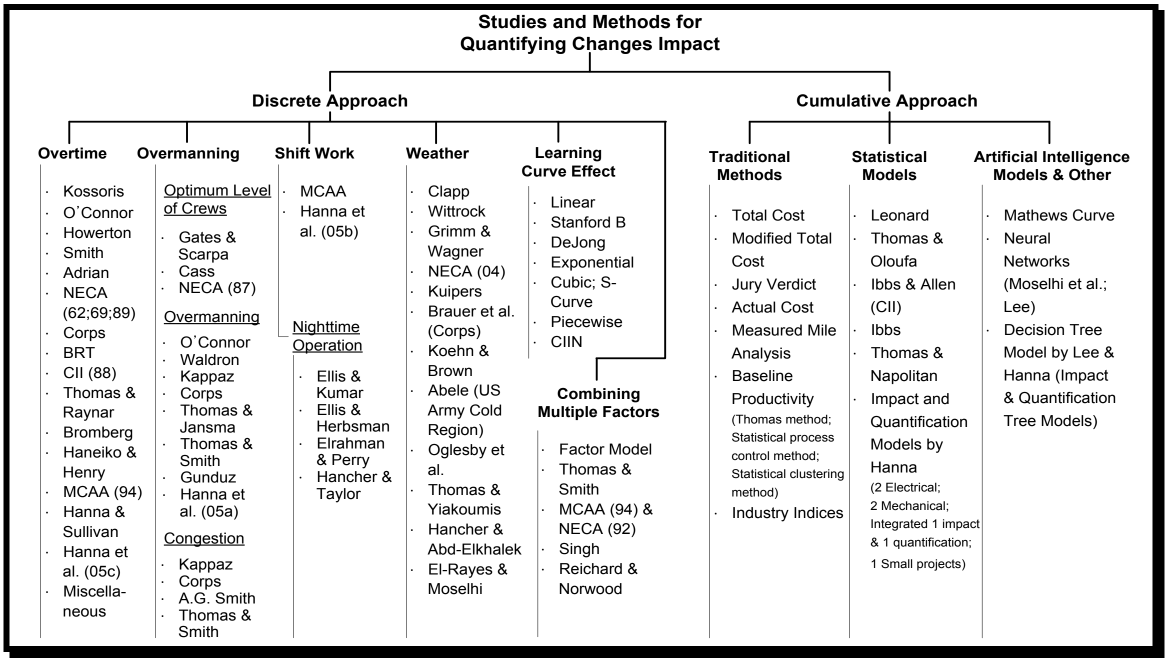

Figure 1 – Loss of Productivity Studies (Ibbs and Lee 2008)

Construction projects are not like other scientific, laboratory settings. They are the result of a set of variables interacting with each other over time. The condition of *ceteris paribus* (all other things being equal) does not apply in the construction industry so in recent times researchers have resorted to cumulative studies. Cumulative studies are a higher-level study and presume that the effects of one variable cannot be microscopically studied with direct cause-and-effect precision. Instead a variable such as project change – regardless of the type of change – is contrasted with another variable such as loss of labor productivity.

Because both discrete and cumulative studies have validity when properly applied, courts and boards have accepted their use. Because of space limits, only some of the studies can be reviewed in this paper. The following sections briefly discuss some of the more prominent studies that have been reported in the professional literature, and summarize their pros and cons.

II.b Loss of Productivity Studies for Individual and Separated Factors

Overtime is use of labor in excess of the worker's standard workday and workweek, in the United States that is an eight-hour day, five-day week. It is not only one of the most common forms of acceleration along with over manning and shift work, but it is also a common strategy for attracting labor. The Business Roundtable (1980) reported that the premium pay of overtime operation attracts labor to a project which is located in a remote area and has difficult job conditions, or cannot get its fair share of the labor force due to the nature of the work.

There are generally two types of overtime depending on the length of the period of overtime: 1) sporadic or spot overtime and 2) scheduled or extended overtime. Spot overtime is used to handle unexpected problems or to finish time-critical work. The second form of overtime usually lasts for at least three consecutive weeks. It is often planned in advance to accommodate special needs such as completing a project earlier than planned or attracting better qualified laborers to the job. The research reported in the professional literature has focused on extended overtime.

