Mechanical Contractors Association
MCAA
of America

Change Orders Productivity Overtime

2016 EDITION

FEATURING NEW CONTENT ON INTEGRATED, COOPERATIVE, AND COLLABORATIVE CPM SCHEDULING

A PRIMER FOR THE CONSTRUCTION INDUSTRY

Change Orders, Productivity, Overtime: A Primer for the Construction Industry

Mechanical Contractors Association of America, Inc.
1385 Piccard Drive
Rockville, MD 20850–4340

Foreword

Change Orders, Productivity, Overtime: A Primer for the Construction Industry was developed to assist construction contractors, their customers, and others involved in construction projects in determining the costs associated with unplanned events, circumstances, and factors that may impact the outcome, productivity, and schedule of those projects. This primer is intended to be a planning tool and not a source for absolute percentages or costs.

The contents of this primer were prepared and peer reviewed by construction industry professionals and expert consultants to the industry. MCAA wishes to thank members of the Management Methods Committee for their contributions of time, insight, and experience.

MCAA thanks Paul Stynchcomb of Vero Construction Consultants Corp. for his numerous contributions to this primer.

Change Orders Productivity Overtime

A PRIMER FOR THE CONSTRUCTION INDUSTRY

Table of Contents

How to Identify and Manage Change Orders

Introduction

Changes on a construction project should be anticipated and can have a significant effect on a contractor's performance, productivity, and profitability. Although changes are common, misunderstanding and disagreement can occur when it comes to identifying whether a change has occurred, pricing a change, and determining the time impact of a change. Detailed documentation of events related to changes can significantly reduce disputes and overall project risks. Changes also may result in a claim under the contract's disputes clause if the owner and contractor, or the general contractor and subcontractor, do not agree as to entitlement to and/or the dollar amount of the change. However, a significant number of claims and disputes can be avoided by following the changes provisions, or changes clauses, in the contract; preparing detailed documentation during the course of the project; and maintaining active communication among the various parties involved in a capital project.

This chapter suggests approaches to the effective management of change orders with the objective of increasing contemporaneous agreements between owners and contractors that resolve the price and time associated with a change and avoid change order disputes. These approaches also apply to changes between general contractors and subcontractors, as well as owner-caused changes that flow down to subcontractors. For brevity, most of the narrative is in the context of a project owner and general contractor, but most of the same principles apply to contracts between general contractors and subcontractors. References to "contractor" apply to general contractors and specialty trade subcontractors. General guidance is provided related to common change order circumstances, however, specific contract laws, working conditions, and practices can vary among jurisdictions and geographic locations. Contractors and owners are encouraged to seek advice from their in-house contracts manager and/or legal counsel as to their respective rights and obligations associated with the contracts they sign, including change orders which are contract modifications. Construction professionals such as other in-house personnel, construction consultants, and legal counsel with cost and time impact experience may be helpful in evaluating the cost and time impacts associated with change orders.

Types of Events Leading to a Change

A variety of events may result in changes to a contractor's actual work from what was planned and set forth in the contract documents, regardless of the project delivery methods used. Some of the issues and events that may cause changes include:

- Owner-driven scope changes that cause an increase or decrease in the amount of work from the scope of work outlined in the original contract;
- Changes in the methods of performance or the materials or equipment to be installed;
- Changes that modify the planned sequence in which the work was to be performed;
- Differing site conditions not anticipated in the original contract price;
- Constructability issues;
- Changes in performance specifications;
- Changes to correct errors, omissions, or inconsistencies in the specifications or drawings;
- Changes in the time for performance;
- Changes resulting from extraordinary, unexpected natural events; and
- Changes due to the actions or inactions of other trades working on the project.

The changes described above fall within two general categories: directed changes and constructive changes. Directed changes are usually easier to recognize and resolve. In this kind of change, the owner specifically directs the contractor to make a change. A directed change can add to or reduce the contract price and it also may involve a change in the construction sequence or schedule. Owners typically have the contractual right to initiate any change. Owner changes often impact the contractor's scope of work. However, changes in a project's size, configuration, or space requirements also can create a schedule impact and/or change the sequence of work, thus impacting the productivity of the base contract work.

In contrast, constructive changes occur from any events that are not owner directed or that have the effect of implicitly requiring the contractor to modify the scope set forth in the original contract. Constructive changes are often more difficult to identify because they are actions or inactions of an owner without the explicit acknowledgment of any change by an owner. Whether the contract in question is a private or a government contract, verbal communication among owner, general contractor, and subcontractors can sometimes be viewed as a change. Contractors are encouraged to follow up in writing if they believe a constructive change has occurred. Some of the common types of constructive changes are:

- Defective contract documents;
- Over-inspection;
- Changes in methods of performance;
- Changes in construction sequence;
- Misinterpretation of specifications;
- Incomplete owner or architect/engineer responses to contractor information requests; and
- Differing site conditions.

Defective specifications are often cited as a cause of constructive changes. The term "defective specifications" covers a multitude of latent change-causing circumstances that result from inaccurate or incomplete specifications. Examples of defective specifications are discussed in the following paragraphs:

Incomplete specifications. Incomplete specifications exist when the contract documents do not provide adequate information necessary to execute the work as planned. These types of changes often occur when the plans and specifications fail to coordinate construction details between different design disciplines, such as architectural and mechanical, resulting in conflicts that require resolution.

Facility space constraints. Conflicts occur when the project design provides insufficient space for all of the elements in an area. For mechanical work, there can be conflicts in shaft and in-wall installation, with above-ceiling mechanical, and with structural, electrical, and plumbing elements that require resolution. Some of these conflicts can be resolved during the coordination process; others may be so significant as to require a re-routing of work or an adjustment in the size of the space in order to properly install the work.

Design discrepancies. Design discrepancies occur due to differences between the plans and specifications, differences between details, dimensional errors, or differences between planned equipment details and actual equipment cut sheets. A design discrepancy may also be found when the same item is specified in different sections of the contract documents with different requirements in each section. Additionally, a design discrepancy can occur when details are omitted from the contract documents or when there are inconsistencies among the construction drawings associated with different trades.

Latent conditions. This term refers to existing differing site or subsurface conditions, unknown at the time of bidding, that affect the contractor's performance. Change orders for latent conditions usually result from either subsurface soil conditions or conditions within the existing site or facility that are materially different from what was shown on the contract documents or materially differ from conditions that are clearly evident and observable.

Nondisclosure. Nondisclosure can be either intentional or unintentional. In either case, a change occurs when the contractor is not given all of the critical design or construction information necessary to facilitate proper project performance.

Changes required by regulatory agencies/using agency. The owner's design team normally has the responsibility to ensure that the project design meets all applicable building code and regulatory requirements. Added work or changes required to meet code or regulatory requirements should result in a change order.

Value engineering. In what is sometimes referred to as value engineering, a contractor may point out changes when superior methods or materials become apparent, or when the same design result can be achieved at a lower cost. Contracts frequently allow for shared savings associated with such improvement, however the cost of reengineering can offset any savings while potentially delaying progress. When improved methods or materials are necessary to overcome an owner-caused problem, such as to mitigate a delay impact, the contractor should be compensated for such changes.

Tools to mitigate or avoid changes. Use of tools that can be utilized to mitigate or avoid costly change conditions in the field is becoming more widespread. For example, tools such as 4D Building Information Modeling (BIM) and Integrated Project Delivery (IPD) processes help coordinate the development of design drawings, and can reduce the number of instances of conflicts in drawings and incomplete specifications. With 4D BIM, the Critical Path Method (CPM) schedule is integrated into a 3D model of the drawings so that the project can be visualized from both a constructability sense and a project execution perspective before the project is started. Updates are provided throughout construction to reflect as-built conditions as a reference point for planning and analyzing the work still to be completed. The time and costs associated with implementing tools such as BIM on a specific project can be tracked and treated as a direct cost of the work in both the initial contract and any changes.

What To Do When a Change is Identified

When a change is identified, one of the first things a contractor should do is provide notice to the owner. Notice provisions are common contract provisions and the parties should follow the applicable contract guidelines for providing change notices. For mechanical contractors and other subcontractors, not only is notification to the general contractor important, but knowledge of any flowdown provisions from the owner to the general contractor and, in turn, to the subcontractors are important. Subcontractors should be aware of any notice requirements that may be part of such flowdown provisions that are incorporated by reference in the subcontract. For example, the notice provision in the changes clause of the ConsensusDocs 200 form contract between owner and contractor states that except for certain delay circumstances covered in a different contract provision, the contractor shall give the owner written notice within fourteen (14) days after the occurrence giving rise to the claim or within fourteen (14) days after the contractor first recognizes the condition giving rise to the claim, whichever is later. This provision continues that the contractor shall submit notice before proceeding with the work, except in the case of an emergency, and shall have twenty-one (21) days after giving notice to submit claim documentation, and then the owner must provide a written acceptance or denial within fourteen (14) days after receipt of the contractor's documentation.

When a change is identified, detailed documentation of the change should be prepared. Typical documentation includes a description of the reason for the change or description of events causing the need for a change order. Documentation should also include a narrative description of the schedule impacts after completing a time impact analysis of the work scope that has changed.

Since constructive changes do not emanate from a directed owner change, it is particularly important for contractors to identify that a change has occurred, document the details of the changed condition(s), and notify the owner of the changed condition in a timely manner. Some contract forms do not include provisions for constructive changes, so a contractor needs to be clear with the owner about proceeding with any work related to a constructive change and documenting such work in a written change order. If a contractor is directed to proceed with the work before a change order is agreed to and signed, the contractor needs to carefully document the costs and time associated with the change and take the following steps to facilitate the resolution of the change with the owner:

- Research the contract documents thoroughly to confirm that a changed condition exists.

- Prepare and submit a change order request proposal, giving the owner a clear and detailed description of the change.
- Be alert to any notice requirements and respond properly.
- Issue notice of intent to file a claim if the change order is denied.
- Inform the owner of any applicable schedule impacts.
- If the change is not resolved, follow the dispute resolution procedures in the contract.

While the owner-directed change is easiest to identify, the contractor must consider schedule and productivity impacts in the analysis and pricing of the change. Time and productivity impacts often are not the subject of initial negotiations regarding the scope, but these topics should be incorporated into the negotiation process. Failure to consider these impacts at the time of the change can result in a waiver of a contractor's ability to recover additional time and money. Contractors should consider their need to reserve rights associated with impacts if they are not quantified and included in a change order price at the time of each change order negotiation.

Schedule time impact analysis arising from change orders. Each change order should be carefully evaluated to determine whether an extension of time is warranted. The chapter entitled "Time Impact Analysis—Measuring Project Delay" contains a detailed description of the manner in which a time extension analysis should be performed using the contemporaneous project schedules and procedures set forth therein. This chapter should be consulted whenever the contractor identifies an impact that could affect any aspect of the schedule. As noted in the chapter, the contractor should pay particular attention to the contract requirements for submitting requests for extensions of time, as well as the scheduling requirements for the project. Failure to adhere to these requirements could affect the contractor's ability to obtain a time extension.

Separate cost coding. The contractor should determine whether it is practical to document the costs of a change using separate project job cost coding. In some instances, it may not be possible to separately track impacted costs or costs associated with an individual changed condition contemporaneously as the impacted work progresses. This could occur if the impacted work is an integral part of the base contract work, such that the base contract work is more difficult to perform and/or takes longer. In other situations it may be feasible to separately track the costs associated with a change via separate cost coding from the base contract cost coding in the contractor's job cost reporting system. When it is impractical to separately track costs associated with the change due to effects on the base contract scope and/or cumulative impacts associated with multiple changes, it is helpful to document the impacts and costs through additional contemporaneous notes in the daily project logs, timesheets, or other daily reports so that the portions of the work that are impacted can be more clearly identified in the absence of separate cost coding. However, when possible, it is recommended that contractors use separate job cost coding to track changed work.

Impacts Arising From Change Orders—Losses Of Productivity

In addition to the direct costs associated with a change, the contractor should be aware of various factors that can have an adverse effect on labor productivity, both in the performance of the changed work and as an impact on the base contract scope of work, depending on the scope of the change and depending on the activities being performed. In order to recover such costs, a contractor must establish the cause and effect between the event and a quantified loss of productivity. Some causes include the following:

1. Worker overtime. Unscheduled overtime may lower both work output and efficiency, depending on the amount of overtime being incurred and the duration of the overtime. Evaluating the extent to which a loss of productivity has occurred resulting from sustained overtime, along with the premium costs, is a factor that contractors should consider when pricing change orders.

2. Manpower availability to perform the changed work. High volume of construction activity in a concentrated geographic area may create a shortage of skilled workers which, in turn, can affect labor costs depending on the type of skilled work that is required and the level of worker training. The additional costs of such labor, such as hourly or daily premiums to attract skilled workers from other locations, including the cost of travel and lodging, should be considered in change order pricing.

3. Other considerations that may affect productivity. Other conditions and circumstances should be considered when evaluating the cost of performing changed work. These circumstances could include things such as:

- Excessive heat, cold, precipitation, or other forms of severe weather (especially unexpected intermittent changes)
- Performing work in a different season, i.e., summer work shifted to winter work
- Contaminated air
- Constructability problems with plans and specifications
- Unusual and unplanned changes in the sequencing of the work
- Unplanned protection of existing facilities, completed portions of construction, furniture, fixtures, machinery, stock, or finished surfaces
- Unplanned daily clean-up of tools and work area
- Unexpected interference by owners, employees, or other trades
- Accessibility to material stores, changes in laydown areas or tool lockers
- Unexpected poor lighting
- Work in tight spaces with unsure footing, interfering tie wires, piping, ducts, hangers, etc. not originally planned
- Frequent repair work from trade damage
- Acceleration

Consideration of the above factors should enable the contractor to more discretely price and explain any added costs of performing changed work when preparing change order requests.

Pricing Change Orders

It is important to identify whether the pricing of a change is to be developed on a forward-pricing lump-sum estimate or if the pricing should be partially or completely based on actual costs plus applicable mark-ups. In the situation of forward pricing change orders, estimating the amount of the change order typically is conducted in the same way that a contractor prepares other lump sum estimates. However, the manhours required to complete a change order may be similar to or different from the productivity and manhours incurred under normal unimpacted conditions. Adjustments must be considered for abnormal or less-than-optimal conditions at the jobsite. Some additional factors to be considered are whether the schedule has been or will be delayed, or if schedule acceleration efforts are underway, for example. These factors may call for consideration of labor productivity impacts when pricing a change.

A common step when evaluating the impact of changed work and evaluating the planned versus actual financial performance of a contract, is to analyze cost underruns and overruns by comparing the actual costs to the project budget. Budget variances can be analyzed by comparing the actual costs to-date to the current contract budget adjusted for the percent complete on the project, or by comparing the forecasted costs at completion to the total contract budget. The contractor's fee should be subtracted from the overall contract budget when analyzing underruns and overruns on a cost-to-cost basis. Analysis of budget variances can be used effectively to evaluate the impact of changed work. For example, analyzing the amount of planned versus actual labor overtime on a project and then isolating when the overtime was incurred and what caused the overtime to be incurred can provide very useful information when evaluating the impact of changed conditions. The usefulness of budget variance analyses are dependent on the quality and level of detail in the original estimate. Contractors are advised to maintain good documentation of how budgets are derived and to prepare budgets in sufficient detail, along with the corresponding job cost coding work breakdown structure, so that variances can be used to effectively quantify project impacts.

In government contracting, costs must also be "reasonable," "allocable," and "allowable." Although an exhaustive analysis of change order pricing on government contracts is beyond the scope of this publication, briefly, as stated in *Federal Acquisition Regulation (FAR)* 31.201-3, "A cost is reasonable if, in its nature and amount, it does not exceed that which would be incurred by a prudent person in the conduct of a competitive business." Factors to consider when evaluating the reasonableness of costs include: whether the costs are ordinary and customary, whether the costs are based on an arm's-length transaction rather than a related-party transaction, and whether the costs reflect what a prudent person would be expected to incur. *FAR* 31.201-4 states, "A cost is allocable if it is assignable or chargeable to one or more cost objectives on the basis of relative benefits received or other equitable relationship." This *FAR* provision further states that a cost is allocable if it, "(A) Is incurred specifically for the contract; (b) Benefits both the contract and other work, and can be distributed to them in reasonable proportion to the benefits received; or (C) Is necessary to the overall operation of the business, although a direct relationship to any particular cost objective cannot be shown." *FAR* 31.201-2 states in part, "The factors to be considered in determining whether a cost is allowable include the following: (1) Reasonableness. (2) Allocability. (3) Standards promulgated by the CAS Board, if applicable; otherwise generally accepted accounting principles and practices appropriate to the particular circumstances. (4) Terms of the contract. (5) Any limitations set forth in this subpart." Contractors must be very careful when preparing a change order involving a government contract to avoid myriad pitfalls. Pricing data, per the *FAR*, must be "current, accurate and complete" as of the date of the agreement on price.

Contractors and owners are encouraged to reach advance agreements on items of cost and mark-ups that will be allowable in change orders and specify these agreements in detail in the contract documents. For example, labor rates to be used for change order pricing can be established at the time of negotiating and signing the contract rather than treating labor as a cost reimbursable item which can be the subject of costly auditing and disagreement. For a summary guide to the allowable versus unallowable costs described in *FAR* 31.205, please refer to Exhibit 18 at the end of this chapter.

Direct Costs Arising From Change Orders. Direct costs are any costs that support one cost objective, meaning that they are directly related to a specific, identifiable task. Materials, equipment, and subcontract costs are usually identifiable to specific tasks and are generally treated as direct costs. However, some costs may appear to be indirect because they are allocable to multiple activities, but are still direct costs related to the performance of the base work or changed work. For example, fuel, oil, and grease are necessary to support the use of equipment to perform direct construction activities, but seldom would these types of costs be separately tracked and coded to individual work tasks or job cost codes. It is common for fuel, oil, and grease to be accumulated in one code, even though they support multiple work activities on a project, or even across multiple projects or contracts. Small tools, consumables, QA/QC activities, localized labor supervision, detailing, BIM, and scheduling activities are all examples of direct costs when contractors track them to a particular project. These types of costs are frequently tracked in general conditions, but sometimes are tracked in one consolidated direct job cost code and sometimes are allocated to jobs as a percentage of labor or some other allocation basis. These examples demonstrate that some direct costs like trade labor are almost universally accepted and defined as a direct cost, but some costs can be coded as either a direct or indirect cost and need to be analyzed to determine their proper categorization. Although general conditions costs are sometimes also referred to as "field overhead," which may imply an indirect nature to this cost grouping, in reality, these costs are direct costs of the work. General conditions costs support various aspects of the project and therefore are often allocated at the project level in a change order situation, or treated as a daily cost in a delay or suspension situation, but the costs are still directly related to a given contract. Such definition and categorization can also be important when it comes to drafting contracts so that the pricing terms are clearly defined for the benefit of the parties and to avoid costly disputes after the contract is signed. For example, there can be challenges with determining the actual cost of using owned equipment so frequently owners and contractors will agree on stipulated rates for the use of equipment in the contract.

Common Categories of Change Order Pricing Elements

The common categories of construction and change order pricing elements are:

- Direct and indirect job costs,
- General and administrative overhead, and
- Profit.

Direct and Indirect Job Costs

The elements of direct and indirect job costs vary depending on the type of building construction and can also vary depending on the size of the contractor. Care must be taken to treat projects consistently within a contractor's organization so that certain cost areas (e.g., superintendents, yard costs, machine shops, etc.) are treated as either direct or indirect and not subject to double charging. This is especially true for contracts being performed in the federal government contracting arena. Direct costs are the costs of labor, materials, supplies, equipment, and subcontracted work that go into, and which can be clearly identified with, a particular segment, phase, or unit of a project. Indirect costs are those costs that cannot be attributed to a single item or unit of a project. Indirect costs are generally divided into two categories—jobsite overhead and general and administrative overhead. General conditions is another term commonly used to describe jobsite overhead. Examples of direct and indirect costs include:

1. Labor, including:
   a. Wages
   b. Overtime premium pay
   c. Union health and welfare benefits
   d. Apprenticeship training
   e. Journeyman training fund
   f. Retirement fund
   g. Vacation
   h. Jury duty, sick pay, or other leave allowances
   i. *Per diem* allowances
   j. Travel expenses
   k. Worker's compensation
   l. Payroll taxes
   m. Other agreed-upon payments similar to those above
2. On-site Supervision
3. Small Tools and Consumables
4. Permanent Materials
5. Project Equipment and Systems incorporated in to the project (elevators, HVAC systems, etc.)
4. Construction Equipment
5. Subcontractor Costs
6. Other Project Costs, such as:
   a. Job insurance
   b. Equipment rental
   c. Job supplies and facilities (ice water, ice, portable toilets, etc.)
   d. Cell phones and radios
   e. On-site office equipment (telephones, computers, copies, fax machines, etc.)
   f. Sales taxes
   g. Construction and performance bonds
   h. Permits
   i. Temporary services and facilities
   j. Miscellaneous costs (instruction manuals, tags, move on/move off expenses, certification, etc.)
   k. Safety
   l. Costs of developing a change order
   m. Drug testing
   n. Material handling and re-stocking costs

o. Clean-up, dumpsters, and garbage hauling

p. Surveying and layout

q. QA/QC

r. Crane and hoisting equipment

s. Scheduling

t. Document control clerk

u. Expeditors

v. Site security

w. Temporary jobsite electricity/lighting

x. Shop drawings, blueprints, reprographics, and photography

y. Mobilization and demobilization

z. Temporary heating and temporary weather protection

General and Administrative Overhead

General and administrative (G&A) costs, sometimes called home office overhead, are not charged directly to a job cost report; they are corporate indirect costs that typically support more than one contract at a time. G&A costs commonly contain essential functions that are necessary for a company to conduct operations, fulfill specific contract obligations, and even perform change order work. Sometimes the allowable percentage for G&A is stipulated in the contract documents. It is often a useful practice to negotiate a G&A overhead rate for change orders at the beginning of a project and incorporate the rate in the contract. In the context of federal government contracts, *FAR* Part 31 provides guidance on the types of G&A costs that are allowable in a change order.

Profit

Profit should be applied as a separate percentage figure. It should be applied after all costs are included, with the appropriate addition for G&A overhead. Sometimes the percentage for profit is stipulated in the contract documents. Like G&A, disputes can be avoided by stipulating a profit rate for change orders in the contract. In other instances, a “fee” percentage is specified which is intended to cover both home office overhead and profit.

Other Considerations in the Pricing of Change Orders

Additions and/or deductions:

1. Where additions only are involved, the contractor is entitled to an addition to the contract sum in the amount of direct and indirect job costs, plus home office overhead and profit. If requested, the contractor may be obligated to provide a detailed breakdown to verify the quotation or, depending on the contract provisions, the contractor may be subject to an audit.

2. Where deductions only are involved, the contractor should calculate the reduction to the contract sum only in the amount of the reduction in direct and indirect job costs unless other, more specific guidelines are provided in the contract.

3. When both additions and deductions are involved, each should be calculated as separate change orders in accordance with 1 and 2 above. If both omitted work and added work is involved in the same change order, the total amount of the change order will be equal to the difference between the additions and the deductions in accordance with 1 and 2 above, unless more specific guidance is pro-

vided in the contract. Sometimes the contract stipulates that overhead and profit, especially when it is a fixed-fee project, will not be reduced for deductive changes; this should be considered when pricing a combination of additive and deductive changes.

Unaccepted change orders: If the schedule and associated pricing of an owner-initiated change order is not accepted and authorized, the contractor may wish to seek reimbursement for all costs incurred in the preparation of the quote. The contractor should have a prior understanding in the contract with the owner regarding the reimbursement and allowability of such costs.

Comparison of contract forms and change order provisions: Multiple references are made in this chapter to change order provisions in the contracts governing the work. Much of the specific change order pricing approach and contractor submittal process is determined by the change order provisions in a subject contract. There are several commonly-used form contracts that frequently serve as the basis or starting point for negotiating contracts between owners and contractors. An overview of the similarities and differences among the change order provisions in these commonly used contracts is provided in this chapter.

The contract forms that are compared in this chapter are the ConsensusDocs, which is endorsed by MCAA and other trade contractors among others; the American Institute of Architects (AIA) 2007 form contracts; the Engineers Joint Contract Documents Committee (EJCDC) forms; and the Construction Management Association of America (CMAA) forms.

All of these form contracts are similar in that they provide for a change to be initiated by the owner in the form of a directed change or identified by the contractor by notifying the owner. However, each of these form contracts have nuances as to the prescribed approach for determining the price and time associated with the change. The following paragraphs address the pricing methodologies among these contracts, but do not address all of the procedural differences. The parties to the contract are strongly encouraged to read and understand all contract and change order language before signing these documents and to seek professional legal assistance when necessary. For example, the ConsensusDocs, AIA, EJCDC, and CMAA forms all include notice provisions, however the number of specific days varies from contract to contract, as do the specified days for submittal of changes and owner response times.

The following table provides a summary comparison of the pricing provisions in these four different form contracts, with further discussion about the pricing provisions in the paragraphs that follow.

Change Order Pricing Alternatives

	Unit Prices	Mutual Acceptance of a Lump Sum	Cost of the Work Plus a Fee
ConsensusDocs 200 (Article 8)	X	X	X
AIA (A201 2007)	X	X	X
EJCDC (Articles 10 - 12)	X	X	X
CMAA (General Conditions Article 11)	X	X	X

ConsensusDocs[1] – Article 8. The ConsensusDocs call for expeditious negotiation of time and price when the owner issues an interim directed change. This form contract does not provide detailed guidance on the determination of cost, overhead, or profit when pricing is based on cost of the work plus a fee, but rather leaves the determination of these pricing elements to the negotiating parties. In the event the parties cannot reach agreement, this contract generally provides for pricing to be determined based on "reasonable and actual expenses and savings." If unit pricing is used, and the quantity or unit items are so different from the original unit prices to cause substantial inequity to owner or contractor, the unit prices are to be equitably adjusted. Also, in the event of a directed change, when pricing cannot be agreed upon, the contract provides that 50 percent of the estimated cost of the work shall be paid on an interim basis.

AIA[2] – Article 7. This form contract does not provide detailed guidance on the determination of cost, overhead, or profit when pricing is based on cost of the work plus a fee, but rather leaves the determination of these pricing elements to the negotiating parties, except when agreement cannot be reached, in which case Article 7.3.7 provides guidance on the elements of cost and guidelines for the determination of overhead and profit. If unit pricing is used, and the quantity or unit items are so different from the original unit prices to cause substantial inequity to owner or contractor, the unit prices are to be equitably adjusted.

EJCDC[3] – Articles 10–12. This form of contract provides detailed guidance on the determination of cost, overhead, and profit and provides guidance on unit price determinations in the event owner and contractor are unable to reach agreement as to the change order price. Parties using this form of contract are encouraged to consult the specified provisions in Articles 10–12.

CMAA[4] – Article 11. When the cost-plus-fee method of change order pricing is used, the CMAA change order pricing provisions provide distinct definitions for "cost of the work" with additional guidance for the quantification of labor, materials, subcontractors, and several other types of costs. The CMAA change order provisions also provide guidance on the quantification of the contractor's fee, which consists of overhead and profit. The change provisions state that the contractor shall be entitled to a mutually acceptable fixed-fee amount. If that amount cannot be agreed upon, then the fee shall be 15 percent of payroll and materials plus 5 percent on subcontractor change work, subject to other detailed exceptions and procedures specified in the contract.

Change Order Procedures and Forms

Authorization procedures. It is incumbent on the contractor to ascertain in writing, either from a review of the contract documents or through a written request to the owner, the specific individuals who have the authority to accept and implement change orders. Often a contract will identify the authorized representatives for both the contractor and owner. When

---

[1] From ConsensusDocs 200 – Standard Agreement and General Conditions Between Owner & Contractor © 2007.

[2] From AIA A201 – 2007 General Conditions of the Contract for Construction © 2007.

[3] From EJCDC C-700 Standard General Conditions of the Construction Contract © 2007.

[4] From CMAA Form CMAR-3 General Conditions of the Construction Contract Between Construction Manager and Contractor © 2005.

negotiating the cost, time, and any specific terms and conditions associated with a change order, it is recommended that the authorized representatives for both the contractor and owner thoroughly review the documentation associated with the change before signing the change order. Otherwise, the owner may contend that the individual who authorized the alleged changed work did not have authority to issue a change. If the contractor believes that the actions of a party within the owner's control, such as the architect/engineer, took action that constitutes a constructive change to its work, the contractor should give timely written notice to the owner that it considers such action a constructive change directive, and will perform the work as a change order and provide a cost accounting of the change when the work is complete. An example of such a written notice of change is:

> Contractor has received the Engineer's Response to Request for Information (RFI) 213, which has rerouted the piping from that shown on Drawing M.402. We have assigned Proposed Change Order 5000 to this item. We will be charging costs for labor, material, services, and equipment to this change order cost code and will provide you with a complete accounting in a formal change order request when the work is complete.

Time for acceptance: Except as specified in a contract, the time limitation for acceptance of a change order should be stipulated by the contractor in a change request. If not accepted within the stipulated time, it should be stated that the quoted price may be subject to escalation.

"Full accord and satisfaction" language. Contractors should be alert to any change order they are requested to execute that includes "full accord and satisfaction" language. Such language is designed to make the written change order a full and final agreement on the applicable cost and time associated with the subject change. A bilateral signing of a change order with this language could bar the recovery of any additional costs associated with the change order, such as loss of productivity, delay-related costs, and/or cumulative impacts. The actual wording will vary, but is likely to be similar in substance to the following:

> The execution of this Change Order represents the Contractor's total and final costs for all impacts, both direct and indirect, arising from this Change Order. A time extension (if any) granted with this Change Order represents the total impact of all delays, both direct and indirect, to the project schedule.

Courts and boards have found that such language may bar the contractor from additional recovery. If there is concern that productivity impacts, cumulative impacts of multiple changes, and delay-related costs cannot be quantified for individual changes, the contractor should consider reserving its rights to make a claim for such impacts separate from individual change orders. An example of such reservation language follows:

> The execution of this Change Order represents the Contractor's estimate of direct costs only. The Contractor expressly reserves the right to submit, at a later date, added costs, applicable mark-ups and time extensions attendant to this change order arising from, but not limited to: extended field and home office overhead, labor inefficiency, disruptions, impacts to the critical path, schedule re-sequencing and/or acceleration.

Again, legal counsel should be consulted before signing a change order that contains either accord and satisfaction language or reservation of rights language.

Dispute resolution. In the event that a change order cannot be mutually agreed upon with a bilateral signing, some changed work may still proceed with a directed change or a unilaterally issued change order. In the event that the parties have exhausted all possible remedies under the changes provisions of a contract, they may need to turn to the dispute resolution provisions of the contract. Occasionally, change orders ultimately become resolved through the dispute resolution provisions of the contract. It is beyond the scope of this chapter to discuss the details of resolving claims outside of the change order clauses in contracts.

Change Order Forms

Having outlined a variety of considerations when faced with changed work, the following forms are recommended for use in estimating and for tracking the costs of such changes. There are three typical types of change order pricing:

- Lump sum,
- Time-and-material, and
- Unit price.

In a lump-sum change, the contractor's original estimate for the change must include all items needed to do the work. Lump-sum pricing is frequently used when pricing changes before the changed work has commenced, meaning that the change is "forward priced." Contractors bear the risk of overruns and receive the benefit of underruns.

In time-and-materials changes, such risks are eliminated and both the contractor and the owner get a clear picture of the profit that will be earned by the contractor. Time-and-materials changes require accurate tracking of all expenditures to allow verification of reimbursable costs. These costs may be invoiced periodically as the work commences, or, on shorter-duration changes, invoiced on completion of the work.

Unit-price contracts specify the unit prices associated with various types of work. In some instances, the parties may agree that, on changes above a specified percentage of the base work (for example, 25 percent), the contractor has the ability to charge on a time-and-materials basis. In these instances, the contractor may be allowed to charge actual costs rather than being limited to charging the unit prices that were established in the contract. Unit prices, in most instances, include direct costs, indirect costs, G&A, and profit.

The forms and procedures (Exhibits 1 through 18) are tools for documenting and tracking costs, determining time impacts, and pricing change orders.

Part 1 deals with lump-sum changes and Part 2 is for cost-plus changes. Included in Part 2 is a Field-Authorized Change Order Form. Designed primarily for field use, it provides a means not only for tracking costs but also for obtaining written authorization for additional work, when necessary. Before adopting the procedures presented here, evaluate them carefully and revise them as necessary to meet the requirements of local conditions and your company's operating procedures.

Part 1: Lump-sum (fixed amount) changes. Lump-sum changes are advantageous to the contractor for two reasons: (1.) they allow the contractor to estimate all costs and markups before work begins. If the contractor includes all items necessary for the work as well as applicable and contractually allowed mark-ups, the probability of making a reasonable profit is enhanced. (2.) they require far less tracking and paperwork in the field than time-and-material changes. Despite these advantages, lump-sum changes must be handled properly to ensure that all cost and time impacts are properly estimated and included. The following procedures and forms will help make that handling accurate and efficient.

Recommended Procedures

1. The key document in controlling change order activity is the Change Order Status Sheet (Exhibit 1). The project manager should record any potential change on the Change Order Status Sheet as soon as the possibility of a change is identified. Formal changes should be numbered sequentially and recorded on the Change Order Status Sheet.

2. Prepare a Change Order Proposal (Exhibit 2) and use it as a cover letter when submitting your change order cost estimate to the project owner or general contractor. Be sure the proposal letter states that you reserve the right to modify your estimate if additional work not covered by the proposal is required. Also state a time limit for the owner's or general contractor's acceptance of the proposal if there are no time limits already specified in the contract.

3. Exhibit 3 is a Change Proposal Cost Summary Sheet. The sheet is used to summarize all estimated costs from the detailed cost estimate sheets in Exhibits 4 through 13. Keep a copy of all change order pricing sheets and related documentation readily available for review with the approving authority should questions arise.

4. Itemize estimated equipment and materials costs on an Equipment Cost Estimate Sheet (Exhibit 4) and a Materials Cost Estimate Sheet (Exhibit 5). Because changes usually involve relatively small amounts of materials, and therefore do not qualify for large volume discounts, it is suggested that all materials be estimated using standard over-the-counter discount prices. Restocking charges should be considered where credits might be involved. Be sure to estimate required quantities of all items and to calculate the materials cost subtotal using the figures in the total cost columns. Also consider lead times required for ordering materials and equipment and the potential need for expediting materials and equipment, which may involve additional costs. Add to subtotals all additional costs, such as sales taxes, drayage charges, warranties, start-ups, etc.

5. Estimate all miscellaneous direct job costs on an Other Direct Job Costs Estimate Sheet (Exhibit 6). Once computed, the labor cost estimates on this form should be transferred to the Labor Summary Sheet (Exhibit 9) and the materials costs to the Change Proposal Cost Summary Sheet (Exhibit 3).

6. Complete an Equipment and Tool Rental Estimate Sheet (Exhibit 7).

7. Complete a Vehicle Operating Cost Estimate Sheet (Exhibit 8), including all gasoline and oil costs anticipated for each vehicle.

8. Itemize all labor costs on the Labor Summary Sheet (Exhibit 9). Rates, fringe benefits, payroll taxes, insurance, travel allowances, etc. for the various labor categories should be shown in the matrix at the top of Sheet #1 of the Labor Summary Sheets. Use items 13–22 (Exhibit 9) and 23–40 (Exhibit 10) to indicate any applicable increases or decreases to the labor estimate due to factors affecting productivity. Once you have itemized the various

labor factors, calculate and total the estimated labor costs using items 41–52 on Exhibit 10.

9. List all subcontractors and subcontract quotes and total the estimated cost of subcontracts on a Subcontracts Summary Form (Exhibit 11).

10. On an Extended Overhead Cost Sheet (Exhibit 12), compute all overhead costs not included on the other estimate forms.

11. Use the Special Inclusions and Exclusions Form (Exhibit 13) to list any additional items that should be part of the change order, as well as specific items that should be excluded from the change order pricing. Be sure that items listed on this form are referenced in either the Change Order Proposal Form (Exhibit 2) or a special cover letter to the proper project authority.

12. The key to effective change order management is documentation. While contractors have been reacting to the present litigious atmosphere in construction with more attention to documentation, it is still not a tool that most contractors use effectively. Good documentation of the events leading to and supporting a contractor's contention that a change has occurred can mean the difference between settling a change order and filing a claim. As a guide to proper documentation, a contractor should, at a minimum, include the following information on every change:

1. Date of discovery
2. Person and/or company making discovery
3. Detailed description of changed conditions
4. Documents supporting assertion that a change exists
5. Notification to owner (date and person)
6. Pertinent records and documents, such as:
   - Affected plans or sketches
   - Daily reports
   - Meeting minutes
   - Letters, notes, memos, and telephone logs
   - Payroll records
   - Equipment reports
   - Material invoices
   - Photographs
   - Subcontractor/supplier cost and schedule impacts
   - Impacted schedules
7. Notification to subcontractors/suppliers
8. Notification to bonding company (if required)

By using the above procedures and the exhibit forms, a contractor's estimate for a lump-sum change order should cover all the necessary items and maximize the contractor's ability to recover a reasonable profit while at the same time avoiding a loss in the performance of the additional work. In addition, the completed estimate forms provide a thorough and complete set of documentation to present to the contractor and/or owner during change order review and negotiations.

Part 2: Time and Material Change Orders. A time-and-material change order requires that the contractor carefully track all expenditures on a change while doing the work. This requires the field personnel to keep accurate records. The following steps can help to enhance accurate recordkeeping:

1. Use a Field-Authorized Change Order Form (Exhibit 14) and Work Authorization Form (Exhibit 15) for all time-and-material changes to ensure that change work is properly authorized and costs are tracked.

2. Incorporate the Sample Instructions for Field-Authorized Changes (Exhibit 16) into your company's operations, modifying them as necessary.

3. Educate on-site supervisory personnel about time-and-material change orders and the proper use of the Field-Authorized Change Order Form. In particular, emphasis must be placed on the importance of controlling and recording all expenditures, and accountability for performing this task properly. There is no reason to lose money on time-and-material changes if your company has established policies for managing such changes and procedures to ensure that your personnel follow those procedures.

4. Exhibit 17 provides a checklist of FAR allowability of costs to be used when pricing time-and-material change orders.

5. Exhibit 18 provides a template for the pricing of unit-price change orders.

Prepared by Paul Ficca, CPA, CMA, CFE, CFF of FTI Consulting, with contributions from Louie Wu, CPA, CFF, also of FTI Consulting. Peer review performed by: Robert Beck, President of John W. Danforth Company; Michael R. Cables, Executive Vice President of Kinetics Systems Inc.; James Durant, President and CEO of Trautman & Shreve; Richard Freeman, Vice President of Stromberg Metal Works; William Goodrum, CFO of John J. Kirlin, LLC; Matthew Hahr, Senior Vice President of Kirlin Mid-Atlantic, LLC; Michael Loulakis, Esq., President/CEO of Capital Project Strategies; Michael Mack, Executive Vice President of John J. Kirlin, Inc.; and Adam Snavely, President and CEO of The Poole & Kent Corporation.

EXHIBIT 1
CHANGE ORDER STATUS SHEET

JOB NAME: | **JOB NO:** 101 | **CONTRACT DATE:** Contract Date

Location:	Owner:	Address:		Our Job Phone:
Gen'l Cont:	Address:	Phone:	G.C. Proj. Mgr.:	G.C. Supt:
Cont.No. & Start Date:	Compl. Date:	Penalty:	Priority:	G.C. Job Phone:
Architect:			Engineer:	
Scope:				
Clarifications:				
			Base Contract Price:	

Change Order - Description	**Requested**		**Quoted**	**Authorized**		**Change Order**		**Change Order**	**Contract**
	By	**Date**	**Date**	**By**	**Date**	**No.**	**Date**	**Amount**	**Revised**
(1) Piping changes per schedule A-1	Smith	8/31		Smith	9/10	6	9/11	$5000.00	$140,000.00

EXHIBIT 2
SAMPLE CHANGE ORDER PROPOSAL FORM

TO: GC/Owner's Name

RE: Job No. 101 ______________________________

Job Name ______________________________

Proposed Change No. ____________________

Gentlemen:

We enclose a breakdown of costs for the changes requested by ______________________________

on ______________________ , designated as Owner or A/E ______________ , Change No. ____________________

We were furnished the following drawings and specifications:
Number and Date

We propose to:

We do not include any of the following:
List exclusions specifically. Don't include work of other crafts.

The total net change to our contract is as follows:

Total adds per breakdown: ____.

Total deducts per breakdown: ____.

Net Change: ____.

This change proposal covers only the direct costs associated with the change order work described above. We reserve the right to assess the impact of this change order at a later date and to submit these costs as they become known.

It is anticipated that all work required by this change will be done on a straight time basis. Overtime work, if required, will be billed as an additional item.

Sales tax is/is not included in this proposal.

This proposal is for acceptance within ________days and is subject to escalation thereafter.

An extension of time of ________ calendar days is required.

We are proceeding with the changes listed above per your instructions.

-OR-

Please advise as soon as possible if we are to proceed.

Yours very truly,

Project Manager's Name

EXHIBIT 3
CHANGE PROPOSAL COST SUMMARY SHEET

Company No. _____________
G.C. No. _____________
Owner No. _____________

Contract ________________________________ No. ______________________________PM __________________________________
Date Requested ________________________ Date Submitted __________________PM __________________________________
Description of Change ____
____

DESCRIPTION OF COSTS		LABOR	MATERIALS	TOTALS
1.	Equipment			
2.	Material			
3.	Subtotal: Item 1 + 2			
4.	Freight, other delivery charges			
5.	Subtotal: Item 3 + 4			
6.	Material Return and Cancellation Costs			
7.	Other Direct Costs			
8.	Equipment Rental			
9.	Gas & Oil			
10.	Subtotal			
11.	Labor Costs			
12.	TOTAL COSTS BEFORE SUBCONTRACTS			
13.	Subcontracts			
14.	Home Office Overhead @ ________%			
15.	Field Office Overhead @ ________%			
16.	Profit @ _________ % on			
17.	Profit @ _________ % on			
18.	TOTAL COSTS AND PROFITS BEFORE BONDS, INSURANCE & OTHER COSTS			
19.	Bonds, Subcontractors			
20.	Bonds, Performance and Payment			
21.	Financing Costs			
22.	Special Insurance and Other Charges			
23.	Extended Overhead			
24.	TOTAL PRICE OF CHANGE PROPOSAL			
25.	Extension of time because of this Change Order is ______ Workdays ❑ deferred* to be applied in proper Schedule Sequence to each Category of Work			
26.	This proposal is based on ❑ Straight Time ❑ Overtime ❑ Shift Work			
27.	This proposal is void unless a written Change Order or Written Notification to Proceed is received by ___________ (45 calendar days if no date shown)			
28.	Extended Overhead Cost: ❑ Included ❑ Deferred* ❑ Not Applicable			

Submitted By: ________________________________ Date: ___________________________
Signature Title

Approved By: ________________________________ Date: ___________________________
Signature Title

*If deferred, cover letter should describe.

EXHIBIT 4
EQUIPMENT COST ESTIMATE SHEET

Date: ____________

QUANTITY	EQUIPMENT	UNIT COST	TOTAL COST
	SUBTOTAL EQUIPMENT		
	Sales Tax 0.00 %		
	Drayage 0.00 %		
	Escalation 0.00 %		
	Warranty 0.00 %		
	Start-up, Test & Punch 0.00 %		
		Total Costs	

EXHIBIT 5
MATERIALS COST ESTIMATE SHEET

Date: ____________

QUANTITY	EQUIPMENT	UNIT COST	TOTAL COST
	SUBTOTAL EQUIPMENT		
	Sales Tax 0.00 %		
	Drayage 0.00 %		
	Consumables 0.00 % (of Labor)		
	Escalation 0.00 %		
	Warranty 0.00 %		
	Start-up, Test & Punch 0.00 %		
		Total Costs	

 Management Methods Bulletin CO1 - 2011; replaces 1976, 1987, and 2005 versions.

EXHIBIT 6
OTHER DIRECT JOB COSTS ESTIMATE SHEET

Date: ____________

OTHER DIRECT COSTS	LABOR	MATERIALS
Resident Management and Expenses		
Superintendent and Expenses		
Other Nonmanual Labor Supervision Expenses		
Field Office Management and Expenses		
Estimating & Cost Analysis and Expenses		
Labor Planning (SLP) and Expenses for Update		
Field Engineering, Detailing, Reproduction, Supplies, Expenses		
Purchasing, Expediting, Traffic and Expenses		
Inventories, Management and Expenses		
Tools & Equipment Management and Expenses		
Payroll Management, Time Keepers, and Expenses		
Secretaries, Clerk Typists and Expenses		
Welding Qualification and Expenses		
Welding Inspection & Testing (NDE)		
Instruction of Owner's Personnel		
CPM Scheduling or Update		
Revising As-built Drawings		
Progress Photos		
Parking Expenses (other than on direct labor)		
Permits, Licenses, Fees, Dues		
QA/QC Expenses		
Extraordinary Estimating Expenses		
Engineering or Design Expenses		
Deliveries, Company		
Special Freight Charges		
Temporary Wiring		
Temporary Power		
Temporary Heat		
Temporary Water		
Temporary Toilets		
Temporary Air		
Temporary Weatherproofing		
Temporary Site Work		
Safety Officer and Related Expenses		
Safety Barricades, Gates, Other materials		
Ventilation		
Tags, Charts, Identification		
Office Furniture and Office Equipment		
EDP Cost		
Prefabrication Facilities		
Storage Facilities - On-site		
Storage Facilities - Off-site		
Office Heat and Electricity		
Office Telephones		
Copier Expense and Office Supplies		
Warranty Reserve		
Contingencies		
Sales Tax on Applicable Items Above		
	Total Costs	

EXHIBIT 7
EQUIPMENT AND TOOL RENTAL ESTIMATE SHEET

Project ______________________________ Type of Work ______________________ Date ________________________
Location ______________________________ Estimated By ______________________

EQUIPMENT/TOOLS	COST PER MONTH	UNIT TOTAL COST
Automobile ______ mos. @		
SUV ______ mos. @		
Pick-up Truck ______ mos. @		
Stake Body Truck - 1-1/2 Ton ______ mos. @		
Stake Body Truck - 1-1/2 Ton w/A-Frame & Winch ______ mos. @		
Flat Bed Truck - 2-Ton ______ mos. @		
Hydralift Truck ______ mos. @		
American Crane - 18-Ton with 30 ft. Boom ______ mos. @		
Austin Western Crane ______ mos. @		
Motor Crane - 25-Ton ______ mos. @		
D-6 Crawler Tractor ______ mos. @		
Backhoe ______ mos. @		
Trenching Machine ______ mos. @		
Air Compressor ______ mos. @		
Gasoline Driven Welding Machine ______ mos. @		
Electric Motor Driven Welding Machine ______ mos. @		
Hellarc Welding Machine ______ mos. @		
Acetylene Rigs Complete ______ mos. @		
8″ Pipe Machine ______ mos. @		
4″ Pipe Machine ______ mos. @		
2″ Pipe Machine - Power Vise ______ mos. @		
Pipe Bending Machine ______ mos. @		
Metal Cutting Band Saw ______ mos. @		
Cut-Off Saw ______ mos. @		
Power Hoist ______ mos. @		
Water Pump ______ mos. @		
Trailer Van ______ mos. @		
Portable Building ______ mos. @		
Dewatering Equipment ______ mos. @		
Fork Lift ______ mos. @		
Portable Hoist ______ mos. @		
Scaffolding ______ mos. @		
Other ______ mos. @		

EQUIPMENT & TOOLS TOTAL COSTS: __________________

EXHIBIT 8
VEHICLE OPERATING COST ESTIMATE SHEET – GASOLINE AND OIL

Project ______________________________ Type of Work ______________________ Date ________________________

Location ______________________________ Estimated By ______________________

EQUIPMENT/TOOLS		COST PER MONTH	UNIT TOTAL COST
Automobile	______ mos. @		
SUV	______ mos. @		
Pick-up Truck	______ mos. @		
Stake Body Truck - 1-1/2 Ton	______ mos. @		
Stake Body Truck - 1-1/2 Ton w/A-Frame & Winch	______ mos. @		
Flat Bed Truck - 2-Ton	______ mos. @		
Hydralift Truck	______ mos. @		
American Crane - 18-Ton with 30 ft. Boom	______ mos. @		
Austin Western Crane	______ mos. @		
Motor Crane - 25-Ton	______ mos. @		
D-6 Crawler Tractor	______ mos. @		
Backhoe	______ mos. @		
Trenching Machine	______ mos. @		
Air Compressor	______ mos. @		
Gasoline Driven Welding Machine	______ mos. @		
Water Pump	______ mos. @		
Fork Lift	______ mos. @		

GASOLINE & OIL TOTAL COSTS ________________

EXHIBIT 9
LABOR SUMMARY SHEET

1. Project and No. ______________________ 2. Estimate No. ______________________
3. Owner and/or Architect-Engineer
   Change Order Request Number ______________________ 4. Date ______________________

HOURLY RATES

5. Job Description	6. Base Rate	7. Fringes	8. Payroll Taxes & Insurance	9. Park/Travel Subsistence as Applicable	10. Wage Escal.	11. Zone Pay	12.	13. Total
Fitter/Plbr. Journeyman								
Fitter/Plbr. Foreman								
Fitter/Plbr. General Foreman								
Sheet Metal Journeyman								
Sheet Metal Foreman								
Sheet Metal General Foreman								
Laborer								
Labor Foreman								
Operator								
Teamster								
Millwright								
BIM/CAD								
Other								

JOURNEYMAN HOURS

13. Fitter/Plbr. Journeyman Hours — Hours ______________________
14. Sheet Metal Journeyman Hours — Hours ______________________
15. Material Handling ______ % of Lines 13 & 14 — Hours ______________________
16. Non-Productive Labor (Relief Break, Tool Pick-up, etc.) ______ % of Lines 13 & 14 — Hours ______________________
17. Safety ______ % of Lines 13 & 14 — Hours ______________________
18. Clean-up ______ % of Lines 13 & 14 — Hours ______________________
19. EEO Implementation & Training ______ % of Lines 13 & 14 — Hours ______________________
20. Equipment Repair ______ % of Lines 13 & 14 — Hours ______________________
21. Height Factor — Hours ______________________
22. Base Journeyman Hours — Hours ______________________

EXHIBIT 10
LABOR SUMMARY SHEET
Labor Corrections

Date: ____________

	AFFECTED MHRS OF CURRENT CONTRACT		MANHOURS OF PROPOSED CHANGE	
23. Percentages are applied to the total affected manhours of the current contract, and to the labor of the proposed change	MHrs ____________ As of ____________		____________(A)	
NEGATIVE PRODUCTION FACTORS	**% of Loss**	**MHRS Lost**	**% of Loss**	**MHRS Lost**
24. Fatigue				
25. Stack of Trades				
26. Morale and Attitude				
27. Reassignment of Manpower				
28. Crew Size Inefficiency				
29. Concurrent Operations				
30. Dilution of Supervision				
31. Learning Curve				
32. Errors and Omissions				
33. Beneficial Occupancy				
34. Joint Occupancy (Other Trades)				
35. Site Access				
36. Logistics				
37. Ripple				
38. Overtime Adjustment				
39.		(B)		(C)
40. B + C -MHrs = Adjusted direct MHrs		Move to Line 41		

HOURS AND LABOR AMOUNT

41.	Journeyman (with corrections)	____________	Hours @	____________= $	____________
42.	Foreman (% of Journeyman hours)	____________	Hours @	____________= $	____________
43.	Gen. Foreman (% of Journeyman hours)	____________	Hours @	____________= $	____________
44.	Laborer (% of Journeyman hours)	____________	Hours @	____________= $	____________
45.	Laborer Foreman	____________	Hours @	____________= $	____________
46.	Operator	____________	Hours @	____________= $	____________
47.	Teamster	____________	Hours @	____________= $	____________
48.	Millwright	____________	Hours @	____________= $	____________
49.	Other	____________	Hours @	____________= $	____________
		____________	Hours @	____________= $	____________
50.	TOTAL DIRECT LABOR				
51.	Total Replacement _____ % of Line 50			$	____________
52.	TOTAL LABOR COSTS			$	____________
				$	____________

EXHIBIT 11
SUBCONTRACTS SUMMARY FORM

Job No. ______________________ Date ______________________

Project______________________ Type of Work ______________________

Location ______________________ Estimated by ______________________

SUBCONTRACTS	QUOTE
Temperature Control	
Insulation	
Fire Protection	
Air & Water Balance	
Excavation	
Rigging	
Painting	
Electrical	
Demolition	
Core Drilling	
Nondestructive Testing	
Other	
TOTAL COSTS	

Note: Similar supporting documentation, described in the other exhibits, may be used for subcontractor detailed cost estimates that are summarized on this form.

EXHIBIT 12
EXTENDED OVERHEAD COST SHEET

Job No. ______________________ Date ______________________

Project ______________________ Type of Work ______________________

Location ______________________ Estimated by ______________________

EXTENDED OVERHEAD	COST	TOTAL
TOTAL COSTS		

EXHIBIT 13
SPECIAL INCLUSIONS AND EXCLUSIONS FORM

Date: ____________________

Special Inclusions and Exclusions

EXHIBIT 14
FIELD-AUTHORIZED CHANGE ORDER

Purchaser Change No. ___________

Change No. _________

Purchaser ____ Date ____

____ Job No. ____

Address ____ Job ____

_____________________________________ Work Complete __________________________ Sheet ___________________

QTY	MATERIAL	PRICE EA.		AMOUNT		DESCRIPTION OF WORK		
						EQUIPMENT & TOOLS		
						_____ Shop Deliveries @ _________		
						_____ hrs Backhoe @ _________		
						_____ hrs Weld Machine @ _________		
						_____ hrs Truck @ _________		
						_____ Miles Travel @ _____/mile		
						_____ @ _____		
						_____ @ _____		
						TOTAL EQUIPMENT & TOOLS		
						LABOR & LABOR BURDEN		
						_____ hrs Supt. @ _______/hr		
						_____ hrs Foreman @ _______/hr		
						_____ hrs Mechanic @ _______/hr		
						_____ hrs Operator @ _______/hr		
						_____ hrs Laborer @ _______/hr		
						_____ hrs @ _______/hr		
						_____ hrs @ _______/hr		
						TOTAL LABOR, FRINGES, TAXES		
						TOTAL MATERIALS COST		
						TOTAL EQUIPMENT COST		
						TOTAL LABOR COST		
						SUBTOTAL		
						PLUS _____ % OVERHEAD		
	TOTAL MATERIALS COST					TOTAL COST		
	PLUS ______% TAXES					PLUS _____ % PROFIT		
	TOTAL MATERIALS & TAXES					TOTAL BILLING		

Supervisor who authorized the work.

Authorized By
PURCHASER'S REPRESENTATIVE

____

Company ____

EXHIBIT 15
FIELD-AUTHORIZED CHANGE ORDER FORM
WORK AUTHORIZATION # __________

SHEET NO. _____ of _____

DATE ______________________ CUSTOMER ORDER NO. ______________________

PROJECT ______________________ JOB NO. ______________________

WORK PERFORMED BY ______________________ FOR ______________________

AUTHORIZED BY ______________________ TITLE ______________________

DESCRIPTION OF WORK ____

____

____

LABOR				MATERIAL	
		ACTUAL HOURS WORKED			
NAME	TRADE	STRAIGHT TIME	PREMIUM TIME	DESCRIPTION	QTY

EQUIPMENT & TOOLS			
DESCRIPTION	TIME	DESCRIPTION	TIME

REMARKS: ____

CONTRACTOR ______________	ARCHITECT OWNER ______________	SUBCONTRACTOR ______________
BY ______________	BY ______________	BY ______________
ADDRESS ______________	ADDRESS ______________	ADDRESS ______________
______________	______________	______________

JOB COMPLETED ❑ YES ❑ NO

NOTE: COMPLETE A SEPARATE DAILY WORK ORDER FOR (1) EACH JOB AND (2) EACH DAY. DO NOT ATTEMPT TO COMBINE JOBS OR DAYS.

WORK AUTHORIZATION NOT SIGNED BECAUSE:
- ❑ UNABLE TO CONTACT REPRESENTATIVE
- ❑ AUTHORIZED BY PHONE
- ❑ FORM ISSUED FOR RECORD PURPOSES ONLY
- ❑ AUTHORIZATION IN DISPUTE

EXHIBIT 16
INSTRUCTIONS FOR FIELD-AUTHORIZED CHANGES (FAC)

1. Call the office and get approval from your Project Manager before starting ANY FAC work.
2. When you call to get approval, be prepared to tell the Project Manager:
   - What work is to be done?
   - Who will pay for the work?
   - To whose attention should the bill be sent?
   - Who is authorizing the work?
   - How long will the job last?
   - What material will be needed?
   - Can you get a written purchase order? If not, will the buyer's representative sign your daily sheets?
3. The Project Manager will assign a number to the FAC work. If the number starts with 8 (example: 8125) ***it is a completely separate job***. You must turn in a separate time sheet for an 8000 series job.
4. FAC sheets are like service tickets—EVERYTHING YOU USE MUST BE LISTED ON THE SHEET. This includes material from your truck stock, material already on your job, or special ordered items such as plumbing fixtures, or equipment. If you don't list an item on the sheet, we won't be paid for it. Don't forget consumables such as welding rod, solder, flux, oxygen, acetylene, etc. Be sure to list subcontractors, if any are used.
5. List the number of delivery trips from the shop.
6. List all the equipment and tools used, except hand tools.
   Examples of chargeable equipment are:

Air Compressors	Fork Lift	Set Transit
Backhoe	Generator	Trench Jacks
Bantam	Grinders	Trucks
Boom Truck	Hilti Drill	Warning Barricades
Comealongs	Hole Dawg	Welding Machine
Copper Cleaning Mach.	Line Up Clamp	Whacker
Core Drill	Pavement Breakers	Zipall Gun
Cutoff Saw	Pipe Benders	
Cutting Rig	Railroad Jacks	
Ditch Pump	Rigid 300 Pipe Machine	
Ditch Witch	Roustabout Lift	

7. Describe the work done as specifically as you can under "Description of Work."
8. Under "Labor," don't fill in any rates unless the customer insists on having a price before signing. If you need a rate for labor, call your Project Manager. ***THIS RATE IS NOT THE SCALE; IT INCLUDES TAXES, INSURANCE, FRINGES, ETC***. Enter the total number of hours worked for each classification. For example, if you have 4 men working 8 hours each, enter 32 hours.