Kossoris's (1947) work is generally considered the earliest reliable work on the subject. It was a study of the wartime manufacturing industry, and showed that not only is overtime correlated with physical fatigue and loss of productivity, but it also could lead to increased errors and poorer work quality of work, absenteeism, and accidents. Because his study was not specific to the construction industry, because he inexplicably only used data from 34 plants out of 800 visited, and because employee turnover was abnormally low in World War II, it generally is not considered applicable to construction settings. It did though spur a series of other studies that were dedicated to the building industry; notably O'Connor (1969); Howerton (1969); Smith (1975); Adrian (1987); National Electrical Contractors Association (1962, 1969, 1989); US Army Corps of Engineers (1979); the Business Roundtable (1974, 1980); Construction Industry Institute (1988); Thomas (1997); Bromberg (1988); Haneiko (1991); Mechanical Contractors Association of America (1994); Hanna (2004); and Hanna (2005a). Figure 2 shows a graphical summary of some of these studies.

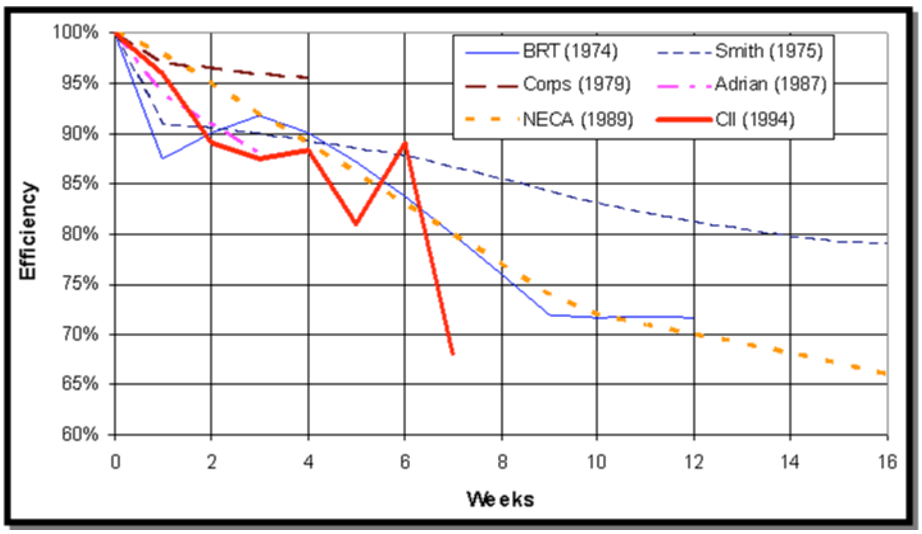

Figure 2

II.c Summary of Various Overtime Studies

The Business Round Table ("BRT") study is probably the most widely cited overtime study in the construction industry. It was based on construction of a series of small projects at a process plant over a ten year period in the 1960s in Green Bay, Wisconsin. Observations were made on a weekly basis with records from physical count or actual payroll hours, with productivity measured as a comparison of actual labor-hours to a 'fixed standard base' or bogey.

Despite its popularity, it has serious flaws: 1) it contains no actual data, only graphs and a table, leading some writers (Seals 2006) to suggest that the curves were not really based on project data but the author's opinions; 2) results are not consistent with the references cited as source data or comparative studies – they sometimes misrepresent the Kossoris report, for instance; 3) data were not collected following the standards in the field; 4) data could have been biased since, as the author described the circumstances as "tranquil labor relations and excellent field management direction;" 5) Wisconsin was not unionized at the time and its demographics do not reflect today's population; and 6) construction means, methods, and technology is dramatically different today.

The point here is not to criticize the BRT overtime report per se, but to point out the lack of scientific completeness in one key report and the tentativeness of applying even a good study to a current, disputed project. It is also important to apply such studies correctly. For example, a laborer spending 20% of his time working overtime on a sporadic basis will not have the same fatiguing effect as a worker continuously working overtime for the last 20% of a project's duration.