   List straight time and overtime hours on separate lines. Be sure to include your time spent surveying the job, calling the Project Manager, ordering the material—all the time spent on the FAC. Where applicable, include time for the General Superintendent.
9. Under Job Completed, enter "YES" or "NO."
10. Number the sheets consecutively.
11. Make three copies of the FAC form. MAIL THE ORIGINAL DAILY WITH YOUR TIME SHEETS. DO NOT WAIT UNTIL THE WORK IS FINISHED TO MAIL THE SHEETS IN.
    Give the second copy to the customer.
    Keep the third copy for your use.

EXHIBIT 17
SUMMARY OF FAR COST ALLOWABILITY

Job No. ______________________ Date ______________________
Project ______________________ Change Order Request (COR) No. ________
Location ______________________ Prepared by ______________________

FAR 31.205 REFERENCE	DESCRIPTION	ALLOWABLE OR UNALLOWABLE	APPLICABILITY TO SUBJECT COR	JOB COST REPORT CODE REFERENCE
1	Public relations & advertising	AR		
3	Bad debts	Un		
4	Bonding costs	A		
6	Compensation for personal services	AR		
7	Contingencies	AR		
8	Contributions or donations	UE		
10	Cost of money	A		
11	Depreciation	AR		
12	Economic planning costs	A		
13	Employee morale, health, welfare, food service	AR		
14	Entertainment costs	Un		
15	Fines, penalties, & mis-charging	UE		
16	Gains & loses on disposition of property	A		
17	Idle facilities	UE		
18	Research & development	AR		
18	Bid and proposal costs	AR		
18	Deferred research & development	UE		
19	Insurance & indemnification	AR		
20	Interest & other financial costs	UE		
21	Labor relations	A		
22	Lobbying costs	UE		
23	Losses on other contracts	Un		
25	Manufacturing & production engineering costs	A		
26	Material costs	A		
27	Organization costs	Un		
28	Select other business expenses	A		
29	Plant protection costs	A		
30	Patent costs	AR		
31	Plant reconversion costs	UE		
32	Precontract costs	A		
33	Professional & consultant service costs	AR		
34	Recruitment costs	A		
35	Relocation costs	AR		
36	Rental costs	AR		
37	Royalties & other costs for use of patents	A		
38	Selling costs	UE		
39	Service & warranty costs	A		
40	Special tooling & test equipment costs	A		
41	Taxes	A, Un		
42	Termination costs	AR		
43	Trade, business, tech & professional costs	A		
44	Training & education	AR		
46	Travel costs	AR		
47	Legal & other proceeding costs	A, Un		
49	Goodwill	Un		
51	Alcoholic beverages	Un		
52	Asset valuations from business combinations	AR		

KEY: A = Allowable; Un = Unallowable; AR = Allowable, but with certain restrictions; UE = Unallowable, but with certain exceptions
Source: www.acquisition.gov/far

EXHIBIT 18
UNIT PRICE CHANGE ORDER PRICING FORM

Job No. ______________________________ Date ______________________________
Project ______________________________ Type of Work ______________________________
Location ______________________________ Prepared by ______________________________

DESCRIPTION	UNIT OF MEASURE	QUANTITY	X	UNIT PRICE	=	DOLLAR AMOUNT
						$_________
TOTAL AMOUNT						$_________

How to Organize and Submit a Claim

Introduction

What is a construction claim? This term is widely used to describe anything from a request for equitable adjustment (or change order request) to a formal lawsuit demanding relief from some court or governmental agency. However, "claim" has recognized definitions in our industry:

According to the *American Institute of Architects Glossary of Construction Industry Terms*:

> A demand or assertion by one of the parties seeking, as a matter of right, adjustment or interpretation of Contract terms, payment of money, extension of time or other relief with respect to terms of the Contract (Ref: AIA Document A201.)[1]

As defined by the *Federal Acquisition Regulation* (FAR) Subpart 2.1, 2,101 (b)(2):

> Claim, means a written demand or written assertion…seeking, as a matter of right, the payment of money in a sum certain, the adjustment or interpretation of contract terms, or other relief arising under or relating to the contract. However, a written demand or written assertion by the contractor seeking the payment of money exceeding $100,000 is not a claim under the Contract Disputes Act of 1978 until certified[2] as required by the Act.

Beyond these formal definitions, the term "claim" has taken on a meaning based on its common use in the construction industry. According to this meaning, a claim is a demand for relief, usually as to cost and/or time, by a contractor to another party, such as a general contractor or owner. In this sense, a claim is filed only after negotiations for a fixed-price change order fail, or after the reviewing party has formally denied the change order request. Thus, in the vernacular, a claim is equated to a dispute between the parties that remains after negotiations to modify the contract have failed. When an issue is resolved by a change order to the contract, usually no claim results.

Most change order requests do not require formal certification. However, claims of over $100,000 on federal government projects must include a certification signed by the claimant with language consistent with the requirements of the Contract Disputes Act. Thus, for projects contracted under the *FAR*, a "claim" of over $100,000 is differentiated from a change order request by the required certification. The

[1] "The Architect's Handbook of Professional Practice" Volume 3, AIA Press.

[2] The issue of claim certification is not the subject of this chapter and is a topic that should be addressed by the claimant's construction counsel.

issue of claim certification requires careful review and consideration by the claimant's upper management and construction counsel and is not the subject of this chapter.

As noted above, a claim typically is filed when negotiations to execute a change order to the contract have not been fruitful. Many contract documents contain critical timing clauses that set forth the time frame within which a contractor must give formal written notice of a claim and further deadlines as to when a claim must be filed in order to be considered by the reviewing party, such as a government agency. Contractors should pay close attention to timing deadlines and content requirements. If they do not, claims may be dismissed or rejected out of hand by the reviewing party for failure to file the claim in a timely fashion or with the proper information and in the proper form.

The content of a mechanical contractor's claim typically will be dictated by the terms and conditions of the contract or by governing regulations, such as the *FAR*. The claimant should carefully review all submission requirements in the contract to ensure that the timing and content of the claim are in conformance with the contract terms.

Many mechanical contractors have the philosophy that claims must be avoided at all cost. While it is certainly desirable to avoid distracting and time-consuming disputes or costly litigation, the failure of a contractor to file a claim in a timely fashion may forever bar the contractor from relief (i.e., costs and/or time extensions) to which the contractor is otherwise entitled. Before a mechanical contractor makes a decision to delay or to avoid filing a claim, the company's upper management should evaluate thoroughly the potential risks and liabilities that would result from this decision.

Steps to Preserve the Contractor's Right to File a Claim

If a contractor determines that claims will inevitably be filed on a project, due perhaps to the exceptionally poor quality of the construction documents or the general contractor's or owner's improper scheduling or project management, certain steps should be considered to preserve the contractor's right to file a claim.

1) Many change order forms used by general contractors and owners contain broad "accord and satisfaction" language that seeks to bar the contractor from recovering time and/or costs for a change in scope over and above the remedies specifically prescribed within the change order itself. Such language has been strictly interpreted and as such, the contractor executing a change order with broad accord and satisfaction language may be held to the bargain defined by change order scope and pricing. In the event the contractor is faced with such language on the change order forms, the appropriate course of action should be formulated by upper management aided by construction counsel.

2) Monthly payment applications often contain broad waiver language that seeks to bar contractors from recovering unsettled claims that are not expressly listed as exceptions on the payment application form itself. Frequently, these forms are not processed by the contractor's field management and thus they are unaware of this waiver language. All outstanding claims and unapproved change orders should be

expressly listed within the exceptions section of the payment application form every month. In the event the owner or general contractor do not provide an exceptions section on the payment applications form, the mechanical contractor should insert its exceptions on the form prior to submitting it for payment.

3) In the event the project is nearing completion with claims still outstanding, the claimant should not accept final payment for the project or execute final releases until all claims are fully settled.

Differentiating a Notice from a Claim

A notice of an event involving a claim is not, in and of itself, a claim. Notices and claims are typically two different documents with varying content. Notice refers to the transmission by a contractor to another party (i.e., the general contractor or owner) of a document that asserts that a delay and/or added costs may be, or have been, encountered on a construction project. A notice is designed to alert the general contractor or owner to a condition that requires remediation or special attention. Most notice letters are written when the details of the impacting event are not fully known and the outcome in terms of delay and added costs, if any, is uncertain. Most contracts include provisions outlining the required components of a proper filing of notice. These requirements may include specific description(s) of the thing or things causing the time and/or cost impact, estimates of the time and/or cost impacts, and other specific requirements that may be set forth in the contract.

Notice letters do not typically contain the same elements that are included in a claim for relief. While a notice letter sets forth a set of conditions that have occurred or may occur, usually giving the other party an opportunity to remedy or mitigate the adverse effects of the condition, a claim letter usually includes the time and cost impacts of the events. The notice letter generally precedes the preparation of a claim. The timing and content of notice letters and claim documents are often provided for in the contract and the claimant should refer to the contract prior to submitting either a notice or a claim document to ensure proper content and timing.

Typically, a claim is a demand for specific relief or remedy and is filed after the impacting event has occurred so that its effects are known; and after change order negotiations have failed to provide for an equitable adjustment. Since a formal claim document usually follows the quantification of the impact, one component of a claim should be specificity—a number of days of extended contract performance time, an amount of money for direct costs, an amount of money for indirect costs, and other components of contract changes that are being requested by the claimant. If the claim does not contain specific requests for contract modification, the claim may be denied based on a lack of specificity.

The Components of a Claim

Proof of entitlement and quantum normally lies with the contractor making the claim (the claimant), meaning it is the contractor's obligation to prove the elements of its claim. There are several common components in a contractor's claim. These may include, depending on the nature of the claim:

- A Critical Path Method (CPM) schedule impact analysis. Such analyses can include fragnets, or time impact analyses (TIA), a windows analysis, and/or as-planned versus as-built schedule analysis to support any claim for a time extension.

- Craft-level analyses showing as-planned versus as-built craft curves.
- Inefficiency studies identifying and quantifying losses in labor productivity.
- An accounting of the direct costs arising from the claimed conditions.
- An accounting of the indirect costs arising from the claimed conditions.
- A narrative of the cause and effect nexus that can include a written description of the events, photographs, contract documents such as letters and electronic correspondence, requests for information (RFI), change directives, and other proofs that demonstrate the changed nature of the work, the resulting damage, and a summary of the desired relief.

The exact content and format of the claim should be thoroughly reviewed by the claimant's senior management and, if appropriate, by the firm's legal counsel and the chief financial officer or outside accountant. As noted, the timing, form, and content of a claim can be critical elements in the claim's acceptance or rejection by the reviewing party.

Read the Contract Before Filing a Claim

As noted above, various contract documents may contain language that seeks to limit a contractor's right to recover delay time and the costs arising from delay and inefficiency. Important time- and cost-related issues such as labor and material escalation, *force majeure* events such as unanticipated adverse weather, unanticipated added impacts arising from previously executed change orders, and other important concepts are frequently discussed in the contract terms. Other important factors such as waiver language on payment applications, "full accord and satisfaction" language regarding change orders, and "no damages for delay"[3] clauses that attempt to limit time-related cost impacts for delays may be included in the contract. Contractual time limits for providing notice and for submission of a claim are important elements to consider. The contract must be fully reviewed to ensure that a claim is in compliance with the contract terms or, if not, why the particulars of the contract may not apply to the claim being filed.

A thorough review of the contract terms, results of the schedule and labor productivity analyses, and damages calculations should be performed before finalizing the entitlement and damages portion of the claim narrative. The contract and applicable regulations should be carefully reviewed in order to ensure that the form of the claim is consistent with the requirements set forth therein, including timing, addressee, contents, and certification. Generally, the claim package should be transmitted to the reviewing party or agency by registered mail

[3] Contact language that attempts to limit a contractor's right to make a claim for a certain element of cost or time impact may not be applicable in all circumstances. By way of example, in some cases a "no damages for delay" clause may not have its intended efficacy, given actual circumstances on a project. However, such clauses cannot be ignored by the claimant and must be carefully considered when a claim is prepared. Review of the contract, in conjunction with the claim, by the contractor's counsel is advised in order to ensure harmony between the requirements of the contract and the claim being submitted.

or by other means that result in a signed and dated proof of receipt.

Content and Order of the Claim

It is true that, to some extent, how seriously the claim is viewed by the party receiving it can be determined by the professional appearance and completeness of the claim document and its supporting exhibits. If the claim is poorly organized, incomplete, or contains a narrative that is vague or confusing and lacking in compelling facts to connect cause and effect, the claim has a greater chance of being dismissed out of hand. However, if the claim package is compelling in its narrative and comprehensive in its supporting documentation, then the chances of an equitable settlement are increased significantly.

The content and order of the claim should be designed to compel the reader, by the weight of the facts, to adopt the claimant's position and to issue an equitable adjustment to the contract. Thus, the claimant should include in the claim package a comprehensive and comprehensible narrative that sets forth the bases of the requests for remedy that can include both an extension of time and added costs. If the reader cannot reasonably navigate through the claim or understand the basis of the demand, a rejection of the claim can be expected.

Addressing the claim to a specific person and/or entity may be of vital importance depending on the jurisdiction in which the claim is submitted. This consideration is in addition to the time restrictions for filing a claim that may be contained in the contract or other governing regulations. For instance, public works contracts in some jurisdictions require that, in order for a claim to be validly served, it must be addressed to a specific individual, within a specific department, within a specific time frame. Copies of the claim also may be sent to other project-related individuals, such as the project manager or resident engineer, but to be valid, the claim must be transmitted to the specific, named party listed in the contract documents. When a contractor is contemplating a claim, in addition to attention to the content of the claim itself, careful attention must be paid to the contractual and regulatory requirements of filing a valid claim.

Typically, a summary stating the basis of the claim is essential. This summary, or claim narrative, should lay out the contractual foundation for making the claim and for the resulting damage. It should directly connect the basis of the claim to the resulting damages—this is called the "cause and effect" nexus. A citation to contract and/or schedule requirements is usually appropriate in the summary or narrative. It is important to consider two general concepts when preparing the summary or claim narrative: a chronological and sequential presentation of the events; and addressing the questions of who, what, where, when, why, how, and how much, as appropriate. Specificity is key to a properly constructed claim document.

The damages portion of a claim may include such components as:

- Days of delay and the attendant time extension request;
- Costs for added performance time due to delays (field and home office overhead costs)[4];

- Direct acceleration costs (payroll differential costs for overtime, shift work, or added supervision and equipment attendant to an increased crew size);
- Indirect labor inefficiency costs such as overtime inefficiency, crew disruption, stacking of trades, or other labor productivity factors;
- Labor wage rate escalation;
- Material cost escalation;
- Extended warranties;
- Equipment "inefficiency";
- Added detailing or drafting/building information modeling (BIM) and schedule update costs;
- Supervision or management added to mitigate labor inefficiencies or to process a large quantity of scope changes;
- Subcontractors' claimed amounts;
- Finance charges;
- Bond costs; and
- Overhead (unless claimed separately) and profit.

Once the particulars of the issues have been introduced in a comprehensive and compelling manner so that that the reviewer is prepared to assimilate the facts, then the documentation and calculations can be presented to support the claim narrative.

Sample Claim Narrative Summary

A claim narrative can be provided in summary form, as shown on the next page, as long as the summary denotes each major category of impact. The documentation supporting each category can be provided in accompanying exhibits. However, a more exhaustive and comprehensive written claim narrative is usually presented. A comprehensive claim narrative can provide a chronologically-ordered description of the impacting events with citations to the drawings, specifications, the contract or other pertinent documents such as letters, purchase orders, or site photographs. A well-written, comprehensive claim narrative can lead the way for expanded understanding of the claimant's position by the reviewer and can also result in an equitable adjustment to the contract. It is much more economical for the contractor to expend appropriate resources in the preparation of its claim narrative and supporting documentation than to later become involved in costly litigation because the claim was denied due to lack of supporting documentation.

Also note from the sample on the next page that the claim contains elements of compensable delay and loss of labor productivity. A compensable delay is one that entitles the claimant to compensation for each day of extended general condition costs. All delays are not necessarily compensable. Some delays are excusable only, meaning that the claimant is relieved from liquidated damages

[4] The components of a compensable delay claim (i.e., extended field office overhead) are frequently large in number and can include the daily costs of on-site project management and supervision, the daily costs of office and storage trailers and warehouses, trucks, fuel, telephones, and other time-related costs. In certain instances, home office overhead may be recoverable. What may or may not be claimed as to delay costs is frequently prescribed in the contract, the *FAR*, generally accepted accounting procedures, or in other related documents. Refer to "How to Identify and Manage Change Orders" for more specific information on damages calculations.

EXHIBIT 1
SAMPLE CLAIM NARRATIVE SUMMARY

Amalgamated Mechanical Contractors
1 Central Street
Any City, USA

Mr. John Smith (Today's Date____________)
Contracting Officer
Department of Construction Services
1 Public Works Square, Any City, USA

Reference: Public Office Building Project, Contact No. 100-00-100

Subject: Claim for Recovery of Added Costs and Contract Time Extension

Dear Mr. Smith:

Pursuant to the Contract, Amalgamated Mechanical Contractors ("AMC") herewith submits its claim for recovery of costs and for a time extension on the above captioned project. A summary of the claim, as supported by the enclosed exhibits, is as follows:

On May 1, 2xxx, AMC discovered a differing site condition involving unforeseen and unsuitable soils that prevented AMC from timely and efficiently installing its underground plumbing and mechanical piping systems. AMC provided timely and proper notice of this condition. Reference Exhibit A containing AMC's notices, site photographs, daily reports showing craft and equipment usage and other documentation. AMC claims $____________ in direct costs for labor, materials and subcontractor costs to remove the unsuitable materials and replace those materials with the prescribed stone and backfill.

This differing site condition critically delayed the approved project schedule by seventy-five (75) calendar days. AMC requests a 75 calendar day compensable time extension to its contract. Reference Exhibit B containing AMC's CPM schedule time impact analysis demonstrating AMC's entitlement to a 75 calendar day extension of time. AMC's claimed costs for delay amount to $___________.

During the discovery period from March 1, 2xxx to June 1, 2xxx, AMC's crews were made inefficient by the piece-meal nature of the work during the period the Government was investigating the differing site conditions. Additionally, AMC was required to demobilize its crews during the remediation period and then remobilize its forces once remedial steps had been completed. Reference Exhibit C containing AMC's loss of labor productivity analysis. AMC's claimed costs for labor inefficiency amount to $_______________.

With appropriate support costs, profit, bond and other appropriate costs, AMC's claimed damages total $________________ for which AMC herewith submits for payment. AMC's summary of damages is included herein at Exhibit D. AMC also requests a time extension of 75 calendar days. This reflects the identifiable cost and time impact associated with this claim. AMC expressly reserves the right to amend this claim as a result of the unforeseeable collateral impacts resulting from this differing site condition, as such impacts become known.

Yours truly,

____
Executive Vice President of Operations

but receives no compensation for the delay. Some delay may be a combination of non-excusable, excusable, and compensable time.

A compensable schedule analysis is normally considerably more complex than a schedule analysis focusing only upon excusable delay. For an excusable delay analysis, the claimant must prove that it was not the sole cause of critical path delay. For example, if the claimant caused the project to finish late by 30 days through its own fault, and another party (e.g., the owner or the prime contractor) independently caused the project to finish 30 days later than allowed by the contract, the claimant would still be entitled to a 30-day excusable, non-compensable delay.

However, in order for a compensatory analysis to prevail, the claimant must demonstrate through a CPM scheduling analysis that its own delays, if any, were not controlling critical path delays and as such, did not independently or concurrently cause the project to finish late. A compensable delay can have many facets that must be analyzed and explained and is frequently a very complex analysis best assigned to scheduling experts. The contract terms, accepted practice in the industry, combined with a technically competent CPM schedule analysis generally determine whether project delay is compensable, excusable, or in some cases, non-excusable.

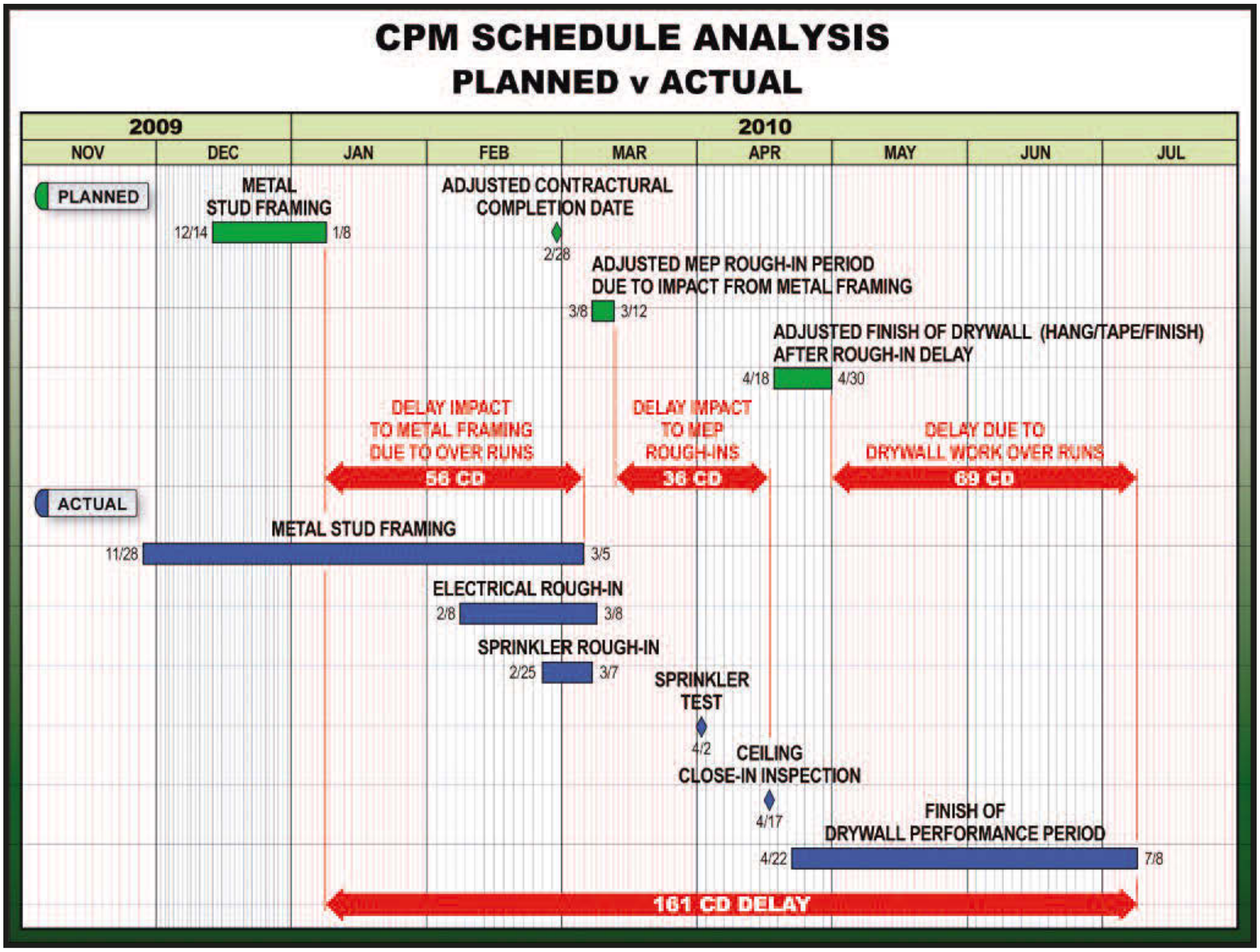
In addition to the claim narrative, supporting documentation can be provided as exhibits to assist the reviewer in reaching the desired conclusion. If a schedule analysis has been performed to support a claim for an excusable and/or compensable time extension,[5] summaries of this analysis can be included in the claim, as shown on the next page.

If the claimant has included a component of damages arising from labor inefficiencies caused by the impacting event, the computations for this component can be added as an exhibit to the claim. There are several methods of quantifying a contractor's loss of labor productivity. These include the: total cost or modified total cost method; measured mile method; and industry study method, such as by the use of the MCAA labor inefficiency factors. An example of an inefficiency exhibit supporting the claimant's loss of labor productivity component may appear as on page 46.

It is well acknowledged in the construction industry that proving labor inefficiency is difficult. In computing a labor inefficiency claim, exactness is not a requirement. However, connecting the causes with the effects is generally a necessary element in any claim submission for loss of labor productivity. There are indicia of labor inefficiencies that many experts look for when preparing a labor inefficiency claim. These indicia can include: unexpectedly high crew sizes, fluctuations in crew sizes, disruption in the productive flow of crews, a high percentage of scope changes as a ratio of changes to base contact labor hours, unanticipated stacking of trades, unreasonable limitations to site access, and many other categories of impacts. Once the causes are established, then the claimant must estimate or calculate the resulting damages in terms of lost labor hours.

Field labor is not the only type of labor that may be susceptible to inefficiencies. The pro-

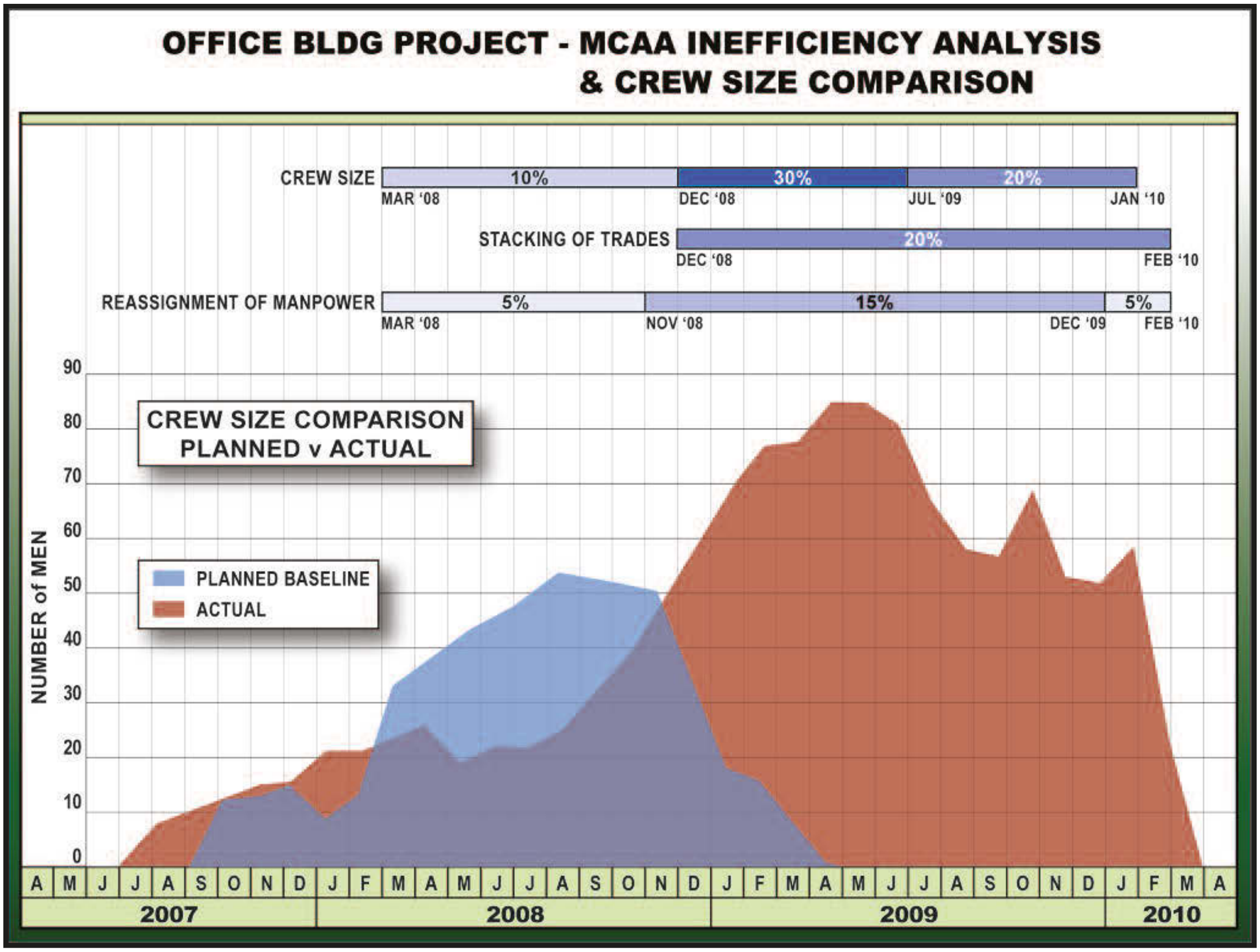
[5] For a more detailed review of the methods of schedule impact analysis, refer to the chapter on "Time Impact Analysis—Measuring Project Delay."



ductivity of coordination, or the BIM[6] process, can also be adversely affected by events on the project. Coordination, or BIM labor, can become inefficient if the plans and specifications are defective, leading to excessive clash identification and remediation. Often, the coordination process is adversely affected by an excessive number of requests for information that slows the progress of the BIM activities and makes such activities inefficient though the effects of piece-mealing of the coordination work and other disruptions. Coordination labor should be carefully analyzed by the claimant in order to ensure that this component of construction is not improperly omitted from a delay and/or inefficiency claim.

Claims for loss of labor productivity can be quantified by several means as described

[6] Building Information Modeling, usually a three-dimensional model of the project showing the elements of the work by the various trade contractors. The BIM process generally occurs at the early stages of the project and labor overruns may be not be properly included in an inefficiency analysis. The claimant should be careful to assess BIM labor overruns to determine if such overruns were occasioned by inefficiencies caused by defective plans and specifications or other non-contractor caused impacts.



above. A more exhaustive discussion regarding the identification and quantification of loss of labor productivity claims can be found in the chapter detailing "How to Use the MCAA Labor Factors."