Another problem with use of these overtime studies is that claimant often fails to "reset the overtime clock" (MCAA 2011). That is, the claimant simply totals the number of overtime hours and the straight time hours worked by the overtime crews and then applies the overtime inefficiency percentages to that total. The error is the failure of many claimants to evaluate the consistency of the overtime schedules of the individual workers. It is understood in the industry that when a worker takes time off from an overtime schedule, this time off basically "resets" the workers' individual inefficiency "clock". Thus, if using the BRT or the National Electrical Contractors Association ("NECA") curve for a fifty hour work week at week seven of continuous overtime, the user would expect to see a reduction in labor productivity of 20%. However, if a portion of the crew took a week off at week five due to fatigue and then returned to the project and continued the fifty hour overtime schedule, at week seven their inefficiency would be much less than the 20% that was expected for continuous overtime. Once rest time is allowed, the workers' inefficiency clock is reset. Thus, where workers are not dedicated to a *continuous* overtime schedule as represented in the various published curves, a claimant can easily overstate the loss of productivity when rest time is not evaluated. This may require that the claimant review its payroll records to ensure that the entire crew worked continuous overtime before applying the inefficiency percentages contained in the various publications.

Related to the overtime studies are the shift work studies by Hanna (2005b) and Haneiko (1991), and the night time studies by Ellis (1993a, 1993b); Elrahman (1997); and Hancher (2001). They are solid studies with their methodologies described in detail. However, the Hanna and Haneiko study methodologies are not described in sufficient detail, and the other four studies have the limitation of being focused on highway construction.

Based on the most widely used overtime inefficiency publications, in 2011 the Mechanical Contractors Association of America ("MCAA") prepared a new chapter in its management manual entitled "How to Estimate the Impacts of Overtime on Labor Productivity" that compared some of the most widely utilized overtime inefficiency curves.

This chapter in the MCAA's publication included and compared four frequently cited overtime inefficiency curves: NECA's curves based on various overtime schedules, the BRT curve, a curve produced by Dr. H. Randolph Thomas of Pennsylvania State University and the

1979 U.S. Army Corps of Engineers "Modification Impact Analysis Guide" which is still in use even though it has been formally withdrawn from publication by the Government.

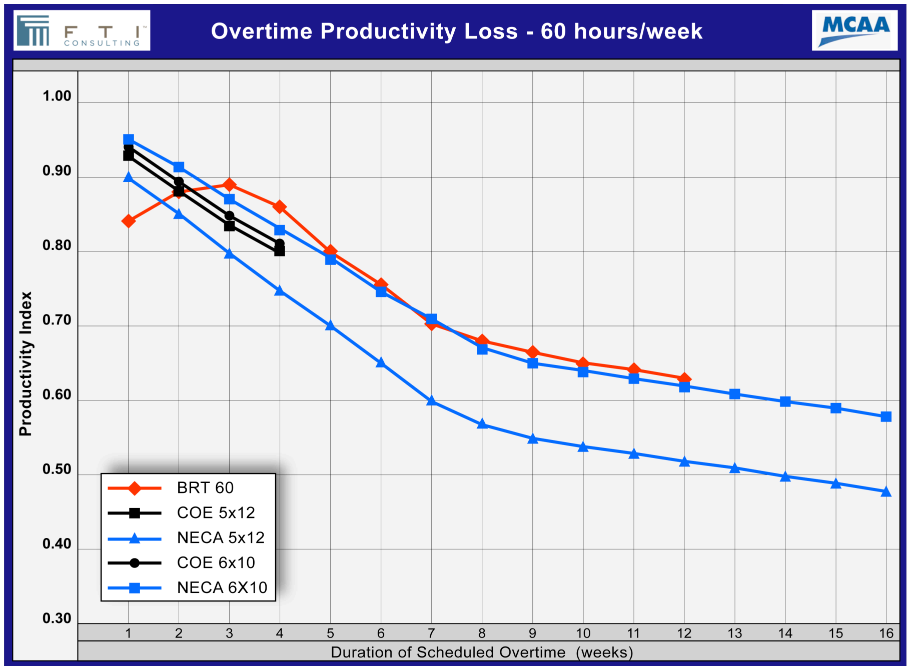

Figure 3 Comparative industry study graph – 60 hour work week reprinted from the MCAA publication

As with the MCAA *Factors* that will be described in detail in a following section of this paper, the empirical data or the base data supporting each set of curves is either not readily available or is not available at all. Other criticisms of the aforementioned data are discussed above, however, no experienced expert in the construction industry has asserted that planned and long term overtime schedules do not have a deleterious effect on labor productivity.

Based on the premise that extended (as opposed to "spot") overtime most certainly reduces worker productivity, the MCAA compared the four sets of overtime inefficiency curves to compare the findings of the four sources. Clear similarities were found between the shapes of the various overtime inefficiency curves. There were differences in some curves for discrete periods and not all data extended for the same duration, however the general shapes of the productivity curves bore noticeable similarities.

Thus, even though the MCAA's 2011 publication did not offer any new overtime inefficiency studies, it has been meaningful in providing a comparison of the shapes of the inefficiency curves represented in several of the most widely accepted overtime publications. These similarities can be important in supporting a contractor's claim of overtime inefficiency.

II.d Weather Studies Utilized in the Construction Industry

Weather impacts on labor productivity are another much-studied factor. Some of the more notable studies are Clapp (1966); Wittrock (1967); Grimm (1974); NECA (2004); Kuipers (1976); Brauer (1984); Koehn (1984); Oglesby (1989); Thomas (1987); Hancher (1998); and El-Rayes (2001).

Some of these studies appear very sophisticated. Grimm, for instance, examined masonry productivity in a study sponsored by the Center for Building Research at the University of Texas, Austin, under the sponsorship of the United States Department of Housing and Urban Development; a consortium of manufacturers; and the Bricklayers, Masons, and Plasterers International Union. Over a nine month period, temperature and humidity were measured and correlated with the work output of 51 masonry workers building 283 test wall panels in 73 US locations. A normal daily production rate was one panel per day. Productivity was found to decline as the temperature and humidity varied from 75°F (24°C) and 60% RH.

Somewhat analogously, NECA researched the temperature and humidity impacts on productivity for standard electrical tasks (NECA 2004). Over a six day time period, the productivity of two experienced journeyman electricians was tracked while they installed electrical receptacles in pre-mounted junction boxes was selected as the work to be measured. This type of work was chosen because it is easy to measure and since a large number of units can be installed in an hour, the error of scale can be minimized. They were not informed about the actual objective of the experiment or that temperature and humidity conditions were being changed. The results of the masonry and electrical work, graphically portrayed in Figure 3, are similar.

Figure 4

Impact of Temperature and Humidity on Productivity Compiled by Ibbs and Lee (2008) from Grimm (1974) and NECA (1974, 2004)

Findings included 1) temperature and humidity can affect and fatigue productivity substantially; 2) above 100°F workers showed signs of belligerence and irritability, and the quality of workmanship deteriorated considerably; 3) unscheduled stoppages of work increased; and 4) carelessness increased, which can lead to safety problems.

The most commonly cited problem with these studies is that they were based on an experiment, where the work environment was set up and artificially controlled. The biggest underlying problem of the controlled work environment is in the workers' psychological reaction. The journeymen knew they were being watched, and they may in turn have exerted some extraordinary efforts to keep the productivity as high as they could, which would not be the case in real situations. In a post-test interview one of the journeymen commented after performing at 110°F and 60% RH, "If I was at a job site, I would have found something else to do in a cooler work area a long time ago." Productivity might have been worse in jobsite conditions than in this controlled setting.

Small sample size reduces the reliability too. The NECA test relied on only two workers and lasted six days. Another issue is that the work in both cases was highly repetitive and simple. They are old studies, the two factors are considered simultaneously; and there is lack of raw data, which would allow validation.