Furthermore, many contractors recognize a phenomenon sometimes called "equipment inefficiency." Equipment, in and of itself, is not inefficient.[7] The labor to use the equipment may be made inefficient by a host of causes. Presumably, the labor required to operate a piece of equipment would be evaluated in a typical labor inefficiency claim. However, due to labor inefficiencies, the time required to use a piece of equipment may become elongated on the project. If it can be shown the a piece of equipment (either rented or owned by the claimant) was required to be on site longer than planned, or if equipment had to be added to the project due solely to the inefficiencies claimed for the labor portion of the project, the attendant costs can be recovered in the claim.

[7] It may be argued that a newer and more fully featured piece of equipment is more efficient or cost effective when compared with an older or less robust model of the same item. However, as it is used herein, efficiency is a function of output over input for a given piece of equipment.

It is therefore important to record planned and actual equipment usage on the project to determine if inefficient conditions have caused an unplanned increase in the cost of equipment.

Damages calculations are an important component of a claim. As noted, the claim should contain a sum certain (i.e., a specific dollar amount for damages) that is being sought by the clamant as a result of the impact event(s) described in the narrative. Damages calculations must conform to accepted accounting practices and to the governing authorities such as the contract or the *FAR*, as applicable.[8] The damages portion of a claim also may be the subject of a review by the contractor's counsel and its chief financial officer or accountant, particularly if a component for extended home office overhead is included. The claimant should anticipate that a claim will be the subject of a full audit and should prepare accordingly.

Amalgamated Mechanical Contractors
1 Central Street
Any City, USA

SUMMARY OF DAMAGES

Extended Field Office Overhead (75 CD x $1,000/CD)	$ 75,000
Extended Home Office Overhead (75 CD x $350/CD)	$ 26,250
Direct Costs for Remediation of the Differing Site Condition	$ 947,500
Loss of Labor Productivity	$ 97,450
Labor Escalation Resulting from the Delay	$ 15,450
Extended Warranties	$ 5,750
SUBTOTAL:	$ 1,167,400
Profit @ 10%	$ 116,740
Bond	$ 11,674
TOTAL CLAIM AMOUNT:	**$ 1,295,814**

Home office overhead as a component of a delay claim may or may not be recoverable as a matter of contract provisions, or as a matter of the current trends in reported cases. At the time of this writing, the ability to recover unabsorbed home office overhead is limited to those situations where the contractor can demonstrate that:

1) The excusable delay period represents a suspension of the work, not just an elongation of the duration of work activities, effectively placing the claimant in a "stand-by" mode;
2) The "stand-by" period is of an uncertain duration; and
3) The claimant can demonstrate that it did not obtain, and could not have reasonably obtained, new work to absorb the home office overhead not being absorbed by the project on which the claim is being filed due to the suspension of work.

The use of allocation-related formulae, such as the Eichleay[9] formula, is common in computing a contractor's home office overhead for the purposes of including those costs in a delay claim. The Eichleay formula allocates a contractor's corporate home office overhead to a particular project and then computes the daily home office overhead allocable to that project. The daily home office allocated rate times the number of days of compensable delay equals the home office overhead component of compensable delay claim.

[8] For a more detailed review of the methods of quantifying impacts, refer to the chapters on "Time Impact Analysis—Measuring Project Delay," "How to Identify and Manage Change Orders," and "How to Use the MCAA Labor Factors." The pricing format for a change order request and a claim are essentially identical.

[9] Reference *Appeal of Eichleay Corporation*, ASBCA No. 5183, 60-2 BCA ¶ 2688 (1960).

Other methods of computing home office overhead have been utilized by contractors with varying degrees of success. The recovery of home office overhead is challenging due to the limitations currently imposed by the courts and boards and the decision by the contractor whether or not to seek recovery of home office overhead costs should be aided by the advice of the contractor's counsel and accountant.

On public contracts, expect to be audited once the claim is submitted. Audits can be performed by such agencies as the Inspector General's Office, the Defense Contract Audit Agency, or other audit groups affiliated with the governmental department with which the contract was executed. A public contract audit of a contractor's claim is not a mere technicality. Many audits probe the contractor's financial and accounting records for possible discrepancies between the claimed amounts and the entries shown in the contractor's books and records. While simple entry or arithmetic errors can be corrected or explained, audits can have serious ramifications to the claimant should the audit uncover apparent improprieties in the claimant's books and records as they are compared with the claimed damages. Apart from an audit of the claimant's monetary damages, an audit can challenge methodologies utilized by the claimant in the preparation of the claim. Audits can be far reaching and have significant impact on how the claim is processed or if the claim is simply denied in its entirety for lack of support or proper record keeping.

Actual or Deemed (Constructive) Denial of a Claim

Regardless of how well a claim is prepared, some claims will be denied. When a claim is denied with a written or oral evaluation or rebuttal, it is incumbent upon the claimant to carefully review the bases for denial and make a determination as to any corrections that may be needed to the original claim submission. It is possible that the reviewer may find disallowed costs or raise questions as to entitlement or the factual events described in the claim. The claimant should timely and constructively respond to those issues with corrections or explanations as to the issues raised by the reviewer. If a constructive dialogue can be established between the claimant and the reviewing party, the potential of an equitable settlement of the claim increases.

In some cases, a reviewer will dismiss the claim out of hand and without any reasoned basis for the rejection. Further, the rejection may not be accompanied by a written or oral rejoinder or rebuttal; simply the other party's deafening silence. The contractor should take written exception to this sort of "constructive" denial and, where appropriate, file an appeal in the manner prescribed by the contract. When a claim is formally denied, it would be prudent to have the claim and its denial reviewed by a construction attorney to ensure that the form of the original claim was correct (if this step was omitted prior to the original submission of the claim) and to prepare the appeal of the denial.

A "deemed" or "constructive" denial of a claim occurs when the party receiving the claim does not respond to the claim in any fashion, or in the prescribed or reasonable amount of time. As noted, in some cases the recipient of the claim may have no response at all. It is usually appropriate to expect a response within 30 to 90 calendar days of the date of submission of the claim. If, after a reasonable period, or the contractually prescribed period, of time has elapsed without a response to the claim, a second demand letter should be transmitted requesting a response to the claim within a reasonable (i.e., 30 days) period of time. If no response is received, the claimant, aided by counsel, may decide to file a notice of deemed or constructive denial of the claim. In this fashion, the claimant has documented its reasonable assumption that the reviewing party has constructively denied the claim. If this course of action is taken, it may trigger contract terms and other issues may arise, such as having to constructively accelerate the work to overcome any claimed excusable delay.

The concept of a "deemed denial" of a contractor's claim is principally a matter of federal contracts, such those executed by the General Services Administration or the U.S. Army Corps of Engineers. That does not mean that if a non-federal owner or prime contractor refuses to acknowledge a contractor's claim, the general concept of constructive denial does not apply. However, the issue of "deemed denial" can be a complex legal issue and may be based on the terms and conditions of the contract, thus this matter is the subject of careful consideration by experienced construction counsel.

Conclusions

A mechanical contractor should carefully assess all options when considering whether or not to file a claim. However, the time restrictions contained in many public and private contracts do not allow the contractor significant latitude as to when a claim can be filed, thus the contractor is normally forced to make this decision promptly. Often, a contractor decides not to file a claim believing that, somehow, disputes will simply resolve themselves by working out the differences on the jobsite. This can lead to unanticipated results when the contractor comes to realize that the only suitable resolution available is that prescribed in the contract documents. If the contractor has made a decision not to file a claim in accordance with the terms of the contract, its rights and remedies may have been irretrievably waived and thus, its ability to be equitably compensated may have passed by.

The proper and timely preparation and submission of a claim can be viewed simply as prudent management. A claim is an avenue to receive a remedy that is provided for in most contracts. The filing of a claim is not, on its face, an adversarial act. It is a business decision that is recognized as the contractor's right under most contracts. It may, in fact, be a business obligation to ensure fair and equitable payment for work performed over and above the base contract scope of work or work performed in a most costly and unanticipated manner.

Prepared by Paul L. Stynchcomb, CCM, PSP, CFCC of Vero Construction Consultants Corp. and Charles Choyce, PSP, PMP, CFCC of FTI Consulting with peer review performed by: Robert Beck, President of John W. Danforth Company; Michael R. Cables, Executive Vice President of Kinetics Systems, Inc.; James Durant, President and CEO of Trautman & Shreve; Richard Freeman, Vice President of Stromberg Metal Works; Matthew Hahr, Senior Vice President of Kirlin Mid-Atlantic, LLC; Michael Loulakis, Esq., President/CEO of Capital Project Strategies; Michael Mack, Executive Vice President of John J. Kirlin, Inc.; and Adam Snavely, President and CEO of The Poole & Kent Corporation.

Integrated, Cooperative, and Collaborative CPM Scheduling... a Roadmap to Success

On the majority of larger and/or more complex construction projects, the prime contractor and/or the owner's construction manager ("prime/CM") has the responsibility to prepare a detailed, baseline critical path method ("CPM") schedule at the outset of the project. At set intervals, usually monthly, the prime/CM is required to update the accepted baseline schedule with progress. Most contract specifications also require that time impacts, known as time impact analyses ("TIAs") or Fragnet analyses, be inserted into the updated schedules to identify and quantify potential delaying events. The subject of TIAs is addressed in a separate chapter within this publication entitled "Time Impact Analysis—Measuring Project Delay." As explained in that chapter, updates to the accepted baseline CPM schedule must contain properly developed TIAs, otherwise the forecasts contained in those schedule updates may be seriously flawed. This chapter is devoted to the development of the baseline CPM schedule. Common scheduling terms utilized in this chapter are defined in the chapter cited above and, in most cases, will not be defined herein.

CPM scheduling should be an inclusive, cooperative and collaborative process on a construction project. The original schedule—the "baseline CPM schedule"—should reflect the knowledge and planning of all of the major trade contractors. In simple terms, the baseline CPM schedule should, if followed, be the "roadmap to success" on a construction project. For the development of a reliable and useful baseline schedule to occur, it must be prepared by persons experienced in the construction industry and with training or extensive experience in the development of CPM schedules. Such individuals may also have had training in the common scheduling software systems utilized in the industry. However, the key elements in the development of useful and accurate schedules are the knowledge of the construction process in general, an understanding of the particular details of the project being scheduled and significant experience with the application of critical path methodologies.

Although contract specifications vary from project to project, usually the mechanical and/or plumbing subcontractor ("M/P subcontractor") is required either to provide the prime/CM with the M/P subcontractor's proposed schedule (sometimes called a "sub-network"), or the M/P subcontractor is required to participate in schedule development meetings with the prime/CM.[1] Notwithstanding the method of information delivery by the M/P subcontractor to the prime/CM, this step should be taken with the utmost attention to detail and accuracy. The project CPM schedule (the baseline schedule and the updates) is usually considered a contract document of record, and as such, deserves a significant amount of focused input to ensure that the prime/CM is properly advised as to the M/P subcontractor's individual activities, sequence, activity durations and crew planning on the project. Before any schedule development meeting with the prime/CM, the M/P subcontractor should be thoroughly knowledgeable regarding the project to be constructed, including the contract terms, drawings, specifications and the M/P subcontractor's own labor plan. To the fullest extent possible, the M/P subcontractor should develop an understanding of the prime/CM's contractual requirements for schedule development, submissions, and updating. Knowing the prime/CM's contractual obligations to the owner regarding the CPM schedule can be very valuable when negotiating with the prime/CM regarding having access to the complete schedule and its updates.

What is a Baseline CPM Schedule?

A "baseline CPM schedule" is a reasonably detailed[2] project schedule prepared using critical path method technology and formulae called the forward and backward pass, usually input into a software system such as Primavera® or Microsoft® Project® that computes the critical path or paths within the schedule network and identifies the non-critical activities. The baseline CPM schedule sets forth the M/P subcontractor's (as well as the other contractors') base contract activities, the estimated durations for those activities, the logical restraints between the activities (i.e., CPM schedule logic ties) and which activities control the project milestone and/or completion date(s). These logic restraints set forth the M/P subcontractor's sequence of performance in terms of its crew flow and the order in which its work activities will be performed. The baseline CPM schedule depicts the original intent of the construction team to meet the various requirements of the contract that includes achieving completion dates set forth in the contract. As such, the baseline CPM schedule on a construction project should reflect an efficient and profitable plan to achieve the contract requirements, and reflect an orderly and efficient sequence of events.

Some contract specifications require that the CPM schedule be "resource loaded," which means that the contractors must provide the number of trade workers per activity that will

[1] The timing and method of schedule information sharing between the M/P subcontractor and the prime/CM may vary depending upon the contractual delivery method. However, with both the design-build and the design-bid-build delivery methods, the baseline CPM schedule is of the utmost importance, as is the input of the M/P subcontractor into the scheduling process.

[2] Often times, the contract specifications set forth the level of scheduling detail that is required on the project and may also provide a maximum duration that can be assigned to a schedule activity. It is important for the M/P subcontractor to obtain, and to review, the prime/CM's contractual scheduling requirements before finalizing the baseline CPM schedule.

be required to perform the base contract work. Other contract specifications may require that the CPM schedule be "cost loaded," which means that the M/P subcontractor's total contract billing value must be divided between the various schedule activities so that the total of the individual activity billing values equals the M/P subcontractor's total contract amount.

When the contract specifications require that the M/P subcontractor "resource load" the baseline schedule, great care should be taken to ensure that the resulting crew curves for both the early and late dates (i.e., curves created by the scheduling software that present the resource data as number of workers, or labor hours, on the y axis depicted over time on an x axis) calculated in the CPM schedule never represent more labor hours than were present in the M/P subcontractor's original estimate or job plan. Some specifications even require the M/P subcontractor to differentiate between "fitters," "welders," "plumbers," and/or "sheet metal workers" within each erection activity in the baseline CPM schedule. The M/P subcontractor should use great care to ensure that each trade's baseline CPM schedule planned labor hours never exceed the hours for each trade that was carried in the M/P subcontractor's estimate or job plan.

If the M/P subcontractor includes more labor hours (expressed in hours or in the number of craft persons by activity) in the baseline CPM schedule than were contained in the original estimate or job plan, this condition is usually the result of an inadvertent data input error or carelessness on the part of the M/P subcontractor in providing the resource data. In some cases, reflecting more labor hours in the schedule than are contained in the M/P subcontractor's estimate demonstrates the identification of an error in the estimate. In cases where the M/P subcontractor encounters a labor over-run on the project, it may be difficult to recover those labor losses that are comprised of the difference between the labor hours in the M/P subcontractor's estimate and the labor hours contained in the M/P subcontractor's baseline CPM schedule, even if an inadvertent error is claimed. Always ensure that the labor hours shown in the baseline schedule never exceed the original estimate or job plan, unless an admitted estimating error has occurred on the part of the M/P subcontractor.

A CPM schedule has two sets of calculated dates: earliest start and finish dates and latest start and finish dates. The mathematical difference between the earliest and latest dates is known as "total float." Total float is the number of days that a particular activity within a CPM schedule can slip in time without impacting an interim milestone date(s) and/or a final project completion date(s). Activities that have zero total float are said to be on the "critical path." If a critical path (zero total float) activity is delayed by even a day, it has a day-for-day impact on finish milestones or final completion dates. In fact, if collateral impacts are present, a one-day delay to a critical path activity may result in more than a day's delay to the project's end date. It is often the case that the M/P subcontractor does not, or is not permitted to, link the activities in the baseline CPM schedule to demonstrate the M/P subcontractor's planned crew flow and crew restraints. When this is the case, the schedule may be invalid due to "false float," which is a calculation of float that is erroneous because planned crew flow (i.e., proper activity sequencing) is not considered in the CPM schedule's mathematical analysis.

Because this is a frequently committed error, the M/P subcontractor must ensure that the number of craft workers shown within the baseline CPM schedule never exceeds the expected peak curves for both the early start dates and the late start dates. The M/P subcontractor should also focus attention on resource loading specialty activities such as welding or other activities that use limited availability skills or equipment to ensure that the individual resource usage on an activity-by-activity basis does not exceed the estimated quantities.

On many projects where the M/P subcontractor does not input, or is not allowed by the prime/CM to input, crew restraints into the baseline CPM schedule logic, the late start date resource curve may far exceed the number of craft persons that were planned to be utilized on the project because of "false float." Examples of crew restraints will be provided later in this chapter.

The baseline CPM schedule is, or should be, a reflection as to how the project is planned to be constructed. That plan includes proper resource allocations that may be input into the scheduling software. This baseline CPM schedule may be used to compare the construction team's planned performance with actual performance by inputting actual start and finish dates, or actual start dates along with progress information for active activities, thus it is imperative that the baseline schedule reflect, to the fullest extent possible, the most economical and realistic model of how the project is being planned to be constructed. Once submitted and approved or accepted by an owner or its authorized representatives, it is difficult to go back in time to revise a defectively prepared baseline CPM schedule. Further, comparisons between a defectively prepared baseline CPM schedule and future updates, particularly on an impacted project, may be rendered unreliable and not useful in a delay impact analysis.

In order to provide accurate and reliable input to the prime/CM, the M/P subcontractor should thoroughly review the contract specifications, drawings, and its own bid and planning documents to gain a detailed understanding regarding the scope of work, time of performance, interim milestones (if any), planned crew sizes, and crew flow and other requirements contained in the contract. For instance, the M/P subcontractor may be required to provide early energization of HVAC equipment for acclimatization of spaces in the building, or other special requirements that are usually defined in the contract documents. Such special milestones or other considerations (e.g., delivery of owner-furnished furniture, fixtures, and equipment) should be included in the schedule logic and thereby, become a part of the M/P subcontractor's baseline scheduling considerations.

Additionally, the M/P subcontractor should carefully consider the timing of its construction activities with regard to the potential effects of weather. In certain areas of the country, historical weather events such as severe winter conditions or seasons of intense heat or heavy rains may adversely affect the productivity of the crews and cause delay. To the extent possible, the M/P subcontractor's schedule sequencing should take those historical (potential) climatological conditions into account. In some cases, these historical weather seasons may require the construction team to take special actions, such as installing temporary building enclosures or temporary roof systems (i.e., temporary building dry-in as a predecessor to water sensitive activities). These considerations should be made when the baseline schedule is being prepared. The M/P subcontractor should also evaluate when the work of other trades is planned to occur, such as the milestone for providing permanent power to the project. This may be particularly important to the commissioning work that may fall under the M/P subcontractor's scope of work. Further, the provision of temporary hoisting and crew lifting equipment should be included in the baseline schedule. Depending on the type of contract delivery method, the M/P subcontractor should also ensure that the baseline schedule includes milestone dates by which decisions are made as to the acceptance or rejection of bid alternates and the receipt of 100% complete construction documents.

At a minimum, there are three areas of special consideration that, on most larger projects, require a detailed analysis by the M/P subcontractor when preparing the baseline CPM schedule or when participating in schedule development meetings. These are:

1. Detailed logic reflecting the requirements and timing of Building Information Modeling ("BIM") and its relationship to piping and sheet metal prefabrication activities that are, in most specifications, successor activities to the approval of the coordinated drawings.
2. Consideration of logic ties that reflect the M/P subcontractor's planned crew flow, crew size restraints, and general sequencing of the M/P subcontractor's activities.
3. Detailed logic reflecting the requirements for building commissioning, including identification of milestone dates for the involvement of the owner's third party commissioning agent in order to forecast accurate commissioning events.

This is certainly not an exhaustive list of important scheduling considerations. On some projects, computerized BIM is not a requirement, or commissioning may be a minimal effort, or may be provided by a party other than the M/P subcontractor. However, on most larger and more complex projects, the M/P subcontractor may have some, or a significant amount of, liability as to prefabrication BIM activities and final commissioning activities. Furthermore, there may be many project-specific considerations, such as owner-furnished equipment and fixtures and training of the owner's personnel that occur near the completion of the project and should be included in the project CPM schedule as discrete activities.

Virtually all construction projects require careful consideration of crew flow and crew size restraints that should be included in the baseline CPM schedule. The M/P subcontractor's crew flow should be demonstrated by actual logic ties or restraints input into the baseline CPM schedule. The resulting crew loading curves for both the early and late dates should be analyzed to ensure that the planned crew sizes meet the M/P subcontractor's reasonable expectations and labor planning.

While some M/P subcontractors may not be responsible for performing the commissioning activities, on many projects the detailed requirements for commissioning fall within the contractual responsibility of the M/P subcontractor. In such cases, the M/P subcontractor should ensure that an accurate and properly sequenced commissioning logic chain be present at the outset of the project, in the baseline CPM schedule. Even when commissioning is provided by another party, the commissioning activities should be included in the baseline CPM schedule by the prime/CM so that the timing of the performance of the predecessor mechanical activities will have realistic forecasted completion dates and total float values.

The three important topics to be considered in the baseline schedule, in addition to the actual erection activities, are described in more detail below.

Defining the BIM (or Conventionally Drafted) Coordination Process and the Dependent Prefabrication Activities in the Baseline CPM Schedule

In today's prefabrication and computer modeling environment, many project specifications contain a requirement for the M/P subcontractor to participate in, or take the lead in, the coordination process, whether achieved by way of BIM or conventional drafting methods. When BIM is required and is undertaken as a collaborative process, developing a three dimensional model of the mechanical, plumbing, sheet metal, electrical, fire protection, and other key systems in spaces such as ceiling plenums and interstitial spaces can solve spatial conflicts prior to the commencement of fabrication and can reduce construction delays and costs. Even if coordination on a project does not include the utilization of a computerized BIM product, and instead utilizes conventional drafted coordination drawings, the need for a collaborative process remains an essential element of a productive and successful planning process. Moreover, the timing of both BIM and conventionally drafted coordination drawings is critical to success on the project. The various coordination methods in use today must be commenced early enough in the project to allow for timely pre-planning, procurement, and prefabrication of the mechanical and plumbing systems. Whether conventional drafted coordination drawings or computerized BIM, these crucial activities must be included in the development of the baseline CPM schedule.

Frequently, the contract specifications or the subcontract documents set forth the requirement that the M/P subcontractor receive approval or acceptance of the coordinated drawings by some party (e.g., the owner's engineer of record, the construction manager, or another party) prior to commencing prefabrication activities, such as the prefabrication of piping systems. Because the approval or acceptance of fully coordinated drawings is usually required prior to the M/P subcontractor commencing prefabrication work, including these prefabrication activities in the baseline CPM schedule is essential. The details of this process should be agreed upon at an early stage in the project planning, such as at the kick-off meeting or at the time when the flow and sequence of the BIM or manually drafted coordination process is established by the construction team. Omitting the prefabrication activities that are the logical successors of the acceptance of the coordinated drawings will result in false float within the schedule and may render the baseline CPM schedule inaccurate and unreliable.

The M/P subcontractor should carefully review all coordination (by way of BIM or other methodologies) requirements in the contract documents prior to commencing the preparation of the baseline CPM schedule. This is a crucial step in the schedule development process because the coordination logic (i.e., the BIM activities, activity durations and logic ties), coupled with the M/P subcontractor's prefabrication activities, will, in most cases, establish the M/P subcontractor's critical path in the baseline CPM schedule, defined as the longest chain of interlinked activities which, if delayed by even a day, will equivalently delay either the project end date, or at least the end date of the M/P subcontractor's work.[3] All too often, the BIM or other coordination activities, with their estimated durations and logic ties to approvals and then the commencement of prefabrication activities, are totally omitted from the prime/CM's baseline schedule, or in other cases, the coordination scope of work is scheduled in such a summary level that it adds little or no usable information within the otherwise reasonably detailed baseline CPM schedule. Such conditions should be avoided in the planning process.

Based on the contract documents, which vary from project to project, a baseline BIM logic chain for a discrete portion (i.e., Area A, Levels 1–4) of a hypothetical project could appear as shown in Figure 1.

In this hypothetical example, the baseline CPM schedule should contain a milestone activity for production of the CAD backgrounds provided by the owner's design team to the M/P subcontractor. This milestone activity commences a chain of events that includes the development of the first set of background drawings that contain base contract activities such as plumbing piping, ductwork, mechanical piping, electrical activities, and the fire sprinkler work within discrete areas of the project's ceiling plenums, as defined by floor levels and/or physical areas.

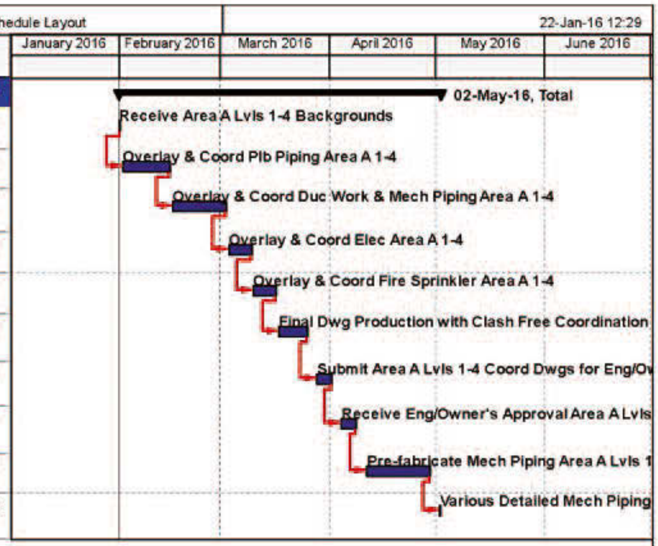
On particularly large or complex projects, it may be desirable to add detail to the coordina-

[3] The M/P subcontractor's critical path (i.e., its longest connected chain of activities) may be different from that of the prime/CM. In some schedules, the M/P subcontractor's work is shown to finish earlier than the prime/CM's work, and if the M/P subcontractor is delayed from its planned finish date, it may be possible to recover delay costs. The theory that a mechanical subcontractor can recover its delay costs (i.e., "delay" as between the mechanical subcontractor's planned finish date and its actual finish date) on a construction project, even when the prime contractor completed on time, was successfully litigated in the case of *E.R. Mitchell Construction Co., Appellant, v. Richard J. Danzig, Secretary of the Navy, Appellee*, 175 F.3d 1369 (Fed. Cir. 1999).

Figure 1

Test — Classic Schedule Layout — 22-Jan-16 12:29

Activity ID	Activity Name	Original Duration	Start	Finish
Total		66	01-Feb-16	02-May-16
10	Receive Area A Lvls 1-4 Backgrounds	1	01-Feb-16*	01-Feb-16
20	Overlay & Coord Plb Piping Area A 1-4	10	02-Feb-16	15-Feb-16
30	Overlay & Coord Duc Work & Mech Piping Area A 1-4	12	16-Feb-16	02-Mar-16
40	Overlay & Coord Elec Area A 1-4	5	03-Mar-16	09-Mar-16
50	Overlay & Coord Fire Sprinkler Area A 1-4	5	10-Mar-16	16-Mar-16
60	Final Dwg Production with Clash Free Coordination	7	17-Mar-16	25-Mar-16
70	Submit Area A Lvls 1-4 Coord Dwgs for Eng/Owner Review	5	28-Mar-16	01-Apr-16
80	Receive Eng/Owner's Approval Area A Lvls 1-4	5	04-Apr-16	08-Apr-16
90	Pre-fabricate Mech Piping Area A Lvls 1-4	15	11-Apr-16	29-Apr-16
100	Various Detailed Mech Piping Installation Activities	1	02-May-16	02-May-16

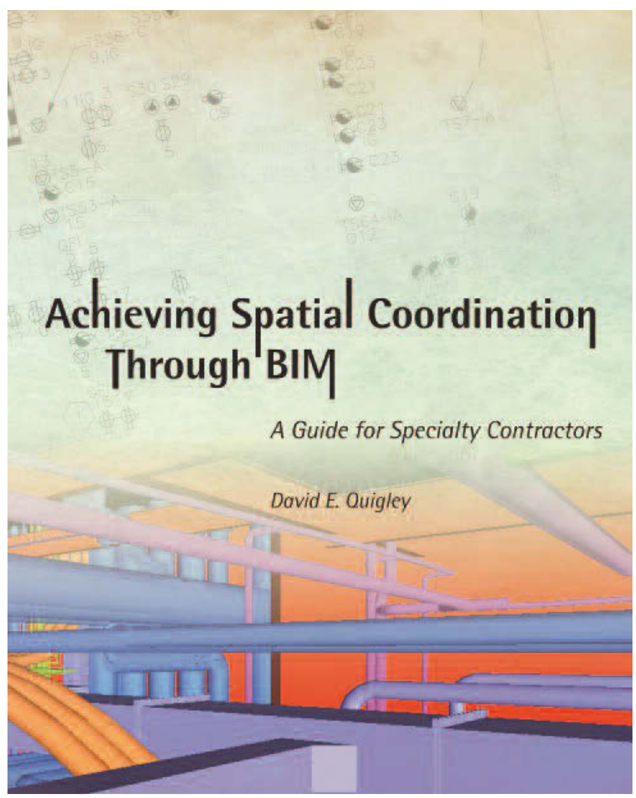


tion (computerized BIM or drafted) logic sub-network. For instance, in the case of projects utilizing BIM, it may be advisable to add discrete activities for the receipt of BIM drawings provided by other trade contractors, for the clash detection and correction steps, and more detailed activities describing the engineer of record's review and acceptance of the BIM drawings prior to the commencement of pre-fabrication activities. In most cases, the level of BIM sub-network detail will be dictated by the contract specifications and the complexity of the project. If the M/P subcontractor suspects that the project may suffer from an incomplete design or defective design, it may behoove the M/P subcontractor to add detail to the baseline BIM schedule sub-network so that added BIM work causing impacts to the schedule can be more easily identified. On projects that are not fully designed at the time of contract execution, the milestone date for the receipt by the M/P subcontractor of 100% complete construction documents should appear in the baseline CPM schedule. In all cases, the BIM sub-network must be inserted into the master baseline CPM schedule and not be analyzed apart from the overall CPM schedule.