II.e Other Discrete Impact Studies

Many other studies of discrete factors exist. For example, learning curve effects were first studied by Wright (1936) while studying the manufacture of World War II bombers. Since that time, Carr (1946); Stanford (1949); Hoffman (1950); DeJong (1957); Gabrielsen (1963); United Nations (1965); Parker (1972); Gates (1972); Carlson (1973); Frantzolas (1984); Belkaoui (1986); Thomas (1986); Smith (1989); Oglesby (1989); Haneiko (1991); Everett (1994); Farghal (1997); Emir (1999); and Singh (2001) have written about the subject. One of the contentious issues what level of operation should be analyzed. For example, the UN study (1965) found reasonable results when looking at the time required to build houses in a large-scale housing development, whereas Thomas (1986) chose to model the installation of precast floor planks in a six-story building. (One of the flaws in Thomas's study was the means by which the planks were lifted into position changed as the work advanced to the upper floors.)

Overstaffing and congestion, which is adding more workers to a task or jobsite than is optimal, is another category of discrete factors. Waldron (1968) finds that overstaffing by 50% can impair productivity by 30%. Other studies have been conducted by O'Connor (1969), Kappaz (1977), Gates (1978), US Army Corps of Engineers (1979), Thomas (1985), Smith (1987), NECA (1987), Thomas (1990), Cass (1992), Gunduz (2003), and Hanna (2005c) and Mobil Oil (Thomas 1990). The Corps (1979) reference is especially interesting because in the appeals board in *Danac* rejected the contractor's use of the guide because it was a general statement, not substantiated by a clear evidentiary link between the guide's meaning of over manning and the disputed project's conditions. Part of the problem was that the contractor's own personnel used the guide rather than an impartial expert.

Along similar lines, Cass (1992) looks at the impact on productivity of a fluctuating crew size. The work is more anecdotal and qualitative, and not surprisingly asserts that steadier crew sizes result in better craft productivity. Other topics that have been studied include storage area organization, material handling and distribution, material availability, tool and equipment availability (Bilal 1990). These studies have had mixed success, largely because the sample size was small.

II.f The MCAA Labor Productivity Factors

By far the most frequently employed method of supporting a contractor's loss of productivity claim is by the use of industry publications, sometimes called industry studies. Of the various industry publications on loss of labor productivity, the labor inefficiency *Factors* prepared and published by the MCAA are the most widely recognized and the most frequently utilized to prepare a contractor's loss of productivity claim. The MCAA *Factors* publication, with the attendant users' manual,[5] have been formally adopted by the Sheet Metal and Air Conditioning National Association ("SMACNA") and NECA as applicable to the sheet metal and electrical trades.

The MCAA *Factors* were prepared by the MCAA's Management Methods Committee and the draft *Factor* descriptions and three potential intensity levels of impacts were circulated at a national MCAA convention. MCAA member contractors participated in a polling method to collect data on potential inefficiency impact categories and three levels of impacts expressed as percentages of estimated inefficiency. The *Factors* were published by the MCAA in 1971 and have remained unchanged since that time. While not the result of empirical studies, the *Factors* have gained wide acceptance in the industry, when applied properly, as a reasonable and reliable means to ***estimate*** a contractor's loss of labor productivity.

In several reported decisions, the *Factors* have passed the gatekeeper's scrutiny and have been applied in a manner that resulted in a recovery of damages by the claimant. Admittedly, the *Factors* have been misused by contractors and experts and claims have been denied because of the improper application of the *Factors*. However, the *Factors* themselves have not been undermined as to the validity of the individual impact categories or even the three intensity levels assigned to each category.

These *Factors* are as follows:

Typical areas of criticism when utilizing the *Factors* include:

1. No empirical support for the impact intensity percentages
2. Application of the *Factors* can be subjective
3. Should be used only with an experienced productivity expert
4. *Factors* don't differentiate between non-contractor and contractor caused impacts
5. Represents no more than a modified total labor hour approach to damages quantification
6. Impact categories are often duplicated, or have substantial overlap
7. When misapplied, can produce absurd results

1) While there was no empirical study performed to support the creation of the *Factor* percentages, a polling method is a well recognized and accepted means of gathering relevant data for a publication of this nature. The MCAA membership was, and is, comprised of some of the largest and most sophisticated, labor intensive contractors in the U.S. MCAA member firms focus on evaluating and improving labor productivity as a cornerstone of their businesses. Thus, use of MCAA member firms to participate in a polling method process in developing the *Factors* was prudent and reasonable. Their use and acceptance, unchanged, for more than forty years also speaks to the reasonableness of the *Factors*.

2) Often the *Factors* are attacked as being a wholly subjective means of estimating a contractor's loss of labor productivity. While any application of a published study, such as the MCAA *Factors*, will be influenced by a level of subjectivity, if the analyst (claimant's personnel or outside expert) performs probative interviews with the fact witnesses and has had experience

using the *Factors*, the level of subjectivity in assigning the *Factor* categories and intensity percentages should be minimal.

3) As to the preference to have the *Factors* applied by an industry expert, while this can be helpful, it is not a requirement for properly applying the *Factor* categories and percentages. If the case is going to trial at a board of contract appeals or other venue that is likely to have a construction-experienced judge, it may be to the claimant's advantage to have an independent expert testifying about any of the labor productivity evaluations and calculations – just to separate the analysis from the employees of the claimant with regard to potential assertions of bias. However, the *Factors* were originally designed to be applied by experienced construction estimators and managers and not by expert witnesses.

4) It is true that the *Factors*, in and of themselves, do not account for the contractor's own inefficiencies. That important task is left to the claimant. If a contractor making an inefficiency claim and who is utilizing the *Factors* to categorize and quantify the loss identifies various inefficiency categories that were self-inflicted, the claimant can use the *Factors* to identify and quantify those inefficiencies which were the not the responsibility of the respondent. The *Factors* Users' Manual clearly identifies the importance of ensuring that the claimant's own inefficiencies are identified and removed from the claimant's damages. The *Factors* can be useful in this regard, as well as in the preparation of the affirmative claim.

5) The *Factors* can be applied to the estimated labor hours or to the actual labor hours, as described in detail in the *Factors* Users' Manual. If the *Factors* are applied to the estimated hours (the "prospective" method), then any use of estimated hours could be viewed as a form of

the modified total labor hour method. This fact should encourage the claimant to carefully vet the original estimate and to remove from the inefficiency calculations all categories of labor hour losses that are not attributable to the respondent. These modifications can include: i) bid mistakes; ii) inherent market inefficiencies such as super-heated labor markets; iii) labor hours attributable to changes in scope; iv) contractor mistakes and rework; and v) contractor's lack of adequate management such as inexperienced supervision or lack of the proper tools and materials. The mere assertion that the *Factors,* when used in a prospective form, can be viewed as a form of a modified total labor hour method should not necessarily deter their use, given the reported decisions as to the acceptability to the courts of reasoned and reasonable estimates of labor losses.

6) If not properly and carefully applied, the various *Factors* categories can contain impact duplications. For instance, the *Factor* category "Reassignment of Manpower" describes disrupted and a piece-meal flow of the construction activities. If a decline in "Morale and Attitude", another MCAA *Factor* category, on the project is solely the result of this disruption that is a part of the category "Reassignment of Manpower", a duplication of categories may result. The individual interviewing the fact witnesses and who is also applying the *Factors* must be probative and ensure, through the interview process, that the *Factor* categories have not been duplicated.

7) It is true of almost any industry study method of quantifying labor inefficiencies, that, when misapplied, absurd results can be produced. Unfortunately, in some cases claimants have prepared inefficiency claims by first looking at the total of lost labor hours indicated in the books and records and then have determined what percent loss is required from the *Factors* listing to

equal the actual loss. If a contractor has an actual loss of 140%, it is not unheard of that the claimant will use most or all 16 categories listed in the *Factors* table with the highest impact intensity to equal 140%, without any attempt to connect the causes with the logical and reasonable effects. This is certainly not an analysis; rather it is a gross misuse of the *Factors* that is solely the responsibility of the claimant and not a weakness in the *Factors* themselves.