Often the M/P subcontractor is the contractually responsible party to incorporate clash corrections identified by a host of other subcontractors (e.g., electrical, sheet metal, fire protection) into a final set of coordinated BIM drawings. Once clash free, the BIM drawing files may be required to be approved by the engineer of record. This is an essential activity in the schedule since any BIM coordination efforts that change the locations or sizes of piping, duct work, electrical and similar systems must be reviewed and approved by the designer of record. In order to reduce liability risks, the M/P subcontractor should request and receive formal approval from the designer of record for any changes in system routing and/or sizing that resulted from the BIM process.

After approval, the prefabrication of the piping systems can commence. This is a crucial logic tie that will ensure that the schedule will not depict the commencement of pipe fabrication until the authorized party (usually the designer of record) approves the coordinated drawings. It is very important to properly depict the coordination logic, whether by BIM or other processes, with reasonable durations, in the baseline CPM schedule.

[4] Copyright 2013 by the MCAA, the Mechanical Contracting Education and Research Foundation, NECA, the New Horizons Foundation, and SMACNA.



The M/P subcontractor may wish to reference an industry publication in the preparation of the detailed BIM logic in the baseline schedule, entitled *Achieving Spatial Coordination Through BIM*.[4] This publication, pictured above, was prepared by representatives of the MCAA, SMACNA and NECA, and is available through the named associations' administrative offices.

With regard to project scheduling, particular attention should be paid to Section 4.3, "Schedules," and Section 5.1, "Establishing Norms for the Project," in the above referenced publication. The former section refers to important considerations when preparing the BIM activities and logic ties within the baseline CPM schedule. The latter section contains the definition of normal and expected coordination for a specialty contractor, which definition has also been published by the National Institute of Building Sciences buildingSMART alliance™ in the *Journal of Building Information Modeling*, Fall 2011 edition. M/P subcontractors should carefully review and consistently apply the published guidelines regarding what can be reasonably expected by the contracting team when a BIM requirement is present on a construction project. When these reasonable and published expectations are not met due to design issues, and the results are added cost and time of performance, the M/P subcontractor should evaluate the damage and, if appropriate, seek an equitable adjustment to the subcontract.

Having detailed BIM coordination logic in the baseline CPM schedule will facilitate more accurate and meaningful comparisons between the baseline plan and the actual execution of the BIM process. Should the clash identification and correction process (with three such clash detection and correction steps expected, consistent with the definition of normal and expected coordination cited in Section 5.1 of the referenced publication) extend beyond the expected norm and thus take longer than reasonably planned, the schedule slippage and critical path delay, if any, can be demonstrated.

Mechanical and/or Plumbing Crew Restraints in the Baseline CPM Schedule

On the vast majority of construction projects, the M/P subcontractor has not estimated, or planned upon, providing unlimited resources. As crew sizes are increased beyond a reasonable plan, the M/P subcontractor must provide added tools, equipment and supervision, which can result in significant and unanticipated added costs. Therefore, the M/P subcontractor must ensure, to the fullest extent permitted by the prime/CM, that reasonable and supportable crew restraints are present in the baseline CPM schedule. The absence of reasonable and supportable crew restraints in the baseline schedule will, in most instances, result in false float and may render the entire baseline schedule unreliable and fatally flawed.

There are three principal reasons why M/P subcontractor's crew restraints (i.e., actual logic ties inserted between activities in the CPM schedule database) are omitted in the prime/CM's baseline CPM schedule. These are: 1) the M/P subcontractor's lack of understanding regarding the importance of installing crew restraints into the baseline schedule; 2) the M/P subcontractor's lack of resource planning that would allow for the definition of crew flows in the CPM schedule by way of logic ties or restraints; and 3) the prime/CM's refusal to allow the M/P subcontractor to insert crew restraints into the

Change Orders

schedule by way of logic ties or restraints. In most instances, the M/P subcontractor must specifically request, preferably in writing, that the prime/CM permit crew restraints to be inserted into the baseline CPM schedule. Also, in most cases, the prime/CM will not know the M/P subcontractor's crew flow or restraints.[5] This information must come from the M/P subcontractor and the preparation of this vital information can only result from a reasonable and well thought out labor plan and crew flow analysis.

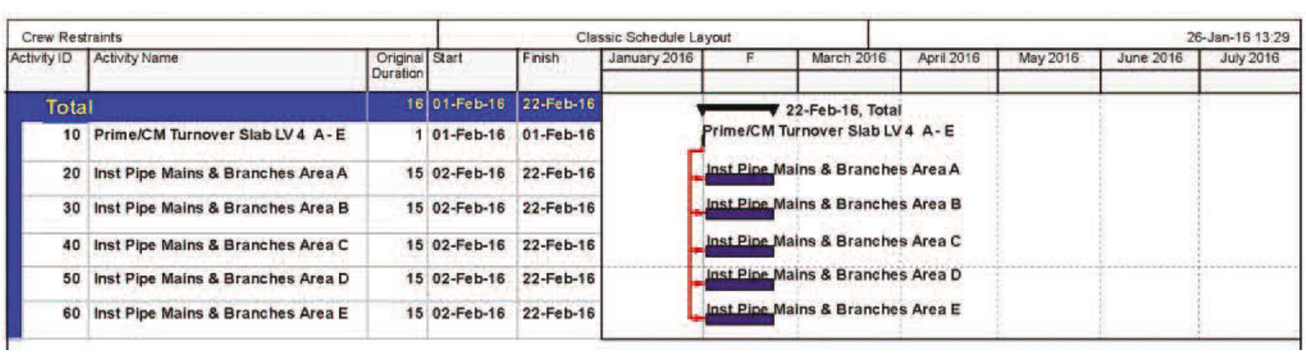
At times, the prime/CM may instruct the M/P subcontractor that crew restraints in the CPM schedule are unnecessary because the M/P subcontractor's form of contact requires the M/P subcontractor to supply whatever labor may be required to meet the prime/CM's CPM schedule. This chapter is not a treatise on construction law, however the prime/CM's duty to cooperate and not to unreasonably hinder or financially harm a subcontractor is well established. To the fullest extent possible, the M/P subcontractor should assert its right, and duty, to insert appropriate crew restraints into the baseline CPM schedule in order to assist in the preparation of a reliable and usable schedule document (i.e., one that does not contain false float due to the absence of proper crew restraints).

Assume the following in this hypothetical example: 1) a cast in place concrete structure on a large high rise medical research building; 2) a sizable quantity of specialty stainless steel welded pharmaceutical grade piping; 3) a limitation on the number of qualified stainless steel welders and orbital welding equipment; 4) five physical "Areas" are designated per floor slab, A through E; and 5) once a floor slab is placed and stripped, all mechanical piping mains can (by the laws of physics and assuming unlimited resource availability) commence at the same time.

The schedule example below (Figure 2) was prepared without any crew flow or crew restraint logic. As a result of the lack of crew restraints, the stacking of critical stainless pipe erection and welding activities is improperly depicted as the M/P subcontractor's baseline

[5] A schedule "restraint" can include by examples: (i) physical restraints such as having site areas, mechanical rooms, or slab surfaces available; (ii) crew or labor restraints such that the schedule will not depict early or late date crew curves in excess of the M/P subcontractor's estimated labor plan; (iii) equipment restraints such as the planned number of welding machines, cranes, or other major equipment items; (iv) BIM and prefabrication restraints to the commencement of prefabrication activities; and (v) procurement restraints from the delivery of material and/or equipment to the installation of those items as shown in the construction schedule.

Figure 2



Activity ID	Activity Name	Original Duration	Start	Finish
	Total	16	01-Feb-16	22-Feb-16
10	Prime/CM Turnover Slab LV 4 A - E	1	01-Feb-16	01-Feb-16
20	Inst Pipe Mains & Branches Area A	15	02-Feb-16	22-Feb-16
30	Inst Pipe Mains & Branches Area B	15	02-Feb-16	22-Feb-16
40	Inst Pipe Mains & Branches Area C	15	02-Feb-16	22-Feb-16
50	Inst Pipe Mains & Branches Area D	15	02-Feb-16	22-Feb-16
60	Inst Pipe Mains & Branches Area E	15	02-Feb-16	22-Feb-16

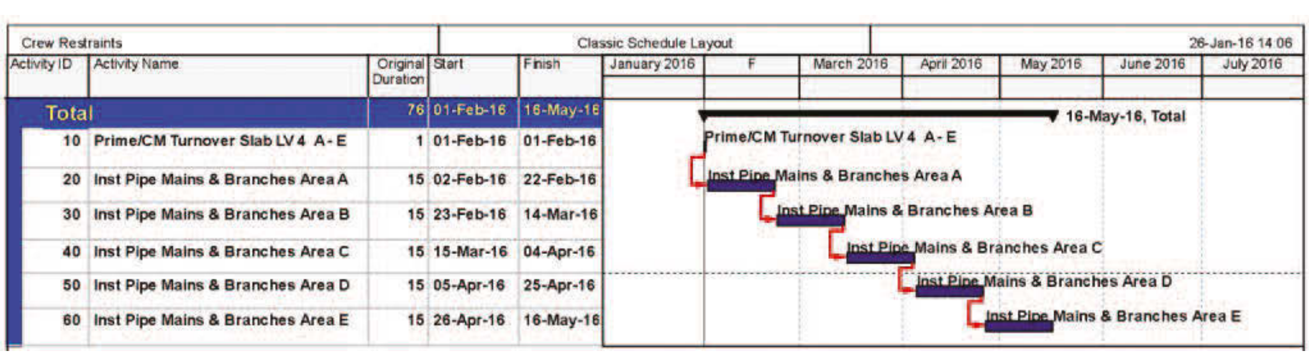
plan. In this hypothetical example, the number of qualified orbital stainless steel welders, and orbital welding machines, is very limited. Without any consideration for the planned crew flow, the schedule allows for the concurrent installation of the stainless steel piping in each area by floor. If the M/P subcontractor is unable to staff the floor with five welding crews and five orbital welding machines, the schedule will exhibit false float and a false planned crew curve.

However, if the M/P subcontractor actually has only one planned stainless steel orbital welding crew and one welding machine and inputs finish to start crew restraints in the baseline schedule to demonstrate that planned limitation, the baseline schedule will show a remarkably different crew curve, expected early and late finish dates and float values. While the example above may be physically possible, it is not reflective of how the M/P subcontractor plans to execute its contract work scope. Moreover, if the M/P subcontractor only planned on utilizing one stainless steel welding crew, Figure 2 represents improper crew stacking that was not contemplated by the M/P subcontractor in its original estimate.

The example (Figure 3) depicting the M/P subcontractor's plan to have only one specialty stainless steel welding crew, provides for accurate crew curves and float computations. If, in the Figure 2 example above, the M/P subcontractor receives a change in scope that elongates activity 20, "Install Pipe Mains & Branches Area A" by 8 days, the effect of this change does not ripple through to the other mechanical piping activities that will utilize this scarce welding resource. However, in the example below, if activity 20 is elongated due to a change, or for that matter, any reason including the M/P subcontractor's own production issues, those delay effects will be shown to ripple through all dependent activities. Thus, the proper effect of schedule impacts will be depicted much more accurately throughout the CPM schedule network. Moreover, the resulting planned crew curve that results in the baseline schedule will accurately depict the M/P subcontractor's plan to install the base contract scope of work.

The logic ties between the various M/P subcontractor's activities are finish to start logic ties that have been inserted into the baseline CPM schedule. Such logic ties must be provided to the prime/CM by the M/P subcontractor. The absence of proper crew restraints in the baseline CPM schedule will, in virtually all cases, result in a flawed and unreliable baseline CPM schedule. In cases where the M/P subcontractor is prevented from inputting proper crew

Figure 3



restraint logic ties in the baseline schedule, the M/P subcontractor should notify the prime/CM, in writing, that the schedule does not reflect the M/P subcontractor's plan to accomplish the work and that the resulting schedule is unacceptable to the M/P subcontractor.

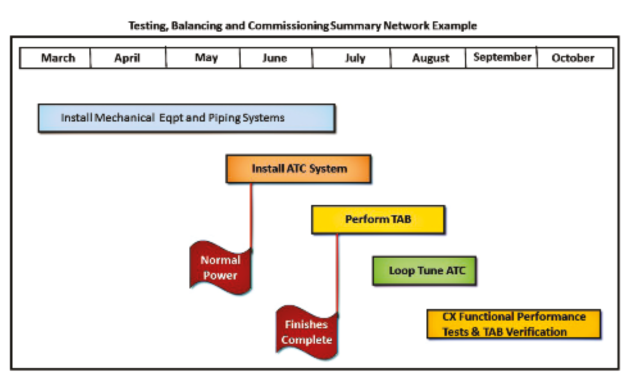
Test & Air Balance ("TAB") and Commissioning ("CX") in the Baseline CPM Schedule

Many construction contracts require the M/P subcontractor to fully commission the project. In such cases, even if the M/P subcontractor issues a subcontract to a separate commissioning agent or contractor, the scheduling of the commissioning process still falls upon the M/P subcontractor. In many baseline CPM schedules, the M/P subcontractor is not asked to provide detailed TAB and CX input to the prime/CM during the development of the baseline CPM schedule. This may lead to improperly shortened CX schedule sub-networks that result in delays at the conclusion of the project because the TAB and CX work was not properly depicted in the schedule (e.g., by way of improperly short activity durations and/or incorrect and missing logic ties).

The first step in the creation of an accurate and reliable TAB and CX sub-network that will be inserted into the prime/CM's baseline CPM schedule is to read the technical provisions of the contract to ascertain what level of TAB and CX is required on the project. On some types of projects, CX is little more than traditional startup operations. However, on many projects, TAB and CX work are a complex, interrelated series of activities that are driven both by the completion of building features and systems (e.g., permanent power available, glass and glazing complete, finished ceilings and doors installed), and by the limitation of specialized commissioning technicians (i.e., TAB and CX crew restraints). If the M/P subcontractor is not familiar with performing TAB and CX tasks on a complex project, the technical representatives who will actually perform the TAB and CX tasks should be engaged early in the planning and scheduling process so that the baseline CPM schedule will accurately reflect the level of effort that will be required to complete the project.

As can be seen in the summary flow chart (Figure 4), the general TAB and CX may, depending on the specifications and type of systems, overlap in time. However, by area of a building, there is generally a finish to start relationship between the TAB and CX activities. As noted above, the TAB and CX activities are logically preceded by such activities as permanent power on line, building envelope complete and certain interior finishes in place (e.g., doors, ceiling system, and windows). These logic restraints must be present in the baseline CPM schedule. The absence of the proper logic restraints from the work of other trades, such as the availability of permanent power, may cause the schedule updates to incorrectly identify the M/P subcontractor as the cause of commissioning delays, when, in fact, such

Figure 4



delay may be the result of the failure of other trades to timely perform their activities.

When developing the baseline CPM schedule, particularly for a complex process mechanical and electrical project such as a manufacturing or research facility, a much more detailed TAB and CX activity sub-network will be required, potentially comprised of many activities. It is essential that a reasonably complete TAB and CX schedule be prepared and included in the baseline schedule. Even if this sub-net has to be refined or revised as the TAB and CX specialists become engaged in the project, having reasonable logic restraints and time slots for the TAB and CX activities are very important to the production of a reasonable baseline schedule. Time spent at the outset of a project to properly plan and sequence the TAB and CX requirements, and to incorporate those sub-networks into the baseline CPM schedule, will result in a much more reliable project management tool. The absence of accurate TAB and CX activity identification, durations and logic ties will result in an inaccurate and unreliable baseline CPM schedule.

Other Important Baseline Schedule Considerations

In addition to the three areas of focus described above, the M/P subcontractor must evaluate the activity descriptions, estimated durations and logic ties that comprise the flow of the work under the subcontract. Duration estimates should be derived from the relationship between the quantity of work, the number of craft persons assigned to the activity and an estimated production rate. The linear feet of piping, number and type of joints, inherent difficulty factor (e.g., taking into consideration height above the finished floor), and crews to be assigned must all be evaluated when the activity duration is estimated. Additional considerations include the following.

Developing the M/P Subcontractor's Activity Descriptions

Carefully defining the activity's description, which allows the project team to know what work is contained within the CPM schedule activity, is a crucial step in preparing a useable and useful baseline CPM schedule. Proper activity descriptions, in addition to a definition of scope, may include locations by floor, area, or phase that further define the location of the work. For erection activities, the M/P subcontractor should be able to reference the activity description in the CPM schedule and then locate the scope of work on the contract documents. By way of example, an activity description should include system type and location, such as: "Install CHWS/R Mains from CL 1 – 10 Level 4, Area C." This specific description includes the system type (CHWS/R) and the specific location of the work by floor and column lines. It is also a good practice to limit activity descriptions, and the resulting scopes or work, to one primary trade. Thus, mechanical piping activities should be separated from plumbing activities, and from sheet metal duct installation. Developing specific activity descriptions allows the M/P subcontractor to better estimate the activity's planned duration and crew requirements in the baseline CPM schedule and will also aide in the progress reporting in the subsequent schedule updates. As a guideline, durations for work activities[6] should fall in

[6] Shop drawing preparation and procurement activities may have significantly longer durations.

a range of between 3 and 22 work days, but may be further defined by terms of the contract specifications.

In many cases in which the M/P subcontractor has not been involved with the development of the baseline CPM schedule, activities such as "MEP Ceiling Rough-in" or similarly vague activities, frequently appear in the schedule. "MEP" refers to "mechanical, electrical and plumbing" system rough-in work. Such descriptions result in forecasting errors in the baseline CPM schedule. In this common example, on most projects, the mechanical piping, ductwork, plumbing and electrical systems are not installed in the ceiling plenums at the same time and concurrently in the same building area. These sorts of "short cut" activities do not properly define the scope of work (in this example, potentially four different trades) required by the contact drawings.

Open Starts and Ends ("Dangles") Within the CPM Schedule Network

Some schedulers improperly prepare a baseline CPM schedule as if it were a loosely tied bar chart. Usually, in such circumstances, the scheduler ties the starts of activities but fails to tie the finishes. This represents incomplete logic within the CPM schedule and results in unreliable and inaccurate schedules. It is a basic tenet of CPM scheduling that there can be only two activities that either have no predecessors or successors. Those two generic activities are "Notice to Proceed" that commences the project and "Project Complete" that denotes the final finish of the contract work. Other than the activities that denote the commencement of the overall project and the completion of the overall project (notwithstanding what the activities are called by the scheduler), with very few exceptions, all other activities must have logic ties at the start and end of the activity.

In a CPM schedule, there are four possible logic ties: finish to start ("F/S"), start to start ("S/S"), finish to finish ("F/F") and start to finish ("S/F"). Within the vast majority of construction schedules, all logic relationships in the CPM schedule are defined by the first three types; S/F logic ties are very seldom used in construction CPM schedules.

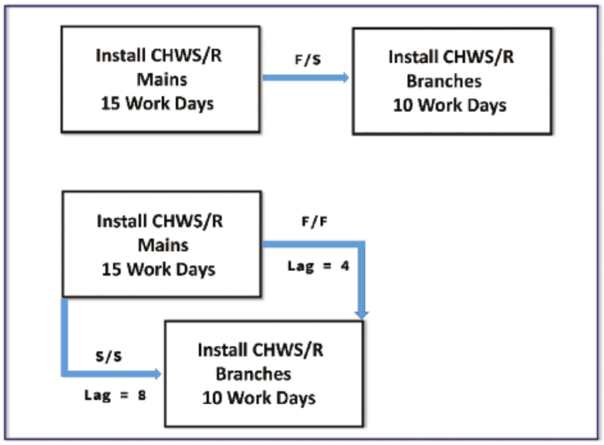
F/S logic ties define a relationship wherein the preceding activity must finish before its successor can start. S/S logic ties define a relationship wherein the preceding activity must start on a date on or before its successor (dependent) activity can start. F/F logic ties define a relationship wherein the preceding activity must finish on a date on or before its successor activity can finish. In addition to these three basic types of logic ties or restraints, the scheduler can impose "lead" and "lag" durations, commonly referred to simply as "lag durations."[7] These lag durations further define the S/S and/or F/F overlaps between the predecessor and successor activities and, like activity durations, are estimated durations of overlap.[8]

[7] "Lead" durations are placed on S/S relationships and "lags" are placed on F/F relationships. It is generally improper to place a lag duration on a F/S relationship. Such cases usually represent the scheduler's attempt to define, for example, a concrete curing duration or some other place holder. In virtually every case, a F/S relationship with a lag implies that the scheduler has failed to define the event, such as procurement of an item or concrete curing, that could better be defined as a discrete activity within the CPM schedule.

[8] Another derivation of the common lag is called a negative lag and is allowed by certain scheduling software systems. The use of negative lags to define activity overlaps is discouraged since lead durations on S/S relationships may be different from lag durations on F/F relationships, and these lead and lag durations affect total float in the CPM schedule.

The three most utilized logic ties appear graphically as follows:

Figure 5



In the examples above, the three most common CPM scheduling restraints are depicted. In the top graphic, the pipe mains must be completed before the branch piping can commence (a finish to start relationship where pipe mains are the predecessor and pipe branches are the successor). In some cases, overlapping of work activities may be desirable and possible (by the laws of physics and based on available crews and equipment). In the bottom graphic, a S/S logic tie with lag duration and a F/F logic tie with lag duration have been utilized to show that 8 work days of the pipe main installation must be started before the branch piping can commence (a start to start relationship with an overlap, or lag duration, of 8 work days). When a S/S logic tie is utilized to define the relationship between the start dates of two activities, in the vast majority of cases, a F/F logic tie must also be utilized. The F/F logic tie prevents the successor activity from finishing before the predecessor activity completes, with an overlap in this example of 4 work days. If the F/F logic tie is omitted and in the presence of an impacting event, it may be possible for the pipe mains to finish later, or in some cases significantly later, than the branch piping that connects to the mains. Also, unless a separate logic tie is introduced into the schedule, the pipe main installation activity would be an "end dangle," also called an open end. If the pipe main installation activity is not tied from its finish to another logical activity, such as to the finish of the branch piping in the same area, then the finish float value of the pipe main activity will be unrealistic.

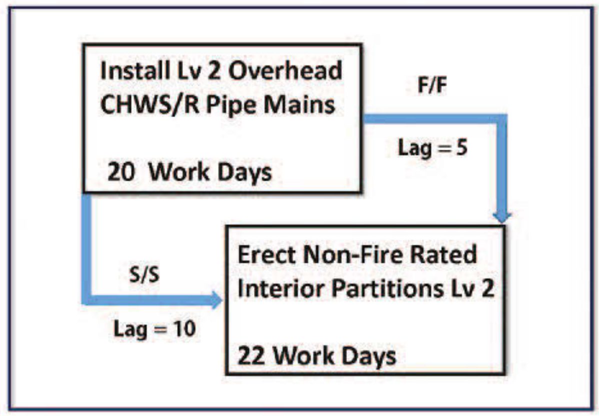
The omission of a F/F logic tie in the presence of a S/S logic tie between two related activities is the most frequently committed technical error in CPM scheduling. The M/P subcontractor should, to the fullest extent possible, review the baseline schedule to ensure that complete logic is depicted, as described above. The absence of proper and complete logic ties will most likely result in inaccurate schedules, and unreliable results when the schedule is progressed and when TIAs are introduced into the schedules to quantify the effects of changes in scope and other delaying events.

Contractual Considerations Regarding the Baseline CPM Schedule for the M/P Subcontractor

Some contracts require that the prime/CM receive from each major subcontractor a "sign off" signifying approval of the baseline schedule so that this record of acceptance can be provided to the owner. The M/P subcontractor should not sign off with an approval of a baseline schedule until that schedule has been thoroughly vetted by the M/P subcontractor. If the M/P subcontractor does not possess the technical scheduling experience to perform a detailed review of the project baseline schedule, a construction scheduling expert or consultant should be retained to assist in the review process. From time to time, subcontracts between the prime/CM and the M/P subcontractor contain a "mutually agreed-to schedule" clause. Such clauses can be very helpful to the M/P subcontractor. A "mutually agreed-to schedule" clause means that the prime/CM expressly commits to expend its best efforts to develop a CPM schedule that is mutually agreed to with other contractors, such as the M/P subcontractor, as to activities, logic ties including crew restraints, and performance dates. In the absence of such a clause and during subcontract negotiations, the M/P subcontractor should negotiate with the prime/CM to have this important requirement added to the final contract documents. The requirement to produce a "mutually agreed-to schedule" is in the best interests of the prime/CM and the M/P subcontractor.

On some projects, agreements are made that affect the subcontract price and timing of certain facets of the work. A very common example of such an agreement is a commitment by the prime/CM to withhold the erection of interior non-bearing or non-fire rated partitions (masonry and/or stud walls) until some measurable portion of the M/P subcontractor's overhead piping mains and/or branch piping has been installed. It is a well-known fact in the industry that when interior walls are erected prior to the installation of overhead mechanical and plumbing piping systems, the M/P subcontractor's labor productivity suffers a decline. When interior partitions are erected in a wholesale fashion before overhead piping systems are commenced, the loss of labor productivity and time impacts can be substantial. Because of this fact, and in the presence of a sequencing agreement as described above, the M/P subcontractor must carefully review the baseline CPM schedule to ensure that the logic restraints that reflect this sort of agreement are present, and correctly linked, in the schedule. This sort of restraint could appear as shown in the following example:

Figure 6



In this example, the CPM schedule logic reflects the agreement that mechanical piping mains must "lead" the start of the dependent non-fire rated wall erection by, in this example, 10 work days, and that the dependent non-fire rated partitions must "lag" the finish of the pipe mains by 5 work days. The lead and lag durations are very important and should be reached by mutual agreement between the M/P subcontractor and the prime/CM. Obviously, the example above can be modified and applied to plumbing piping, sheet metal duct, electrical feeders, or other affected activities.

Shop Drawing, Engineer's Review, and Procurement Activities in the Baseline CPM Schedule

In addition to installation activities, the M/P subcontractor should consider incorporating its shop drawing or submittal package development, the owner's review of the shop drawing or submittal package and the procurement (manufacturing and delivery) activity that precedes the installation of equipment or material items such as chillers, boilers, air handling units, pipe supports, piping, and piping appurtenances. These procurement activities should commence in conjunction with the notice to proceed, or in conjunction with the appropriate BIM step in the coordination process.

The activity durations for the preparation of the shop drawings or submittal package and the durations for the fabrication and delivery of equipment and materials should be derived from, or at least verified with, the vendors. To the extent that certain stages in the BIM coordination process affect when submittal preparation or procurement activities can occur, these logic restraints must be present in the baseline CPM schedule. Most construction contracts provide a minimum duration that the contractor must allow to the designers/engineers for review of the contractors' shop drawings. These minimum durations should be included in the baseline schedule for the "review and approval" activity in the procurement logic. In some cases, as with complex mechanical and plumbing systems, a resubmittal and a re-review set of activities should be considered within the baseline schedule in order to provide a more realistic overall duration to obtain acceptance of such submittals.

Obtaining the Baseline CPM Schedule from the Prime/CM

Obviously, it benefits every trade on a construction project when the prime/CM provides the complete CPM schedule for a thorough review and comment session. The most effective means to accomplish a trade contractor's review of a CPM schedule is for the prime/CM to provide the native scheduling file to any of the subcontractors who have the means (internally or through a scheduling consultant) to read a native schedule file. Two of the most widely utilized scheduling software systems, Primavera and Microsoft Project, export the complete schedule files in formats that can be opened and reviewed on computers that utilize those software systems.

Only by having the native schedule data file can a complete and thorough review of the durations and logic be performed.[9] While some prime/CMs have corporate policies that prevent the field management staff from sharing the native schedule files with the subcontractors, this is counterproductive and does not represent a cooperative approach to utilize one of the most important management tools on the project—namely the CPM schedule. It is unfortunate that many prime/CM's take the position that the baseline CPM schedule and the subsequent updates, in their native forms, constitute proprietary information that cannot be shared with the prime/CM's partners on the project—the various the trade contractors.

In cases where the M/P subcontractor has the capability to open and read the native scheduling program files, and wishes to perform a thorough schedule review on a project, a request for the native scheduling files should be made, in writing, to the prime/CM. This request letter should be positive and con-

[9] Although it may be claimed that a thorough logic review can be performed utilizing only a tabular report, on larger projects, this is highly impractical and overly burdensome and may, in fact, be an impossibility.

structive. In the cases where the prime/CM refuses to provide the native schedule files, and instead only provides static PDF "pictures" of the schedule or portions thereof,[10] the M/P subcontractor should object in writing, asserting that the only means of fully analyzing a CPM schedule, with its myriad of logic ties and potential lag values, is by use of the native schedule files.

Unfortunately, when the prime/CM refuses to provide to the M/P subcontractor the native schedule files (assuming that there is no contractual requirement for these files to be provided to the trade contractors), the only non-litigious step the M/P subcontractor can take is to document this action in writing, taking strong but professional objection to this obfuscation of the project CPM schedule. In cases where the prime/CM refuses to provide reasonable access to the CPM schedule, the M/P subcontractor must put the prime/CM on written notice at the outset of the project and with each schedule update, requesting the native schedule files in order to perform a competent review of the baseline CPM schedule and the subsequent updates. If the M/P subcontractor can determine, from the printed (PDF) versions of the schedule that may be provided by the prime/CM, that the schedule is incorrect as to activities, durations, float values and/or dates, the M/P subcontractor should notify the prime/CM, in writing, that the schedule is not acceptable. The M/P subcontractor should also request meetings to review the schedule and to offer corrective suggestions so as to assist the prime/CM with the preparation of an acceptable baseline CPM schedule.