MCAA and NECA do have vulnerabilities. For instance, the sixteen factors and three degrees of severity in the MCAA model translate into forty-eight possible combinations of loss of productivity percentage. In the hands of a biased or inexperienced analyst, erroneous results may happen. Another criticism is that owner opinions were not surveyed or used in their compilation.

The MCAA and NECA models have been accepted by various courts and boards, though they must be used judiciously. Shepardson (2001) describes the reason for success in applying MCAA in *Hensel Phelps* was that the expert witness conservatively assigned his own percentages of impact based on his experience in the industry and thorough study of the case, rather than simply using the values given in the manual in applying six of the *Factors*. Since the manual in publication at that time did not provide much guidance, relying on the productivity expert seems to have been the key to success in this case. The lack of a comprehensive users' manual has since been remedied by the MCAA in its recent editions of the publication.

Another well-known industry study is the "Modification Impact Evaluation Guide" by the U.S. Army Corps of Engineers (1979). The study identified four factors as typical causes of labor productivity loss on unchanged work resulting from modifications (change orders): (1) disruption, (2) crowding, (3) acceleration, and (4) morale. Nothing is known about the source of the data used in this report, nor does it guide the reader how the four factors should be combined (addition, multiplication?). There are no reports of it being successfully used in a published decision, and it was rescinded by the Corps in July 1996 without explanation.

II.g Loss of Productivity Studies for Cumulative Impacts

The cumulative approach considers the productivity losses as the collective results of multiple change orders and other changes that occur during the project. It does not specifically identify exactly what factors contribute to productivity losses, but instead captures the loss of productivity arising from all changes occurring on a project and their synergistic effects on the change and base contract work. The various research works described in this section rely upon change-productivity data from a large number of projects. Statistical regression analyses are the applied to such data to form regression models.

The first work in this regard was Leonard (1988), in which he analyzed ninety cases drawn from fifty-seven electrical-mechanical and civil-architectural projects. He then rated the projects as Type 1, in which change orders were the only major cause of loss of productivity, Type 2 in which change orders and one other "major factor" caused the loss of productivity, and type 3 where change orders and two or more other factors were present. Applying statistical regression analysis then allowed him to develop graphs such as Figure 5.

Figure 5

Leonard Loss of Productivity Curve for Civil/Architectural Projects

The biggest limitation of this study is that the data were taken from the files of a claims consultant, meaning the projects were likely not representative of the industry. Another problem is that Leonard does not clearly define nor quantify the presence of the "major factors." Moreover, if the factors covered by Type 2 and Type 3 curves were sufficiently different from what was anticipated at the time of contract signing, they might have been converted into change orders. The fact that they were not, suggests that the factors were not "major." Lastly, Leonard uses linear models to fit the data whereas later analysis indicates that nonlinear models would give better fits (Ibbs 2012).

Still, the work is important because it pioneered a new line of loss of productivity research and convinced many industry professionals that once change exceeds a certain level (in Leonard's case, 10%) cumulative impact conditions appear. In such circumstances, it is often impractical to foresee all the loss of productivity that arises from change, and therefore retrospective analyses are justified.

Ibbs (1997, 2005) has followed by collecting data from 183 projects representative of the industry. The projects range in size from less than $1 million to more than $15 billion, and come from virtually all segments of the industry with different delivery systems. Ibbs found that projects with more change, as measured in labor-hours of change work, have more loss of productivity; and changes occurring late in a project have more impact on productivity than early changes. Figure 6 shows the impact of change's timing. Thomas (1995) has conducted a similar study on nine projects and found similar results.

Figure 6

Ibbs Change vs. Loss of Productivity Curves

Hanna (1999a, 1999b) has conducted similar research, introducing six different models: two for electrical, two for mechanical, a model for both electrical and mechanical, and a model for small projects. Generally the projects are small (under $5 million in contract value) and performed as a subcontract. Like Ibbs, he found that change late in the project is more disruptive.