[10] It has become a standard practice in the industry for the prime/CM to only provide to the trade contractors PDF images of the schedule or portions thereof, and in many instances, the late start and finish dates and total float values are suppressed in the PDF schedule snapshots. This sort of limited schedule presentation gives the reviewer little or nothing to use as a means to evaluate logic ties, lag values, late dates, and float values.

Early Finish in the Baseline CPM Schedule

The contract documents on most construction projects contain an overall project completion date[11] by which the work must be substantially complete. Often, the contact contains a liquidated damages provision whereby the owner may assess a stipulated amount for each calendar day the project is inexcusably delayed beyond the contract completion date. The M/P subcontractor should determine the contractual finish date of the project and know the amount of liquidated damages that may be assessed for certain kinds of delay.

Some prime/CMs employ a strategy to reduce the bid or proposal price of the project by preparing a baseline schedule that contemplates completing the work earlier than the required contract completion date. This strategy reduces the number of weeks or months a prime/CM plans to expend field and home office overhead costs, which on some projects are substantial. This is called an early finish schedule. Such schedules can impose upon the M/P subcontractor a finish date that is earlier than the project completion date shown in the contract. If the baseline schedule has been prepared cooperatively, then the prime/CM will have

[11] The contract may contain other required completion dates on interim milestones or specific phases of the work and the M/P subcontractor should be aware of all contractually required finish dates.

shared this strategy with the M/P subcontractor so that the work can be planned within the early finish schedule. This early finish schedule may require expedited delivery of equipment and materials, added crews and/or the use of overtime. In any event, the M/P subcontractor should carefully review the baseline schedule to ensure that the project completion date(s) comport with those contained in the contract, or those which have been agreed upon between the prime/CM and the M/P subcontractor at the outset of the project.

In cases where the M/P subcontractor has not been involved in the development of the baseline CPM schedule, and where the prime/CM has unilaterally included an unacceptable early finish date for the work, the M/P subcontractor should notify the prime/CM accordingly. If the early finish schedule could result in added costs to the M/P subcontractor, the prime/CM must be notified in writing of the potential for such unanticipated and added costs, and that a request for equitable adjustment will be submitted at a future date to recover these costs.

The M/P subcontractor should also evaluate the risk of not being able to recover the costs of delay to an early finish schedule prepared by the prime/CM. While there have been reported cases that support a contractor's right to finish earlier than a contract finish milestone date, and to recover extended general condition costs for otherwise compensable delays to that early finish date, in many instances the owner will refuse to recognize this right to finish early and will consider the duration between the contractor's scheduled early finish and the contractual finish date as total float which can be used by either the owner or the contractor with impunity. The M/P subcontractor should consider the potential financial risks versus the rewards of submitting an early finish baseline schedule.

Documenting Issues with the Prime/CM's CPM Schedule

Most subcontracts between a prime/CM and a M/P subcontractor require that notices of potential impacts be transmitted in writing and within a specified period of time. Such requirements extend to scheduling issues, such as the absence of a reliable schedule, or in the case that the M/P subcontractor's review of the prime/CM's schedule reveals substantial defects that prevent the M/P subcontractor from accepting the baseline CPM schedule. It is recommended practice that the M/P subcontractor respond in writing to each and every schedule submittal provided by the prime/CM to the M/P subcontractor, which include draft schedules, the baseline CPM schedule, and each and every update to the baseline CPM schedule. Such evaluations and notices of deficiencies should be written in a constructive fashion and should include specific examples of unacceptable scheduling practices that can include: 1) missing or incorrect activities; 2) unrealistic activity durations; 3) improper sequencing (e.g., lack of crew restraints, out of sequence work); 4) questionable total float values; 5) inaccurate progress reporting in the updates to the baseline schedule; and 6) the absence of the schedule itself (i.e., when the schedule is not provided to the M/P subcontractor). As previously noted, all requests for schedule data, including requests for the native schedule electronic media, should be in writing.

In some cases, even when the prime/CM refuses to provide the native electronic scheduling files or even sufficiently detailed and complete print-outs of the schedule, the M/P subcontractor may be able to determine that the schedule is defective. In this event, the M/P subcontractor should notify the prime/CM, in writing, that the schedule is not acceptable. Even when the M/P subcontractor cannot ascertain the reasonableness of the prime/CM's baseline CPM schedule due to the lack of sufficient data, the M/P subcontractor should notify the prime/CM, in writing, that a thorough schedule review has not been possible, accompanied by a reservation of rights to recover any damages that may arise from attempting to adhere to the CPM schedule.

The M/P subcontractor must carefully read all provisions of the contract documents, giving consideration to the notice provisions and any waiver language that may appear within the contract or that is included in change order forms or within the payment application documents.[12] Notifications of potential or actual schedule and/or cost impacts must be transmitted to the appropriate party or parties in strict accordance with the applicable provisions of the contract. To the fullest extent possible, the M/P subcontractor should confirm that that prime/GC is timely forwarding the scheduling and cost impact notices and REAs to the owner, in accordance with the contract provisions, so as not to waive the M/P subcontractor's rights to an equitable adjustment in the event that the impact is an owner-caused event. Also, the M/P subcontractor should encourage the prime/GC to avoid signing unmodified[13] contract documents such as change order forms and monthly payment applications that may contain waiver language.

Even when the prime/CM does not respond to the M/P subcontractor's notifications and/or TIAs, such non-responsiveness does not relieve the M/P subcontractor of its contractual duties and responsibilities. In cases where the M/P subcontractor detects that the CPM schedule (baseline or updated) has been modified and is thereafter directed to proceed with changed work scopes or sequencing[14] that the M/P subcontractor believes may, or will, adversely affect its timing and/or costs, before proceeding with the revised schedule the M/P subcontractor must provide proper and timely notice of such conditions.

Management of a construction project requires vigilance by the M/P subcontractor as to the timing and sequence of the work. That requirement of vigilance extends to the development and use of the CPM schedule.

---

[12] Examples of waiver language, such as change order "full accord and satisfaction" clauses and payment application waiver language, are addressed in other chapters within this publication.

[13] In some cases, and in the presence of waiver language on contract forms, the M/P subcontractor should attempt to have the prime/GC utilize revised language that reduces the M/P subcontractor's risks, and/or provide any qualifying information, such as a listing of unexecuted scope changes on payment application forms that contain restrictive language. This is a very important issue that should be addressed by the M/P subcontractor's construction counsel.

[14] Most contracts allow the prime/CM to direct the M/P subcontractor to perform added or changed work prior to the execution of a change order. While in most cases the M/P subcontractor must proceed with this modified work, the prime/CM must be notified in writing that the prosecution of the modified work is being performed under protest and that a request for equitable adjustment will follow as soon as the time and/or cost impacts can be ascertained. Note that the resulting impacts can include a loss of labor productivity.

In addition to the comprehensive CPM schedule, many prime/CMs also utilize short interval schedules, usually of two, four or six weeks in duration, Lean® project control methods, and scheduling "pull" planning sessions. These management methods can be effective in focusing the construction team on near term control of the construction process. However, in no case should these complementary project control methods replace the overall project CPM schedule or the periodic updates to the total project CPM schedule. Only by the use of the updated, total project CPM schedule can time impacts be reliably computed and assessed in terms of their potential impact to interim milestones or to the final completion date of the project. It is essential to maintain the total project CPM schedule in an accurate and updated condition in order to comply with most contract scheduling requirements, and to provide for total project progress and impact analyses, the latter of which cannot be accomplished in the absence of an updated, reliable, and comprehensive CPM schedule that depicts the entire project scope of work. The absence of vigilance on the part of the M/P subcontractor with regarding to the CPM schedule will often come at a substantial cost.

Conclusion

The CPM schedule is one of the most dynamic, collaborative and vital project management tools available to the construction team. It does not profit the construction team for the prime/CM to refuse to distribute the CPM schedule in its native form to the larger trade contractors. However, this appears to be the norm in today's construction marketplace, not the exception.

As such, the M/P subcontractor must be proactive regarding the development and use of the project CPM schedule. Should the M/P subcontractor ignore the schedules provided by the prime/CM and offer no written responses to the prime/CM's schedules, fail to request the complete schedule in writing, fail to follow the schedule when possible or to notify the prime/CM when adherence to the schedule is not possible or not practicable, the M/P subcontractor will be diminishing the ability to protect its contractual position and its planned profitability. The M/P subcontractor should attempt to convince the prime/CM of the value of using the CPM schedule as a cooperative and powerful management tool. In the absence of cooperation by the prime/CM regarding the distribution and use of the CPM schedule, the M/P subcontractor must take all reasonable precautions, in a timely and professional manner, to advise the prime/CM of the potentially deleterious results that may be arise from its conduct regarding the CPM schedule.

Prepared by Paul L. Stynchcomb, CCM, PSP, CFCC of Vero Construction Consultants Corp. with peer review performed by: Robert Beck, President of John W. Danforth Company, Charles F. Mitchell, General Counsel of The Kirlin Group, Richard Freeman, Vice President of Stromberg Metal Works, Inc., Robert Turner, President/CEO of Tucker Mechanical, An EMCOR Company and Robert N. Lindbloom, Account Executive at Apollo Mechanical Contractors.

Time Impact Analysis — Measuring Project Delay

Introduction

Schedule delays are a frequent occurrence on many construction projects and can have immense cost consequences. Without the remedy of a time extension, mechanical contractors are often forced to work overtime and may be required to increase crews and supervision to mitigate delays, even when caused by others. Mechanical contractors may also be assessed liquidated damages for delay, along with possibly having to defend against delay claims from the prime contractor or other trades. In some instances, a mechanical contractor is not made aware of delaying events until it is too late to remedy the delay without incurring added costs that can be substantial.

The purpose of this chapter is to alert mechanical contractors to several of the key elements of schedule usage and the development of time impact analyses to identify and quantify project delays. An important first step in this process is the mechanical contractor's thorough review of the contract documents. The specifications generally contain the scheduling requirements for the project. Within this section of the specifications is often found the provisions governing timely notice and the requirements for a schedule impact analysis. Read the general conditions of your contract specifications carefully before any work is performed on the project. It is not unusual to find terms and conditions such as:

> **Contractor's failure to submit its time impact analysis, with all supporting documentation and within the time period provided for in this contract, will constitute a full and final waiver of the contractor's right to an extension of time arising from the alleged changed condition. Absent the timely and complete submission of the contractor's time impact analysis as required by this contract, it is mutually agreed that the alleged changed condition has no effect on the critical path of the project schedule.**

The method of delay impact analysis described in this chapter is known as the "contemporaneous windows" method of analysis. The windows method measures delay at specific time windows throughout the project. The contemporaneous windows in time used for this type of analysis are usually the dates of the monthly update of the project schedule. While there are other methods of construction delay analysis, such as the "impacted as-planned," the "as-built," or the "collapsed as-built" methodologies, none offer the ability to evaluate the project at specific windows of time throughout the duration of the work. Moreover, some methodologies, including the "impacted as-planned" technique, have been generally discredited or strongly critiqued by courts and boards in reported cases.

Many modern contract specifications require the "contemporaneous windows" method of delay impact analysis. This bulletin will describe this method of analysis using the terms employed by contract specifications that are encountered on many public and private construction projects.

Terms and Concepts Used in Delay Analysis

Activity—the basic unit of work in a construction schedule. The activity is the unit of work[1] into which the overall project is divided for the purposes of tracking and managing time and labor during the construction process. The overall project is divided into activities during the job planning phase. Each activity is defined by specific geographic or contract boundaries such as phase, building, floor, and sectors; and by other designations, such as column lines, systems, rooms, crew codes, or other definitions that will allow specific identification of the work on the contract drawings. Each activity is given an estimated duration and is linked to other activities in the schedule by the use of logic restraints. Logic restraints (i.e., finish to start, start to start, finish to finish, and start to finish) define the relationship between activities in a construction schedule and are input by the scheduler to develop the overall Schedule Network.

Critical Path Method (CPM) Scheduling—a formalized, and usually computerized, method of construction scheduling. This dynamic construction management tool requires the development of activities and interconnecting logic restraints. The activities are analyzed to determine how each interrelates to other activities on the overall project with regard to performance dates. Logic restraints are created between the activities to create the CPM schedule network, which is the graphic representation of the overall schedule showing the activities and the interconnecting logic restraints. The CPM schedule should demonstrate the most efficient and profitable means of completing the project within the performance time set forth in the contract.

Critical Path—the longest connected chain (or chains, in the case of multiple critical paths) of activities in a CPM schedule that, if delayed, will have an equivalent impact on the end date of the project.

Total Float—the number of days an activity can be delayed from its earliest start date, or its earliest finish date, without causing delay to the completion of the project. Activities on the critical path have zero (0) total float.[2] Total float is a computation that is derived from the CPM schedule network and is dependent on the duration of the activities and the logic restraints that are input by the scheduler. Total float can change with each progress update or modification made to the original schedule.

Most contract specifications contain a "shared total float" clause. Such clauses state

[1] A "unit of work" includes all elements of field installation as well as submittal preparation, engineer's submittal review, and prefabrication.

[2] It is possible for the most critical path to have positive float, a concept which is not discussed herein.

that total float is a commodity to be shared between the parties to the contract. In the case of a delaying event, a time extension will be granted only to the extent that the delay first consumes the entire available total float and, thereafter, causes a delay to the critical path. Impact events, which only consume positive float when analyzed in the CPM schedule, will usually not result in the granting of a time extension.

Time Impact Analysis (TIA)—a series of activities and logic restraints that define what is known about a changed condition,[3] such as work added by a scope change or work occasioned by a differing site condition. As the conditions change, or as more information is known about the potential delay, the TIA must be modified (evolved). The TIA has become a term of art in the industry and is referenced in many contract specifications regarding project scheduling, notice, and delay analysis. TIAs are input into the CPM schedule as soon as the changed condition is recognized and are inserted into the CPM schedule update with a status, or "data date," closest in time to the date of the initiation or discovery of the potential impact event.

Fragnet—another term of art in the construction industry having the same definition as the TIA. The fragnet is a fragmentary portion of an overall project CPM schedule network that depicts the activities and logic associated with a potential schedule impact. The **gapless evolving fragnet** is a term of art that describes a process of identifying, defining, and developing over time, the discrete activities that form a potential impact to the project schedule. Maintaining contemporaneous documentation supporting the details of each delay activity is important in developing and supporting the TIA, or gapless evolving fragnet. The terms "TIA" and "fragnet" will be used interchangeably herein.

[3] TIAs are generally created at the outset of a potential delay and, as such, will not contain a complete delay analysis because the entire scope of the TIA will not be apparent. Therefore, the TIA must be evolved from month to month to show the development of the potential delay. This evolution requires the addition of new activities to the TIA, such as responses to RFIs, approval of a change order, direction to proceed, and definition of the actual work involved in the change.

The Project Schedule

While this bulletin does not cover the means and methods of CPM schedule development, updating, and maintenance, some commentary concerning the scheduling process is useful. If the mechanical contractor is also the prime contractor on the project, the development and control of the schedule should not pose a problem. The prime mechanical contractor is usually tasked with the same type of overall scheduling responsibilities as would a typical general trades contractor or construction manager. In such cases, the prime mechanical contractor will be fully aware of the requirements of the project schedule and will know when TIAs are required to be developed and input into the overall project schedule.

The majority of mechanical contractors, however, are in the role of subcontractor to a prime contractor or construction manager. In such cases, the mechanical subcontractor may not have unfettered access to the prime contractor's schedule. When that is the case, the mechanical subcontractor must take some affirmative steps regarding participation in the scheduling process. It is recommended that the following minimum steps be followed on every project:

- **Request the opportunity to participate in the development of the project schedule.**

It is essential that the mechanical subcontractor request that it be given a full and complete opportunity to participate in the development of the overall project schedule prepared by the prime contractor or construction manager. Furthermore, the mechanical subcontractor may, from time to time, be asked by the prime contractor to review, or to provide input into, the overall project schedule. The mechanical contractor should respond competently, comprehensively, and in a timely fashion to such requests.

- **Request electronic copies of the project schedule and all updates.**

It is often difficult, if not impossible, to conduct a meaningful schedule review using only a paper copy of the project schedule or updates thereto. Thus, the mechanical subcontractor should request in writing a magnetic media copy[4] of the prime contractor's baseline schedule and each progress update thereto. The mechanical subcontractor is then able to perform a much more detailed and thorough review of the prime contractor's schedule. On public projects, when requests for the electronic scheduling files are denied by the owner, construction manager, or prime contractor, such files can sometimes be obtained through a Freedom of Information Act (FOIA) or "public information act" request filed by counsel.

[4] All scheduling software systems, such as Primavera®, allow the electronic schedule files to be written onto transferable media such as compact discs. The electronic scheduling files can also be easily transmitted by e-mail.

- **Timely submit any TIAs in accordance with the contract documents.**

With or without the prime contractor's assistance and cooperation, the mechanical subcontractor must submit its TIAs in accordance with the requirements of the specifications. The fact that a prime contractor may not utilize the TIA, or properly insert the TIA into the overall project schedule, does not relieve the mechanical subcontractor from fulfilling, to the fullest extent possible, its contractual obligations, if so specified, to develop and submit TIAs for events affecting the work of the mechanical contractor.

- **Utilize crew and equipment restraints to avoid "False Float" and possible stacking of trades or crew size inefficiencies.**

False float is an important concept to grasp for the mechanical contractor because the presence of false float may result in understated time impact analysis. Many contractors do not take into consideration the limitations of available crews or equipment items, such as cranes, and fail to insert crew and equipment restraints into the logic of the CPM schedule. The absence of these vital logic restraints can create false float[5] which, in the event of a delay, may improperly consume the impacts when a TIA is inserted into the project schedule. When mechanical crew and equipment restraints are missing, a delay impact may show no delay computation in

[5] "False Float" is relative float (relative to the float on the controlling critical path) that is improperly shown in a CPM schedule, usually arising from the absence of proper crew and equipment restraints. In many cases, False Float incorrectly absorbs the time impacts of fragnets inserted into the schedule, resulting in no measurable delaying effect on the project end date. False float can deprive a contractor of its entitlement to an otherwise excusable delay event.

the project schedule due to false float. In fact, because of the lack of crew and equipment restraints, the mechanical subcontractor's activities may become improperly "stacked" in the schedule in a manner that was totally unanticipated, in turn, leading to unplanned increases in crew or equipment requirements and their associated inefficiency and financial impact to the mechanical subcontractor.

Contractual Obligations to Submit the TIA

Most current contract specifications contain requirements that the contractors submit a TIA, or fragnet analysis, in order to demonstrate the impact of changes or delays to the project schedule. Since most prime contractors include "flow down" provisions[6] in their subcontracts with mechanical subcontractors, the mechanical subcontractor bears the same, or even a greater,[7] burden as does the prime contractor in order to demonstrate the impact of changes, delays, and other disruptions to its work.

An illustrative example of the clauses that typically appear in many contract specifications is the following:

Contractor shall submit its time impact analysis within seven (7) calendar days after the initiation of the event that causes the alleged delay. The seven calendar day period shall begin at the point in time when the delaying event was known, or should have been known, to the contractor. The contractor shall submit its time impact analysis in the form of a CPM schedule fragnet analysis that will be inserted into the approved schedule update closest to the initiation of the delaying event. Failure of the contractor to submit its time impact analysis within the time limits set forth herein will result in a waiver by the contractor of any entitlement to an extension of time to the contract. By failing to submit its time impact analysis in the format and within the time requirements described herein, the contractor agrees that no time extension is required by the alleged change in scope or event and forevermore waives its rights to claim for such delay or impact of any sort or type.

- **Notice requirements for TIAs should be strictly followed.**

The time element imposed by the contract is dependent upon the specific project—some specifications allow as little as three (3) calendar days, some as much as thirty (30) calendar days or more. Notwithstanding the relatively short period allowed by many specifications to provide written notice and a TIA, such clauses may be enforceable under the controlling laws and, thus, cannot be taken lightly by the mechanical subcontractor. To vault the dual hurdles of delay identification and timely notice is a formidable task for the mechanical contractor. It is foolhardy to rely upon assurances from the prime contractor or construction manager's employees that such requirements will not be enforced

[6] A "flow down" provision contains language that places the same requirements and obligations on the subcontractor as the prime contractor has with the owner or construction manager.

[7] In many subcontracts, the mechanical subcontractor is required to provide its notice of delay, or TIA, in such a manner that the prime contractor can meet its timing obligations for notice and quantification with the owner in its contract. Essentially, this requirement means that the mechanical contractor must submit its TIA or notice in less time than the prime contractor is provided in its contract with the owner or construction manager to submit its TIA or notice.

or that issues of delay and associated costs will "be dealt with" at the end of the job. In order to accommodate the rigid requirements of many current specifications, the mechanical subcontractor must strictly adhere to the CPM scheduling techniques described in the contract specifications.

- **Contract conditions, payment applications, and change orders should be reviewed by the contractor and/or its legal counsel to avoid waiving valuable rights.**

With more and more contract specifications being written with strict waiver clauses regarding notice and TIAs, it is a wise and prudent investment for the mechanical contractor and/or its construction counsel to review carefully the contract general conditions, payment application forms, and change order forms.[8] Such a review at the outset of the project is critical to alerting the project management team as to its responsibilities and obligations regarding these crucial issues.

[8] The regular monthly payment application form provided to the mechanical contractor by the prime contractor, construction manager, or owner may contain waiver language that must be addressed with each and every monthly payment application in order to preserve the contractor's rights for compensation for such things as unsettled change orders and impact events that are known, but not covered, by a formal change in scope. Some prime contractors' monthly payment application forms contain full or partial release language that attempts to bar the subcontractor's recovery of unexecuted changes in scope or delay and impact claims. Similarly, the change order form used on the project may contain "full accord and satisfaction" language that may severely limit or restrict the contractor's rights to seek additional relief beyond what is explicitly set forth in the change order.

Development of the TIA

As described herein, many contract documents (usually a section in the scheduling specifications within the general conditions) require that fragnets, or TIAs, be inserted into the project schedule as delay events are known. These TIAs are to be placed into the update of the schedule closest in time to the notice to proceed of the changed condition, or in the update closest to the start of the impact of the changed condition. Since most TIAs are prepared and submitted before all of the potentially delaying events are known, the TIA must be evolved from update to update. The steps to prepare an evolving TIA are generally as follows:

- **Draw out the TIA logic, in detail, to include all discrete activities that are known at the time the potential impact is identified, or can be reasonably predicted as a result of the impact event.**

Such information may include the issuance of an RFI, the waiting period for a response, the analysis and pricing of the response and a forecast of change order processing time, procurement of any materials and equipment required by the impact event, and the actual work to address the event. Each of these items should be designated as a separate activity in the TIA.

- **Ensure that there are no unidentified gaps in time within the fragnet.**

From the start date of the fragnet event until it finishes, or is forecast to finish, every significant period in time must be identified as an activity within the TIA. For instance, if the contractor must wait for five (5) weeks for the owner's response to an RFI, then the five (5) week period would be identified as an activity, such as "Contractor Waiting for Owner's

Response to RFI No. 50." The TIA must be gapless—every day must be accounted for by an activity describing the events of each time period, whether "waiting" for a response, "negotiating" the change documents, or actually performing the changed work scope.

- **The actual start and finish dates for historical portions of the TIA (those activities that have been completed) should be verified against the project records and the source of all actual dates and durations should be noted for future reference.**
- **Starting with the first update in which the impact of the fragnet is identified, the TIA should include those portions of the fragnet that are known at the time of that update as historical data. All forecasted information (activities not yet accomplished that are part of the TIA) should be entered into the schedule update as new activities.**
- **The existing base contract activity(ies) that are, or may be, affected by the TIA must be identified. The TIA is then logically tied to the affected activity(ies) in the CPM schedule to determine what, if any, impact has been caused by the event.**

The mathematical analysis of the schedule update can be rerun and the scheduler can determine if the fragnet has changed the critical path by comparing the pre-impacted schedule with the impacted version.

- **Each succeeding month after the first update into which the TIA has been inserted, the TIA can be "evolved" with information as it becomes available regarding the scope and timing of the TIA Activities.**

Although the step of forecasting activities in the evolving TIA (also known as the **gapless evolving fragnet**) may be somewhat subjective, it is essential in meeting many of the specification requirements now being included in contracts. Contemporaneously, maintaining notations or other records that support these forecasts of future events that are depicted in the TIA can provide an important historical record. In addition, including the latest information regarding the TIA in the most current schedule update allows the mechanical contractor to manage the work to mitigate the impact of the delay.

- **As the contractor looks forward in the CPM schedule to the point at which the potential delay event will affect the base contract work, it is important to tie the ending activity of the TIA into the earliest base contract activity which could be affected by the TIA logic.**

This tie point from the TIA into the base contract schedule is extremely important and should be established with care. With regard to new scopes of work arising from the TIA that must be defined as activities, it is essential that these new activities be sequenced within the existing logic of the schedule so as to maintain the contractor's planned crew restraints.

- **With each update, the scheduler can note the effects of the various TIAs on the overall Critical Path of the project schedule.**

The Critical Path impacts, if any, will evolve along with the input and updating of the TIA data. In fact, the impact of the TIA on the Critical Path may change from month to month as other job conditions also change.

- **If the impacts of the TIA are expected to include labor inefficiencies, these estimated inefficiencies can be forward priced using "Factors Affecting Labor Productivity" and "How to Use the MCAA Labor Factors."**

Change Orders

To the extent that the mechanical contractor must, or desires to, include all of the potential impacts in a forward looking TIA, the contractor must consider if the TIA will impact the productivity of the base contract work. If the contractor will be required to bring in new workers that may be unfamiliar with the project, work overtime, or work in an unanticipated manner concurrently with other trades, the scope change work and the base contract work could be adversely affected in terms of labor productivity. In such cases, the mechanical contractor should reference "Factors Affecting Labor Productivity" on page 99 and "How to Use the MCAA Labor Factors" on page 103 to estimate the potential loss of labor productivity to the scope change work and possibly to the base contract work as well.[9] This loss of productivity will be manifested in either added labor to overcome the effects of the inefficiencies, overtime, or longer activity durations that can result from inefficiency.

For example, if a base contract activity of 18 planned work days for the installation of piping branches is expected to sustain a loss of productivity of 20 percent caused by "stacking of trades" because it will be performed in a different working environment resulting from the time slippage demonstrated by a TIA, the duration of the activity can be increased to 22 work days (18 x 1.2).

[9] The concept of impacts of multiple changes to the base contract work is known as a "cumulative impact claim" and care must be taken to price comprehensively the effects of changes to the base contract hours. The contractor should provide exculpatory language on the change proposal in the event that comprehensive pricing is not possible. It is recommended that "How to Use the MCAA Labor Factors" be consulted for a more detailed explanation of this condition.

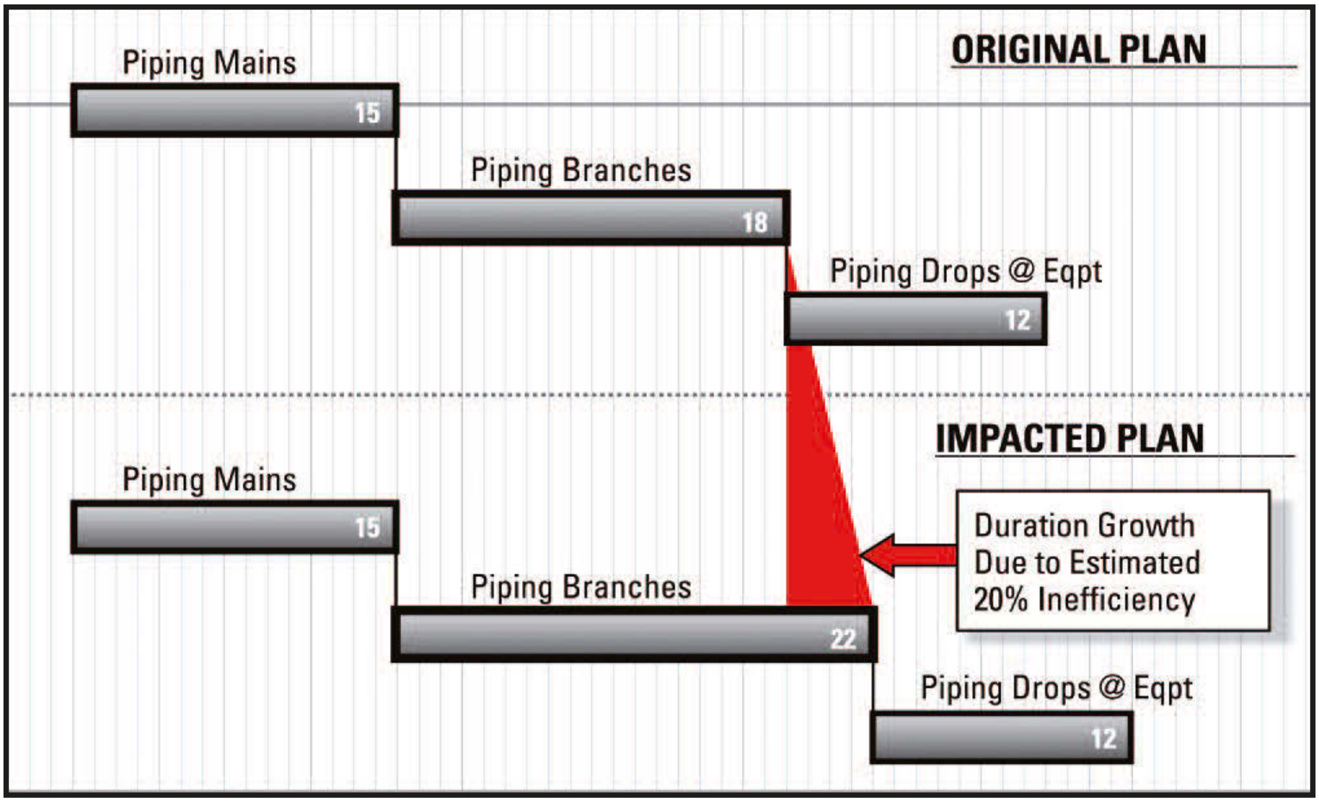
By including this consideration, where possible, in the overall TIA, the mechanical contractor may be more fully compensated for impacts arising from changes in scope. "How to Use the MCAA Labor Factors" explains how the estimated durations of schedule activities can be impacted using the inefficiency factors contained in "Factors Affecting Labor Productivity."