One of the problems with this work is that the input variables for the models differ. As an example, years of project manager experience is important in one model but not in another. Some of the variables are subjective, such as whether the project's schedule was compressed. There is vagueness in Hanna's definitions too. For instance, number of change orders is an input variable for one of Hanna's models, but no control is imposed on the research to differentiate between a change order that might be small or deductive versus another that might be large or additive. Hanna's models may also have a statistical colinearity problem, meaning that his input variables are not mutually exclusive resulting in a double-counting effect (Harmon 2006a, 2006b).

III. Strengthening the Use of Industry Studies

The claimant and/or its expert can strengthen the reliance on the utilization of industry studies and publications. The instructions or users' manuals that accompany most industry studies should be carefully read and the study should be applied in strict accordance with those instructions. Common sense should be applied as well. To the fullest extent possible, credible and knowledgeable fact witnesses should be directly involved with the preparation of the loss of labor productivity claim.

When preparing a claimant's loss of labor productivity analysis using industry studies, it must be remembered that the results are ***estimates*** and not precise determinations of labor inefficiencies. What is important is that these industry study-derived estimates are reliable, reasonable and to the fullest extent possible, based on input from the fact witnesses.

As explained earlier, dozens of reports, studies, and publications exist showing the quantitative impacts of project change. Many of the studies are old, have incomplete explanations of the underlying research methodology or flawed research methodologies, or are limited to a particular type of construction. Nevertheless, they can provide valuable guidance if the person applying them understands their strengths and limitations and applies them judiciously. These studies cal also provide valuable and credible guidance to triers-of-fact.

Figure 7 contains a set of questions that can be used to understand any of these studies and their suitability to a disputed project. Properly used, these questions will help inquiring counsel determine if the analyst using the studies understands them and has applied them properly.

Figure 7

Questions to Ask about Loss of Productivity Studies

Data Source	▪ From what project(s) and what trades are the data? ▪ Are the data republished from previous studies? ▪ Does the study use data from other studies with manipulation? ▪ How old are the data (compatible with current construction industry)? ▪ Is there biased or unrelated data due to unique environment? ▪ Is the source known? ▪ Has this study been accepted by other courts or boards?
Data Size	▪ Are the data from a single or multiple projects? ▪ Is the sample size (data points) big enough?
Data Collection Method	▪ Were data obtained through direct observations, surveys, interviews, or past records and documents? ▪ Was the collection method reasonable and fair (no potential for a bias)?
Data Processing	▪ Were the data processing methods such as data screening, data categorization, and manipulation (summing, adding, etc.) fully disclosed? ▪ If so, was the process reasonable? ▪ If not disclosed, can the process be presumed to be reasonable? Any flaws?
Analysis Procedures	▪ If any further analyses were performed to develop some kinds of predicting models, were the procedures disclosed? ▪ Were they reasonable and logical? Any flaws?
Project Types and Scope	▪ Does the study fairly represent the ordinary, common situations of the type of projects in question? ▪ Does the project scope match? ▪ Are there unique conditions, environments, or biases in the source projects?
Type of Trades	▪ Do the types of trades studied match or include the trades in question?

	▪ Is the study too general and covers too many trades?

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3 While the terms “modified total cost” or “total cost” method are well understood in the construction industry, we will use the term “modified labor” method to supplant cost values with labor hour values. The theory is the same. A “modified total labor” identifies scope change/change order hours, T&M hours, contractor bid mistake hours and/or contractor construction error hours and adjusts for these before reaching the bottom line of labor hour gain or loss for each discrete element of work.

4 The implementation of this policy of not recording actual change order hours can result in the skewing of the contractor’s labor tracking reports, even if the contractor adjusts the planned hours for estimated change order hours that appear in the change order proposal.

5 As published in the book entitled “Change Orders • Productivity • Overtime A Primer for the Construction Industry”, copyright 2012, the Mechanical Contractors Association of America, Inc. All excerpts printed herein are with the permission of the MCAA.