- **If a change order is executed regarding an evolving TIA (i.e., is executed before the delay impacts are actualized), the contractor should reserve its rights as to any future impacts of the evolving delay events.**

Assuming that the delay event is recognized as a change in scope to the mechanical contractor's contract, a formal change order may be executed. The change order form may contain "full accord and satisfaction" language that is designed to bar the contractor from receiving any further compensation (time and/or money) arising from the change. If the mechanical contractor is required, or decides, to execute such change order forms before the full effect of the TIA is known, it is essential that the estimates for future impacts of the TIA to the schedule be very carefully assessed.[10] Once the mechanical contractor executes a "full and final" change order, it may be difficult or impossible for the contractor to later make a claim for added costs arising from the change, such as longer than anticipated procurement

[10] If the mechanical contractor is required to execute "full accord and satisfaction" change orders before delay impacts are actualized by, among other things, the threat of non-payment for the change work, it is prudent for the contractor to consult with legal counsel as to options that may limit or qualify the "full accord" language.

Labor Inefficiency Arising from Changed Conditions Can Adversely Affect the Project CPM Schedule (Exhibit A)



times or for inefficiencies arising from a disruption to the crews performing the work.

The aforementioned steps that describe the TIA process are graphically depicted in this bulletin and they are as follows:

- **Step 1:** The process starts with a properly developed CPM schedule (one which includes a reasonable level of detail, mechanical crew, and equipment restraints). A faulty CPM schedule[11] will serve little purpose in managing the project or in analyzing the effects of changes as they occur. The graphic in step 1 shows a portion of the base contract work in a mechanical equipment room depicted in a CPM schedule format. Note that this example contains properly developed CPM schedule activities that describe discrete scopes of work within a definable geographic area of the project. The ability to identify the limits of a schedule activity by referring to the contract drawings is essential in the proper assignment of potential impacts arising from the insertion of the TIA. Unless the scope of work in the schedule

[11] If the mechanical contractor has reason to believe that the prime contractor's CPM schedule is defective, written notice of this determination should be transmitted to the prime contractor with regard to the baseline (original as-planned schedule) and each successive update thereto.

activities is known, it will be difficult to identify where, in the CPM schedule logic, a potential impact event restrains specific base contract activities.

- **Step 2:** In this example, assume that the mechanical contractor discovers a differing condition or design deficiency. By way of example, assume that structural elements of the building conflict with the physical location of major mechanical equipment in a mechanical room. The mechanical contractor prepares and submits an RFI upon discovering this condition and must await the owner's response. Note that, in the example shown in Step 2, the contractor has prepared a TIA starting with an activity that describes the submittal of the RFI, the period awaiting a response, and the date on which the response was received; all of which are historical dates in this example. However, from this point forward, the contractor may not know the scope of the change nor does the contractor have authority to proceed with a modified scope of work. Therefore, in this TIA example, the contractor has estimated a period of 20 work days for the owner to define the scope of the changed condition and agree upon a cost for the added work. Having complete and detailed information concerning all of the elements of a TIA is not a condition precedent to the development of an evolving TIA.

- **Step 3:** Within the next update period, the TIA is evolved by the mechanical contractor. By schedule update No. 2, as shown on the graphic, the mechanical contractor and owner have defined the modified scope of work and the contractor has received a notice to proceed to perform the scope change. The new activities are added to the TIA and now sufficient information is available for the mechanical contractor to understand what work must be accomplished in the field to carry out the scope change. As such, the contractor has added the forecast for the required equipment relocation for 10 days and has identified 10 days of work that must be added to the base contract work for the relocation of CHWS/R branch piping.

- **Step 4:** The TIA has been evolved to the extent that the mechanical contractor can tie the TIA logic into the base contract activity(ies) in the master CPM schedule. In Step 4, the TIA activity for equipment relocation for 10 days will be performed by a separate rigging crew and thus can begin as soon as the change order is approved. However, the additional 10 days of work associated with relocation of the branch piping will be performed by the mechanical contractor's existing piping crew. Therefore, the TIA activity that describes the added work for CHWS/R branch piping must be inserted **within** the existing crew flow[12] for the piping work.

  In this manner, the schedule will maintain the planned flow of the crews and will not depict added crews that the contractor did not anticipate. The failure to integrate TIA activities into the existing

[12] This operation assumes that the mechanical contractor plans to execute the scope change work with the crews already on site. In the event that the contractor mobilizes new or separate crews to perform scope change work, it may not be necessary to consider the disruption of the TIA Activities to the existing crew flow.

logic with regard to crew flow may result in false float and no impact, or incorrectly attenuated impact, to the CPM schedule.

By inserting the TIA activity that is to be performed by the base contract crew (in this graphic example, the added work for relocation of the CHWS/R branch piping) within the existing crew flow, the dependent activity of CHWS/R piping drops to the chillers and pumps is impacted by 10 work days. To the extent that this base contract work was on the critical path of the CPM schedule, the mechanical contractor would be entitled to a time extension of 10 work days, or 14 calendar days. This time extension could be both excusable and compensable.

Conclusion

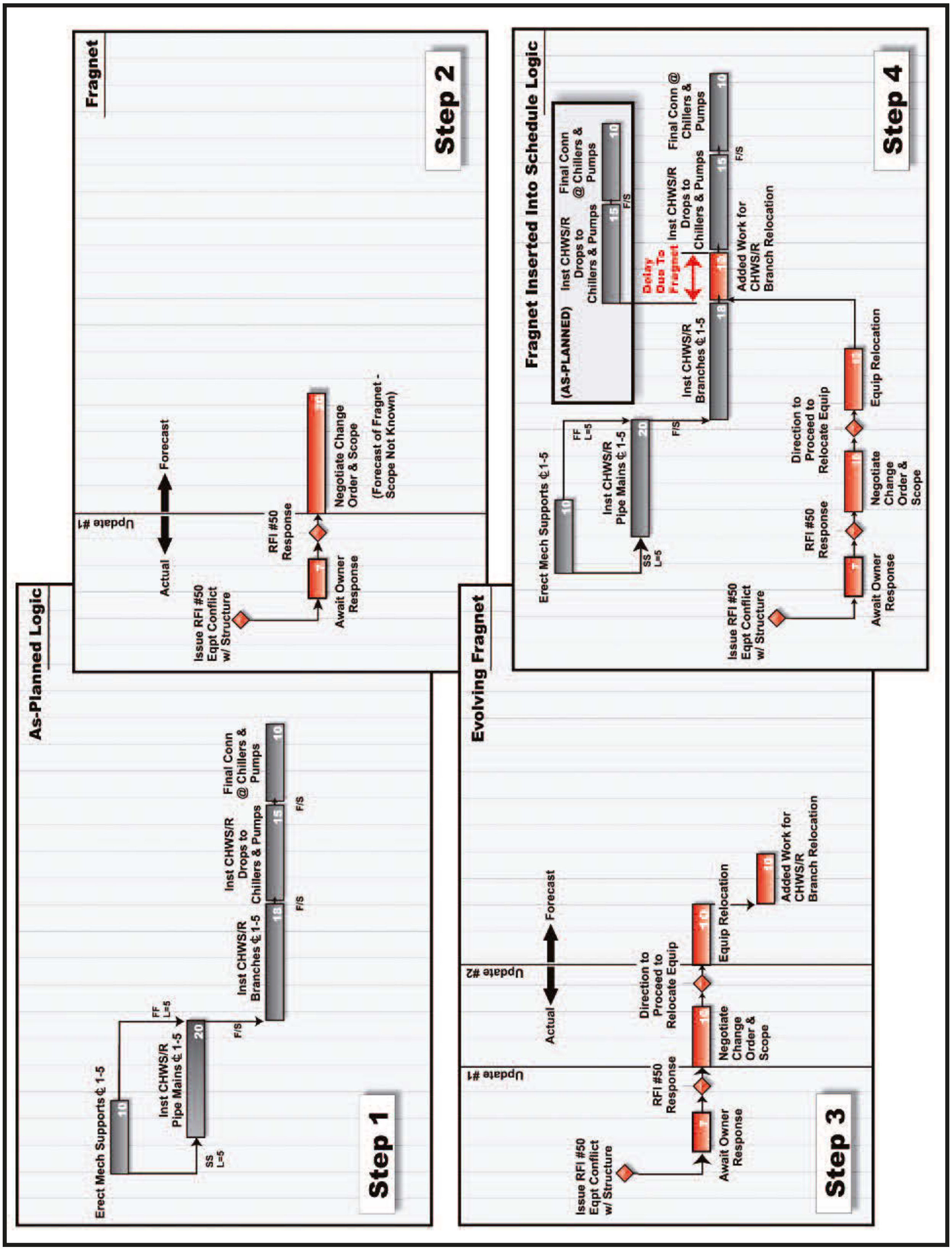
While it would be desirable for all of the impact events to become historical (actualized) before a change order is initiated to cover the effects (costs and time) of a delay impact, the current specifications in wide use today attempt to provide a means for scope changes to be fully executed early in the life of a time impact so that all of the time and cost impacts are included in the change order. This goal, if achieved, can reduce the incidence of "after-the-fact" claims that are submitted at the conclusion of the project. If properly and cooperatively implemented, "real time" TIA analyses that lead to the settlement of delay events, such as changes in scope, can mutually benefit the contracting community and owners. Unfortunately, the contemporaneous settlement of "real time" TIAs is the exception, not the rule, in the construction industry.

In order for this potential benefit of "real time" impact settlements to be realized however, the subcontractors, prime contractor, and construction managers/owners must make the CPM schedule a mutually shared commodity. If the prime contractor holds the scheduling information under lock and key and does not encourage, or allow, the mechanical contractor to participate in the development of the baseline schedule and in the maintenance and updating of the schedule as the project moves forward, the goal of obtaining "real time" impact settlements will remain elusive.

In most instances, the terms and conditions of the contract will dictate what the mechanical contractor must do with regard to development and submission of TIAs. Unfortunately, in some cases this means that the mechanical contractor may have to prepare its TIAs without the assistance or cooperation of the prime contractor. That notwithstanding, in today's litigious environment, the mechanical contractor cannot afford to ignore any of the requirements contained within the general conditions of the contract and must take every reasonable step to preserve its right to be fairly compensated for impacts and delays.

Prepared by Paul L. Stynchcomb, CCM, PSP, CFCC of Vero Construction Consultants Corp., with peer review performed by: Ronald Pearson, President/CEO of The NewMech Companies; Matthew Hahr, Senior Vice President of Kirlin Mid-Atlantic, LLC; Richard Freeman, Vice President of Stromberg Metal Works, Inc.; Robert Cox, Esq. of Watt, Tieder, Hoffar & Fitzgerald; and Roger Jones, Esq. of Huddles & Jones, P.C.

Four Step Fragnet Example (Exhibit B)



Maintaining Control of Labor Productivity

Introduction

In the mechanical contracting sector of the construction industry, as with all labor intensive trades, once the project has been bought out and the material and equipment purchase orders have been entered into the job cost system, the largest single variable (and the most volatile component) that controls profit on the project is the expenditure of labor hours. Therefore, one of the keys to profitability on a project-by-project basis is maintaining control of labor productivity.

Surprisingly, many labor intensive contractors do not make any attempt to monitor and control labor hour expenditures during the life of a construction project. All labor charges are recorded to one or two general project codes, such as "field labor" or "shop labor." This method of labor control may be adequate for small and very simple projects with limited risks of labor overruns. However, on large and complex projects that offer a mechanical contractor the potential to lose thousands, or perhaps tens of thousands, of labor hours, a system of general and summary level labor tracking results in an unacceptable level of risk.

It is not standard practice in our industry for the team that prepared the original estimate to also be the team that manages its installation. Generally, most large mechanical contractors maintain an estimating department comprised of estimating professionals that will not, in the final analysis, be held responsible for the final labor expenditures on the project. Therefore, it is important to conduct in-house project initiation meetings wherein the estimators can explain, in detail, what was included and excluded in the estimate as well as defining any assumptions that were made in the preparation of the estimate. Furthermore, the basis of the labor estimate, along with any factors or special productivity rates that were used by the estimators, can be communicated to the project management team.

With so much profit or loss at stake, it is important that labor-intensive contractors make a management decision to track labor expenditures on a specific and identifiable basis on every major construction project. As set forth in this bulletin, the reasons offered for not tracking field labor are varied and generally lack substance. One excuse that is frequently put forth regarding the contemporaneous tracking of labor by element of work is the difficulty in the field with ensuring reasonably accurate reporting, such as disseminating to the labor managers the meaning of the various labor codes. Since the reporting may be unreliable, a contractor may elect not to maintain reasonably detailed labor records. Other labor managers simply aver that tracking labor by multiple-labor codes on a regular basis is too much work and the investment of resources is not sufficiently rewarded by the value of the information gained in the process.

This bulletin will explore the arguments supporting more specific and defined labor tracking and some of the methods of achieving greater control over the expenditure of craft labor on construction projects.

Terms and Concepts Used in Project Planning and Labor Tracking

Original Estimate—the collection of bid forms, take off sheets, labor adjustment sheets,[1] material, equipment and labor pricing documents and other, similar material that comprise the bases for the final labor estimate included in the lump sum bid for the project. Obviously, an important historical set of documents regarding the original estimate are the bid set of drawings and specifications.

Job Planning (the Job Plan)—the process whereby the estimators and/or the construction managers divide the original estimate into identifiable units of work to which can be assigned the materials and equipment that must be installed and the labor and construction equipment that is required to complete each unit of work.

Activity—the basic unit of work in a construction job plan (and in the construction schedule). The activity is the unit of work into which the overall original estimate is divided for the purposes of tracking and managing craft labor during the construction process. The original estimate is divided into activities during the job planning phase. Each activity is defined by specific geographic or contract boundaries such as: phase, building, floor, sectors and by other designations such as by column lines, systems, rooms, crew codes or other definitions that will allow specific identification of the work on the contract drawings. Each activity should be given a detailed and specific description of up to 48 characters in length[2] in order to comport with critical path method ("CPM") schedules that are typically developed from the job plan activity listing.

The recommended size of the activity (i.e., the amount of work that is included in an activity), and the resulting duration for the activity, are based on the principle of optimized tracking. Optimized tracking refers to the greatest reasonable degree of reporting accuracy that can be expected during the course of the project. The concept of optimized tracking dictates the size of the activity in the job plan, as well as in the project

[1] For the purpose of increasing the competitive nature of a bid, many mechanical contractors "discount" the detailed labor estimate by some factor or percentage. Any such adjustments should be carefully documented in the bid file.

[2] In today's construction environment, the most widely used CPM scheduling software system is Primavera®. This software system allows activity descriptions of up to 48 characters in length, however the software allows for many additional fields into which the planner may place area, floor, column line, crew identification, or other code information in order to track the activity with greater particularity.

CPM schedule. In scheduling, the general guideline regarding the durations of erection activities[3] for optimized tracking suggests a range of between three to 22 work days for the majority of the activities defined in the job plan. Obviously, some activities will be only one or two days in length by necessity. However the majority of the activities in the job plan and schedule should have durations that fall within the range of 3 to 22 work days. This range or duration for the activities used in the schedule also provides for optimized tracking when these activities are also used in the job plan reporting system.

The duration of an activity is calculated by estimating the number of labor hours that will be required to complete the activity and by estimating the crew size for the work. The duration is derived by dividing the total estimated labor hours by the hours required for the crew per day. For instance, if the activity will consume 640 labor hours and the contractor plans to utilize a crew of four mechanics (i.e., totaling 32 hours per day), the resulting duration for the activity would be 20 work days.

Obviously and within reason, the more specific the activity data, the more valuable is the reporting information. Therefore, it is advisable to differentiate between the types of systems that may occur within the same geographic area, resulting in more than one activity in an area. For instance, if the mechanical contractor has HVAC piping, plumbing piping and duct work within the same area, each principal trade would have its work identified by separate activities. Similarly, if the mechanical contractor has large bore weld joint carbon steel pipe, socket weld small bore pipe and thin wall stainless steel pipe work, all in the same area or phase of the project, it is useful to divide this work into three discrete activities by type of piping system based on the crews that will perform the installation work.

Furthermore, the activity should be defined during the job planning phase such that the work can be commenced and not halted until the activity is completed. This is one of the characteristics of an efficiently planned construction project; namely that the activities express continuity of work such that there is no planned "start-stop-start" disruption contemplated in the baseline job plan or CPM schedule.

Once the mechanical contractor has developed its activities, this information should be shared with the prime contractor for integration into the project master schedule. If the prime contractor has already prepared the overall master schedule, the mechanical contractor must determine if the activities created in its job plan comport with the mechanical activities created by the prime contractor. If the activity durations of the prime contractor do not comport with those contained in the mechanical contractor's job plan, then a written request should be submitted to the prime contractor requesting the required modifications. If the prime contractor refuses the reasonable schedule modification requests of the mechanical contractor, the prime contractor should be placed on notice that the baseline master schedule is

[3] "Erection Activity" as opposed to procurement activities, such as "Fabricate and Deliver Chiller," which may have a duration of many months and will not be assigned field erection labor in the job plan or in the schedule.

not reasonable. Specifics should be provided in the written notice as to the activities and/or logic that are incorrect or inconsistent with the mechanical contractor's reasonable plan to prosecute its base contract work.

Activity Identification ("ID") Code—the unique numeric, or alphanumeric, identifier that is given to each activity. The application of activity IDs may be dictated by the contractor's job costing system, the labor performance software in use and by the scheduling software that may be employed on the project. In order to simplify the overall labor tracking operation on a construction project, it is important to utilize the same codes for all cost, labor and schedule tracking software systems. Having one single set of activity IDs for all control systems used on a project will increase the accuracy of the reporting and reduce the overhead costs to develop and update the systems.

Labor Performance Report ("LPR")—the report format that provides the planned and the actual performance data for use by field and office management during the life of the project. There is not a single, "best" form of this report and many mechanical contractors have developed their own, highly effective, version of the LPR. The LPR can take on many different forms and is called by different names by various mechanical contractors, but for the purpose of this bulletin, the report that provides the labor tracking information will be known as the LPR. One example of an LPR is shown below.

The code fields are identified from left to right as follows:

Activity ID Code—the unique identifier for each activity

Activity Description—the definition of the work that is to be performed

Planned Hours—the originally estimated (or re-estimated hours)[4] hours to perform the work

CO Hours—estimated change order, or scope change, hours

[4] Some mechanical contractors require that the construction team "re-plan" the project once it has been transferred from the estimating department. The construction team may find differences in the "construction estimate" as opposed to the original estimate. The job plan should reflect the planned hours determined by the team that will actually take responsibility for the profitability of the project.

The Labor Performance Report (Example of Detailed Activities)

Activity ID Code	Activity Description	Planned Hours	CO Hrs	Rev Plan	Last % C	Current % C	Earned Hours	PT AH	C Act Hrs	Wk -2	Wk -1	Cw
7550	Inst CHWS&R Mains Area B	500		500	30	50	250	300	450	–75	–150	–200
7570	Inst CHWS&R Brnchs Area B	700	50	750	10	20	150	120	200	–40	–45	–50
7590	Connections @ Mech Equip	100		100	10	15	15	10	12	0	0	3

Revised Plan—the total of the original estimated hours and estimated change order hours

Last Percent Complete—the progress of the activity at the previous reporting period[5]

Current Percent Complete—the progress of the activity at the current reporting period

Earned Hours—the "should have spent" hours (Revised Plan × Current Percent Complete)

Previous Total Actual Hours—the actual hours charged as of the last reporting period

Current Actual Hours—the actual hours charged through the current reporting period

Variance Week –2—the craft hour variance as of two weeks prior to the current period

Variance Week –1—the craft hour variance as of one week prior to the current period

Current Week—the current period craft hour variance (– over budget / + under budget)

By maintaining a current and accurate job plan, the productivity of each activity of work can be measured on a period-by-period basis (usually measured by pay period). Once the activity ID codes, activity descriptions and the planned hours have been input at the outset of the project, the regular input data consists of: (i) any revisions to the original job plan hours (i.e., changes in scope); (ii) the actual hours from payroll information; and (iii) the percent complete of the activity. In return for the input of the above-listed data, the project team has at its disposal a powerful tool that allows management to review with specificity the areas of labor expenditure that exceed the budgeted job plan labor hours. Most importantly, it permits the project management team to identify specific activities of work that are indicating unproductive progress before the activity is complete, thus allowing the project management team to proactively address the forecast labor overrun before it becomes an historical loss.

[5] The frequency of the reporting periods is generally governed by the frequency of the pay periods of the field craft labor, which is usually weekly or twice monthly. The longest effective reporting period in terms of labor tracking and trending is approximately monthly.

The Purposes of, and Methodologies for, Tracking Labor

The single, best reason to maintain better control of field labor expenditures is to increase profit. There are other sound reasons for a higher degree of labor control on construction projects, which include:

- Establishing, or verifying, the accuracy of the contractor's bidding units
- Developing an early warning system that will allow proactive management intervention
- Mitigating, or documenting, the inefficiencies associated with non-contractor caused impacts as well as accurately quantifying the associated costs

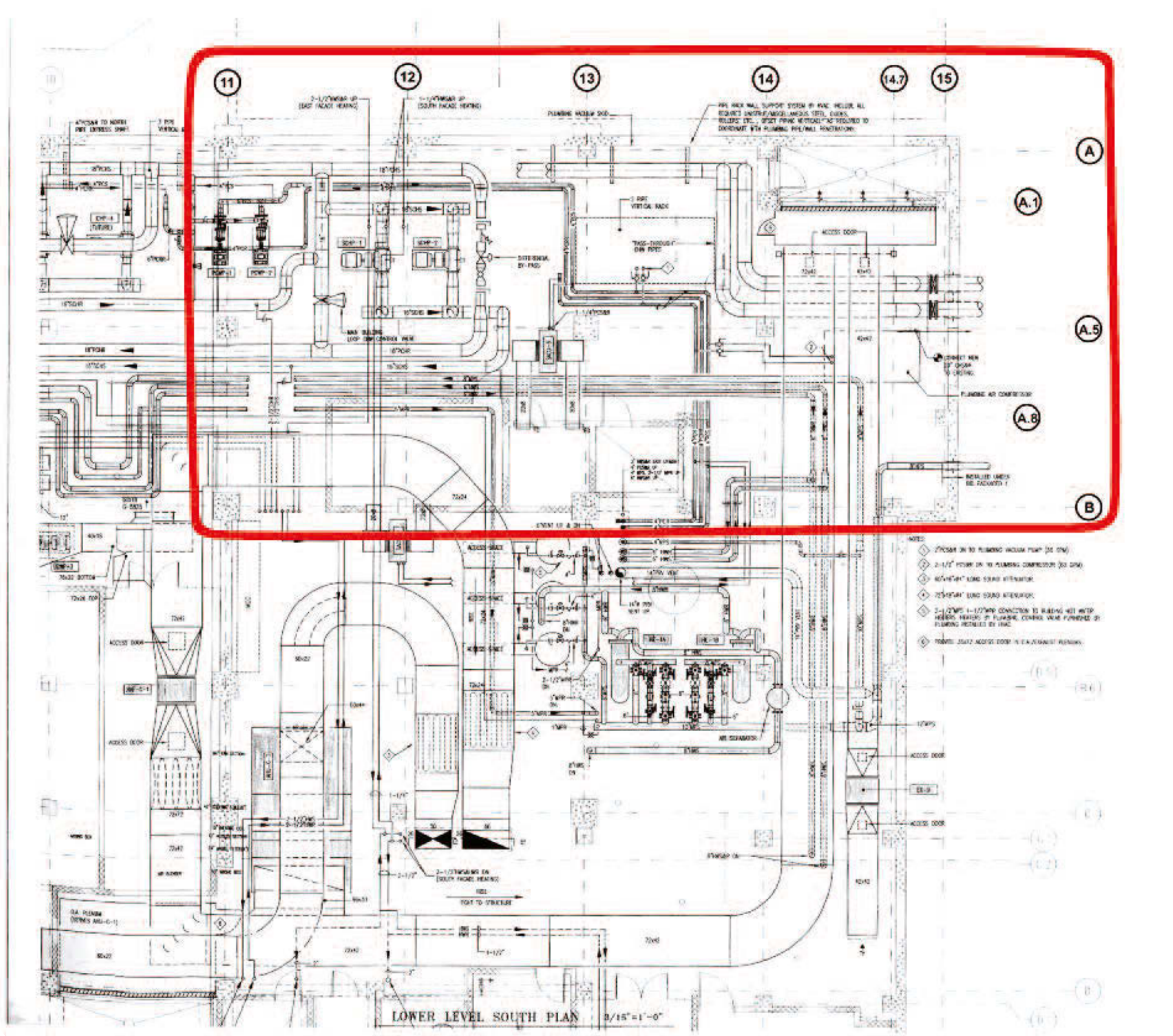
In fact, these reasons to track labor expenditures contribute to the concept of maintaining, or increasing, profit on the project.

The job plan should be developed with the input and direct assistance of the field labor supervisors (sometimes called the labor superintendent or general foreman). The inclusion of the principal labor managers will increase the opportunity for accurate labor reporting. An essential element of accurate labor reporting is the clear definition of the work included in an activity.

Documenting the elements of an activity is an essential ingredient in achieving accurate labor reporting. One means of meeting this goal is to mark the outlines or boundaries of each activity on a set of contract drawings. The graphic example below shows how depicting the extents of a specific job plan

Activity Boundaries Marked on the Contract Drawings

Activity 7550 - Mechanical Room Mains Column Lines 11-15/A-B



activity can provide relevant documentation that can be constantly referenced during the life of the project.

In addition, other forms can be utilized to capture the details of each activity that can be referenced during the project to ensure that the actual labor hour reporting is accurate. The form shown below has been used on large and complex projects to document the labor, equipment and material required to perform each activity. The form allows the contractor's planning team[6] to record each set, or task, which will be required to complete the activity. Such records can

[6] Many mechanical contractors find it very valuable, and highly profitable, to have the construction team perform a re-estimate of the project before commencement of the work. While time-intensive, this operation provides an invaluable learning experience for the project team concerning the particulars of their specific project and will provide for a reasonably detailed job plan that relates to the manner in which the project team will actually prosecute the work. Another benefit of this process is the identification of long lead-time procurement items.

Activity Planning Form

JOB Number :.................... ACTIVITY :.....................................

DESCRIPTION.. DATE : / /

INSTALLATION STEPS	DWG REF	Labor Planned			Total Quantity Planned	Material Required		
		Crew Size	Days	Man Hours		Quantity	Size	Description

Equipment Rental, Totals, Scaffolding etc.	Days Req	Cost Day	Amount

Remarks:

substantially improve the quality and accuracy of actual labor hour reporting in the field.

Any project reporting system requires an investment in terms of management resources. If a contractor expects to derive valuable management information from any reporting system, whether cost or labor efficiency, attention to detail and accuracy are a necessity. A "corporate culture" that supports accurate cost and labor reporting is essential.

Once the initial data has been input and collected, the contractor has the following data that must be accurately coded and input on a period-by-period basis:

- Actual field craft labor hours charged to each activity ID code
- Estimated scope change hours that must be input to update the job plan
- Current period percent complete progress by activity ID code

The foregoing represents the ongoing data that must be collected and entered into the LPR to allow the report to provide a variety of output data that can be used by the project management team proactively to address productivity "events" that serve to reduce profits and/or cause delays to the construction schedule. The software cost for implementing and maintaining a labor tracking and trending system is not the limiting factor for the use of such systems. Reporting systems as described herein can now be accomplished using some of the more advanced features of Microsoft Excel®. Therefore, the actual costs of the software and computer platform to run such systems are no longer a bar to their implementation. It is simply reduced to the will of the mechanical contractor to track the expenditure of its most valuable and volatile resource—field labor.

With an accurate LPR, the project management team can readily and effectively evaluate the productivity of defined areas of the project including specific crews, labor managers or other defined features of the work. Often, inspection of the updated job plan activity ID codes will alert the project management team to inefficient labor trends that can be investigated by physically observing the work and interviewing the labor foremen to determine whether the deteriorating labor productivity has been caused by changed conditions, unanswered RFIs, other impact events beyond the control of the mechanical contractor or self-induced inefficiencies.

However, if the contractor does not institute quality control checks and reviews of the data and the period-by-period coding of the actual labor hours to the job plan activity ID codes, the resulting inaccuracies arising from this neglect may render the LPR unreliable. For instance, some mechanical contractors offer a bonus to labor managers for hours saved on the project. This program may have the unintended effect of promoting the "balancing" of actual labor hour charges each reporting period. If the craft labor manager sees an activity ID code decreasing in efficiency (i.e., the negative variance increases each period), there may be a temptation to improperly reassign craft hours from the inefficient code to a labor code that is reporting highly productive work. This sort of "balancing" renders the LPR information suspect and unreliable.

Every reasonable effort should be engaged to ensure that the craft labor managers who generally decide to which activity ID code actual labor hours are assigned are charging the hours to the correct activity ID codes. This may even entail changing the contractor's bonus incentive plans to move away from bonuses granted purely on incremental reporting of labor efficiency. In addition, the labor managers must be given the time and clerical support to allow for accurate collection of the necessary data. Whatever steps are employed to ensure accurate charging of actual labor hours will be effort well spent in terms of providing an invaluable tool for the project management team to detect potential losses of labor productivity before they become significant.

The primary goal of the labor tracking and trending methods described herein is to increase profit. The mechanism by which that goal is achieved is known as "proactive management." Simply put, this sort of management occurs when a project team is able to identify negative trends within its labor budgets early enough to allow the manager to identify the discrete work activity in which the inefficiency is occurring and to take steps to totally remedy or mitigate, or at least identify the source and location of, the productivity loss. Assuming that the activity has been properly developed, it will have definable and specific geographical boundaries such that the labor manager can walk onto the project and "stand" in the area of the activity. The presence of such specific labor tracking and trending can allow the manager to evaluate the potential causes of the reported inefficiencies and take the appropriate action before the loss becomes project-wide.

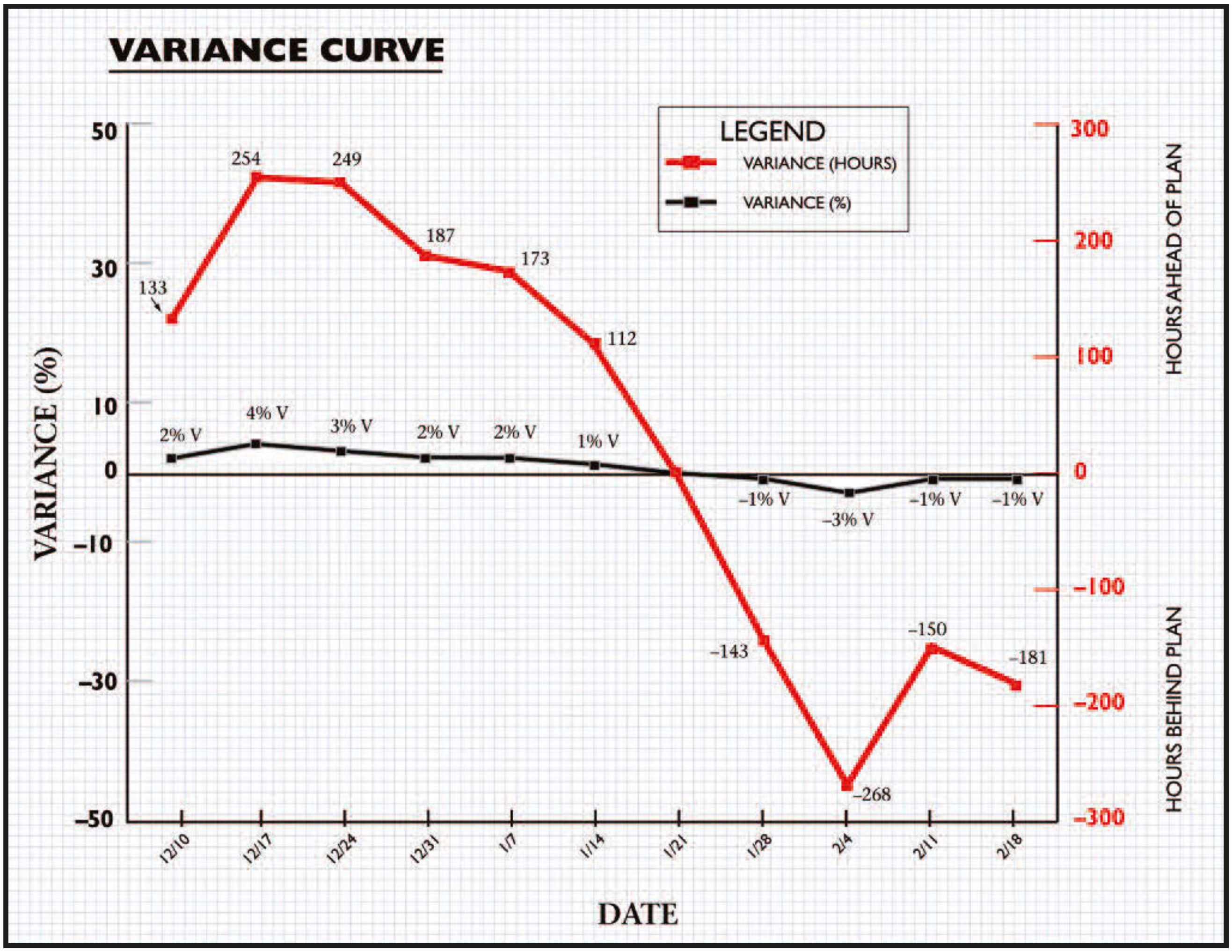
Labor Productivity Trending

In order to grasp quickly the overall labor productivity on a construction project, it is essential that the data be presented in a format that can be readily acted upon by the management team. Various summary reports and trending curves can be produced from the LPR. For instance, from the summary of the LPR, the total project (or the mechanical portion thereof) can be computed on a period-by-period basis. This data, in combination with the variances computed within the LPR, can be combined to create a curve or trend of labor productivity, as can be seen in the example below:

From this sample curve, the trend of the labor expenditures can be plotted and quickly evaluated by the project management team. On this example, the total project percent complete, labor hours over/under budget and percent variance are shown on one chart. These types of easily assimilated graphic presentations can be augmented with other types of "roll up" trending reports that have their data derived from the LPR without any further input by the project team. Other sorts of "roll up," summary level reporting that can be generated from the data described previously herein includes the following example:

Productivity

Labor Productivity Variance Tracking & Trending Curve



Such summary level reports require no further input from that described herein and can provide valuable management information.

From the above example, the following data can be derived:

- Total hours ahead or behind the job plan
- Total project percent complete in terms of labor hours
- Progress gained by period in terms of labor hours
- The progress (by percent complete) that must be achieved by period
- Required crew size at the planned rate of performance
- Required crew size at the actual rate of performance
- Historical reporting on the activities that have been completed
- Trending of the active activities

Labor Performance Summary

Issue	12/10	12/17	12/24	12/31	1/7	1/14	1/21	1/28	2/4	2/11	2/18
Mechanical Work											
Planned Hours	17908	18208	18208	17848	17848	18526	18526	18526	18526	19882	19882
Completed Hours	5867	6510	7190	7596	8075	8718	9280	9919	10602	11554	12310
Actual Hours	5734	6256	6941	7409	7902	8606	9282	10062	10870	11704	12491
Hours This Week	585	522	685	468	493	699	676	780	808	722	787
Variance (Hours)	133	254	249	187	173	112	–2	–143	–268	–150	–181
Variance (%)	2%	4%	3%	2%	2%	1%	0%	–1%	–3%	–1%	–1%
Effective Crew Size	16	15	19	13	14	19	19	22	22	20	22
Current & Complete	33%	36%	39%	43%	45%	47%	50%	54%	57%	58%	62%
Progress This Week (%)	3%	3%	4%	3%	3%	2%	3%	3%	4%	1%	4%
Progress: 4 Week Average	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Required % Comp./Wk	4%	4%	4%	4%	4%	4%	4%	4%	4%	5%	4%
Weeks Available Left	18	17	16	15	14	13	12	11	10	9	10
Job End Date	4/14	4/14	4/14	4/14	4/14	4/14	4/14	4/14	4/14	4/14	4/28
Req. Crew @ Plan Rate	20	20	19	19	19	21	21	22	22	26	21
Req. Crew @ Actual Rate	19	19	18	19	19	21	21	22	23	26	21
95–100% Activities (Plan)	420	420	420	420	861	2478	3095	4582	5559	6067	6749
95–100% Activities (Actual)	434	434	434	434	830	2419	2933	4600	5864	6065	6810
100% Better/Worse (Hrs.)	14%	–14%	–14%	–14%	31%	59%	162%	–18%	–305%	2%	–61%
100% Better/Worse (%)	–3%	–3%	–3%	–3%	4%	2%	5%	0%	–5%	0%	–1%
5–95% (Plan)	11842	12142	13792	15272	15272	10078	9428	8014	8111	9073	9196
% of Mech. Plan Action	**66%**	**67%**	**76%**	**86%**	**86%**	**54%**	**51%**	**43%**	**44%**	**46%**	**46%**

These data can provide further insight into the typically non-linear expenditure of labor hours on a construction project and within each discrete activity. The object of any reporting methodology and output reporting is to increase profits and eliminate the end-of-project labor loss “surprise” that afflicts a large number of otherwise sophisticated and successful mechanical contractors.

When Loss of Labor Productivity Claims Arise

On some projects, the mechanical contractor sustains a substantial loss of labor productivity for which the contractor seeks recovery from a prime contractor or owner. Each year, MCAA member firms incur hundreds of millions of dollars in unplanned labor expenditures due to loss of productivity impacts not caused by the mechanical contractor. To the extent that it can be demonstrated that the mechanical contractor was not the cause of such losses, it may be necessary to develop a loss of productivity claim. In some cases, the very survival of the contractor may depend on the success of such a request for equitable adjustment.

Once the mechanical contractor’s estimate has been eliminated as the source of the loss, the mechanical contractor should determine what other events cause the loss of productivity. Some commonly overlooked items are the impacts of RFI's, field change directives and "field fit-to-suit" conditions, which are seldom incorporated into the compensation for change orders. After careful evaluation of the events that adversely affected the labor productivity on a project, the mechanical contractor has the option of either absorbing the loss or preparing a loss of productivity claim. One of the acceptable methods of computing loss of productivity is the "measured mile" method. This method is described in the MCAA's Publication "*How to Use the MCAA Labor Factors*." Simply put, this methodology computes inefficiencies by measuring a contractor's actual productivity rate achieved in a time frame or area of lesser impact and compares the contractor's actual productivity in a time frame or area of representative impact. Among other information that is necessary in order to perform a measured mile analysis, the contractor must have available comparative data in order to compute the varying production rates. If the contractor maintained an LPR system similar to that described herein, then the data required to perform a measured mile analysis can usually be compiled.

By referencing its estimate, or by taking off systems by activity ID codes, the contractor can equate labor hours to the quantity of material installed. A measured mile analysis requires knowing the actual hours expended to install a unit of material; for instance, hours actually expended to install a linear foot of 14" ASTM A-53 schedule 40 butt weld pipe by area or time frame. The vast majority of mechanical contractors do not track materials installed on a period-by-period basis. However, the materials and conditions of installation can be readily analyzed by reviewing the historical data that supports the job plan and the LPR. Assuming the mechanical contractor has retained the records (such as contract drawings marked by activity ID code or the Activity Planning Form) that provide the basis of each activity, the materials installed in the activity can be estimated or, if the Activity Planning Form has been used, the material data are readily available without the need to reestimate the materials.[7]

Assuming that the contractor has accurately recorded the actual hours charged to each activity ID code, the hours required to install the material and equipment within an activity are identifiable. With that information in hand, a contractor can compare the labor required to install systems in less impacted time frames or areas with the labor required to install similar systems in the impacted time frame or area. The measured mile method is not dependent upon the contractor's estimate because it uses actual installation rates achieved on that particular project site to form the basis of the productivity comparison.

As noted in "How to Use the MCAA Labor Factors," on some projects it will be impossible to perform a measured mile analysis, even if proper labor productivity data is available. On many projects, there is no identifiable unimpacted, or less impacted, period thereby preventing the contractor

[7] To the extent that change orders have been issued, the original estimate for materials must be adjusted for the material items added by the change orders to create the "adjusted estimated quantities." This is true for field labor as well.

from applying a measured mile analysis. In such cases, the MCAA factors described in "Factors Affecting Labor Productivity" and "How to Use the MCAA Labor Factors" can be useful in estimating the cause and effect of various sources of inefficiency such as "Reassignment of Manpower," "Crew Size Inefficiency," "Dilution of Supervision" and "Overtime Inefficiency." This data and an explanation of what a loss of productivity claim entails are addressed in the other MCAA publications as noted above.

Conclusion

Measuring labor productivity during the course of a construction project requires discipline, dedication of the labor management team and an earnest desire to understand the somewhat ethereal and amorphous concept of labor inefficiency. The pursuit of this understanding, however, can lead to more profitable construction projects and avoidance of substantial losses that are occasioned by impacts causing loss of labor productivity.

Author's Note

Obviously, the labor tracking and trending concepts described herein were not originated by the writer. I am compelled to credit many experienced and highly profitable mechanical contracting firms, well known within the MCAA membership, for developing, testing and proving the inestimable value of the labor tracking and trending systems described in this bulletin. The writer had the privilege of having been employed by one such firm and had the opportunity, on a first-hand basis, of experiencing the hard work developing and maintaining an accurate LPR system and also of witnessing the material benefits that resulted from this proactive management concept.

Paul L. Stynchcomb, CCM, PSP, CFCC
Vero Construction Consultants Corp.

Prepared by Paul L. Stynchcomb, CCM, PSP, CFCC of Vero Construction Consultants Corp., with peer review performed by: Ronald Pearson, President/CEO of The NewMech Companies; Matthew Hahr, Senior Vice President of Kirlin Mid-Atlantic, LLC; Richard Freeman, Vice President of Stromberg Metal Works, Inc.; Robert Cox, Esq. of Watt, Tieder, Hoffar & Fitzgerald; and Robert Windus, Esq. and Stuart Sakwa, Esq. of Moore & Lee, LLP.

Factors Affecting Labor Productivity

Instructions on the use of MCAA's Labor Factors are provided in the section titled "How to Use the MCAA Labor Factors."

Factor	Percent of Loss per Factor		
	Minor	Average	Severe
1. STACKING OF TRADES: Operations take place within physically limited space with other contractors. Results in congestion of personnel, inability to locate tools conveniently, increased loss of tools, additional safety hazards and increased visitors. Optimum crew size cannot be utilized.	10%	20%	30%
2. MORALE AND ATTITUDE: Excessive hazard, competition for overtime, over-inspection, multiple contract changes and rework, disruption of labor rhythm and scheduling, poor site conditions, etc.	5%	15%	30%
3. REASSIGNMENT OF MANPOWER: Loss occurs with move-on, move-off men because of unexpected changes, excessive changes, or demand made to expedite or reschedule completion of certain work phases. Preparation not possible for orderly change.	5%	10%	15%
4. CREW SIZE INEFFICIENCY: Additional workers to existing crews "breaks up"original team effort, affects labor rhythm. Applies to basic contract hours also.	10%	20%	30%
5. CONCURRENT OPERATIONS: Stacking of this contractor's own force. Effect of adding operation to already planned sequence of operations. Unless gradual and controlled implementation of additional operations made, factor will apply to all remaining and proposed contract hours.	5%	15%	25%
6. DILUTION OF SUPERVISION: Applies to both basic contract and proposed change. Supervision must be diverted to (a) analyze and plan change, (b) stop and replan affected work, (c) take-off, order and expedite material and equipment, (d) incorporate change into schedule, (e) instruct foreman and journeyman, (f) supervise work in progress, and (g) revise punch lists, testing and start-up requirements.	10%	15%	25%

Productivity

Factor	Percent of Loss per Factor		
	Minor	Average	Severe
7. LEARNING CURVE: Period of orientation in order to become familiar with changed condition. If new men are added to project, effects more severe as they learn tool locations, work procedures, etc. Turnover of crew.	5%	15%	30%
8. ERRORS AND OMISSIONS: Increases in errors and omissions because changes usually performed on crash basis, out of sequence or cause dilution of supervision or any other negative factors.	1%	3%	6%
9. BENEFICIAL OCCUPANCY: Working over, around or in close proximity to owner's personnel or production equipment. Also badging, noise limitations, dust and special safety requirements and access restrictions because of owner. Using premises by owner prior to contract completion.	15%	25%	40%
10. JOINT OCCUPANCY: Change cause work to be performed while facility occupied by other trades and not anticipated under original bid.	5%	12%	20%
11. SITE ACCESS: Interferences with convenient access to work areas, poor man-lift management or large and congested worksites.	5%	12%	30%
12. LOGISTICS: Owner furnished materials and problems of dealing with his storehouse people, no control over material flow to work areas. Also contract changes causing problems of procurement and delivery of materials and rehandling of substituted materials at site.	10%	25%	50%
13. FATIGUE: Unusual physical exertion. If on change order work and men return to base contract work, effects also affect performance on base contract.	8%	10%	12%
14. RIPPLE: Changes in other trades' work affecting our work such as alteration of our schedule. A solution is to request, at first job meeting, that all change notices/bulletins be sent to our Contract Manager.	10%	15%	20%
15. OVERTIME: Lowers work output and efficiency through physical fatigue and poor mental attitude.	10%	15%	20%
16. SEASON AND WEATHER CHANGE: Either very hot or very cold weather.	10%	20%	30%

Connecting the "Cause" and "Effect" in Loss of Productivity Claims

By Gerson B. Kramer

Gerson B. Kramer began acquiring his vast experience in measuring differential productivity during his first post-college job at the Department of Labor's Bureau of Labor Statistics. After graduating from George Washington University School of Law, Mr. Kramer joined the Justice Department's Court of Claims Section and later the Commerce Department's Appeals Board. For ten years prior to his retirement, Mr. Kramer served as chairman and chief administrative judge of the Department of Transportation's Contract Appeals Board. In that capacity, Mr. Kramer heard cases involving contractors' claims for loss of labor productivity and authored a reported decision on one of the government's largest inefficiency cases in the history of any major board of contract appeals.

The construction industry is one of the leading capital industries that drive the U.S. economy. As an industry, it depends to a great extent upon labor productivity to remain profitable. Yet, many construction firms do not maintain the necessary records to supply the quantification of its labor productivity.

A contractor needs to maintain accurate contemporaneous productivity records to manage its labor forces and to serve as a foundation in the event of a productivity claim. While the courts and boards have established the principle that a contractor need not compute its loss of productivity with exactness, it would appear that accurate recording of a contractor's productivity is simply a management necessity to ensure profitability, irrespective of the portent of an inefficiency claim.

One of the fundamental issues that a trier of fact considers in hearing a contractor's inefficiency claim is "cause and effect." Important in the consideration is the question of whether or not the contractor's claims as to productivity impacts comport with the quantum being sought. In my experience, "productivity" can be summed up as the efficiency that contractors achieve in converting inputs to outputs. In the construction industry, this usually means the conversion of labor hours to a quantity of installed materials, such as tons of steel erected, cubic yards of concrete poured or linear feet of pipe installed. However, where productivity is concerned, there is no general agreement and no "black letter" law as to how this is to be quantified. This is equally true of quantifying the loss of productivity. Furthermore, standard cost accounting categories and standard monetary categories do not readily yield the necessary quantifications of labor productivity or loss of productivity. Neither the IRS nor the vast majority of construction CFOs arrange for, or demand, the reporting of the necessary elements to calculate or quantify productivity or its loss.

This lack of quantification on productivity or its loss becomes problematical when disputes arise. The disputes process that is presented to tribunals calls for magistrates to make findings of fact on very specific matters. Although there is currently no accepted empirical study that delineates a specific methodology or a particular means of record keeping to prove productivity or the loss of productivity, one method of labor productivity quantification that has achieved a relatively high level of acceptance is known as the "measured mile" analysis. This methodology is highly dependent upon the contractor's books and records and also upon the presence of an unimpacted and impacted area or period by which a production ratio can be computed. While this methodology has been well received by the courts and boards, it is also true that this methodology cannot be applied on many construction projects for a host of reasons, two being the lack of detailed productivity record keeping and the lack of suitable or comparable unimpacted areas or time frames. The inability to prepare a measured mile analysis does not, in and of itself, bar a contractor's loss of productivity claim. In such cases, the contractor must apply a different methodology to connect the cause and effect.

It is a fact that the MCAA factors have been in use for over 30 years in furnishing a means of estimating loss of productivity in construction matters. One of the most beneficial and advantageous facts is that the MCAA factors require users to consider carefully the narrative facts and project events or milestones with the trends shown by the numbers. "How to Use the MCAA Labor Factors" repeatedly instructs users to assess carefully each and every element of fact along with the use of the percentage factors provided by "Factors Affecting Labor Productivity." Direct and indirect impacts need to be quantified carefully in conjunction with the specific events of the project.

This process of matching the facts with the claimed loss of productivity is designed to provide the deciding tribunals with a degree of confidence necessary to reach the ultimate decisions. It is well recognized that a contractor does not have to prove its loss of productivity with mathematical exactitude; however this does not relieve the contractor from making a compelling case as to the specific causes of the impacts and to connect then with a logical effect. In this regard, the MCAA factors have been found to be a reliable means of estimating a contractor's loss of productivity caused by individual categories of causation. For this reason, "How to Use the MCAA Labor Factors," which outlines how to use the MCAA factors to arrive at a reasonable estimate of productivity or loss of productivity, should furnish much needed and useful guidance to users who need to estimate productivity quantities and costs.

MCAA thanks Judge Kramer for providing this introduction.

How to Use the MCAA Labor Factors

Introduction

Since 1971 the MCAA has offered "Factors Affecting Labor Productivity" in its *Management Methods Manual*. Known as the "MCAA factors," they have been used by contractors to forward price estimated losses of labor productivity in change order proposals, and to retroactively price estimated losses of labor productivity in the whole after the completion of a project. Since their introduction in 1971, the factor titles, descriptions and the percentage of estimated impacts have remained unchanged.

"How to Use the MCAA Labor Factors" has been developed to provide detailed explanations suggesting the proper use of the MCAA factors in estimating losses of labor productivity for both forward and retroactively priced change requests and for performing labor productivity analyses.

Also included are some points of consideration when assessing change order conditions and contract language that may affect the contractor's ability to recover its damages. However, this chapter offers no legal opinions or conclusions and the contractor should review all project documents and conditions with counsel.

This chapter has been prepared to assist the contractor with the quantification of the loss of labor productivity caused by occurrences described by the various MCAA factors. Of all construction-related subjects, the proof and quantification of the loss of labor productivity are recognized as among the most difficult and complex to describe. An attempt has been made to avoid the overly scientific and complex. It is understood that quantifying a loss of labor productivity is oftentimes based on an estimate of losses. However, by the very complex nature of the issue of the quantification of labor productivity loss, detailed explanations and qualifications of applications must be offered to the contractor.

The MCAA factors have proven to be a reliable means of estimating the loss of labor productivity on construction projects for over 30 years. The specific values shown in the factor tables must be applied with careful consideration and a review of the facts surrounding the events, which caused the loss of productivity. The applications of the various MCAA factor percentages will vary as project conditions dictate. This chapter will provide specific guidelines and examples of several methods of application for the proper use of the MCAA factors in calculating the loss of labor productivity on construction projects.

It is important to note that the MCAA factors have gained wide acceptance in the construction industry and before various courts, boards of contract appeals and tribunals of the American Arbitration Association. For example, reference the *Appeal of Clark Concrete*.[1] In this recent decision by the General Services Board of Contract Appeals, the board wrote, in part:

> "To assess the impact of unanticipated conditions on productivity … P&K used a manual published by the Mechanical Contractors Association of America (MCA). … P&K has used it on other projects to measure similar impacts, and the publication is generally accepted in the mechanical industry for this purpose. … We have previously accepted the use of this manual for this purpose as well. Stroh Corp., 96-1 BCA at 141.132; also see Fire Securities Systems, Inc., VABCA 3086. 91-2 BCA 23,743 at 118.902. … The manual lists various types of impacts, and for each, a percent of labor costs which represents loss of labor productivity under each of minor, average, and severe impacts."

Coupled with credible testimony, the MCAA factors can be useful to contractors, owners, boards of contract appeals and other courts and tribunals for the purpose of estimating a contractor's loss of labor productivity.

There are many definitions for the impact costs associated with a productivity loss on a construction project. The Department of Veterans Affairs Board of Contract Appeals in one decision offered the following cogent explanation:

> "Impact costs are additional costs occurring as a result of the loss of productivity; loss of productivity is also termed inefficiency. Thus, impact costs are simply increased labor costs that stem from the disruption to labor productivity resulting from a change in working conditions caused by a contract change. Productivity is inversely proportional to the manhours necessary to produce a given unit of work. As is self-evident, if productivity declines, the number of manhours of labor to produce a given task will increase."

The board continued in its explanations of inefficiencies:

> "Direct impact is generally characterized as the immediate and direct disruption resulting from a change that lowers productivity in the performance of the changed or unchanged work. Direct impact is considered foreseeable and the disrupting relationship to unchanged work can be related in time and space to a specific change. Cumulative impact is the unforeseeable disruption of productivity resulting from the "synergistic" effect of an undifferentiated group of changes. Cumulative impact is referred to as the "ripple effect" of changes on unchanged work that causes a decrease in productivity and is not analyzed in terms of spatial or temporal relationships. This phenomenon arises at the point the ripple caused by an indivisible body on two or more changes on the pond of a construction project sufficiently overlap and disturb the surface such that entitlement to recover additional costs resulting from the turbulence spontaneously erupts. This overlapping of the ripples is also described as the "synergistic effect" of accumulated changes. This effect is unforeseeable and indirect. Cumulative impact has also been described in terms of the fundamental alteration of the parties' bargain resulting from the change."[2]

[1] *Appeal of Clark Concrete*, GSBCA 14340 99-1 BCA @ 630, 820 (1999).

The Armed Services Board of Contract Appeals has also found that two types of productivity impacts can arise from changes to the contract and the board wrote as follows:

> "It is undisputed that the costs of performing changed work include both (a) those costs directly related to the accomplishment of the changed work, called 'hardcore costs,' and (b) those costs arising from the interaction between the changed work and unchanged work or expended to offset inefficiencies experienced as a result of changes, called 'impact.' Viewed broadly, 'impact' embraces: the man hours, labor costs, and material costs that are expended to offset inefficiencies experienced as a result of Government-caused or contractor-caused changes or other departures from the plan. Included is the process by which the above inefficiencies in the performance of contract work are created.
>
> Among other things, 'impact' includes: inefficiencies due to overcrowding, over or undermanning, skill dilution, extended overtime, shift work, and local and cumulative disruption.
>
> 'Local [or direct] disruption' refers to the direct impact that changed work has on other unchanged work going on around it. Conceptually, for purposes of this appeal, 'cumulative disruption': Is the disruption which occurs between two or more change orders and basic work and is exclusive of that local disruption that can be ascribed to a specific change. It is the synergistic effect . . . . of changes on the unchanged work and on other changes."[3]

It is clear that a contractor must consider both the direct impacts of a loss of labor productivity caused by a change to the contract scope of work, as well as the cumulative impact of changes in scope to the unchanged work. In the past, many contractors have used the MCAA factors only when "forward pricing" a loss of productivity component of a change order proposal. In addition to providing updated general instruction on the uses of the MCAA factors, this chapter seeks to explain how the MCAA factors can also be applied equitably and reasonably when retroactively quantifying the cumulative effects of changes on the productivity of a construction project.

General Discussion of Loss of Labor Productivity

To offer the lowest bid price or negotiated price for a construction project, labor intensive contractors such as mechanical and electrical contractors must plan to control labor productivity. Controlling the productivity of labor during construction is central to maintaining a fair and reasonable profit. When events occur which could not reasonably be foreseen by a contractor during the bidding or negotiating process, and which materially and negatively impact the contractor's labor productivity through no fault of the contractor, the contractor should consider seeking recovery of the costs of the loss of labor productivity.

For the purposes of this chapter, "owner" refers to the party with whom the contractor executed a "contract." If a subcontractor, it could be the general trade contractor; if a prime mechanical/electrical contractor, it could be the project "owner," whether public or private.

Contractors have long understood that adding new scopes of work to the original work plan can disrupt the flow and rhythm of the otherwise productive crews. The added work often

[2] *Appeal of Centex Bateson Construction Co., Inc.*, VABCA-4613 and 5162-5165.

[3] *Triple "A" South*, 94-3 BCA P 27, 194, ASBCA No. 46, 866.

comes at the peak of the planned effort on the project, when craft levels are already at their highest points on the labor curve. Also, added scope often affects the schedule, available work spaces, ability of labor supervisors to effectively manage base contract craft labor, material and equipment procurement and many other productivity-related factors. Sometimes the effects of a scope change/change order, or a series of such changes, on labor productivity can be of a higher dollar value than the direct cost of the change itself.

Assuming that the contractor did not cause the changed conditions, the contractor should seek to recover those losses in labor productivity either within the change order, or, if necessary, at the end of the project when all of the effects of project-wide changes on the total labor productivity can be measured. The courts have stated clearly that exact methods of loss of labor productivity quantification are not a condition precedent for recovery. Boards and courts have recognized the difficulty of measuring productivity loss and allow the contractor to use several methods, including the MCAA factors, to measure such losses.

Often, contract language known as "full accord and satisfaction" language, contained in some change order forms, may require the contractor to attempt to price all categories of productivity loss within the change itself, as estimated values. This is called a forward priced productivity loss and the cost of this estimated loss can be included as a line item in the change order proposal. While it can be highly beneficial to include all estimated impacts within a change order, thus "closing out" the change, many owners refuse to recognize labor productivity impacts caused by scope changes or other factors beyond the control of the contractor. This leaves the contractor in the unwanted position of either not executing change orders due to the risk of waiving its rights or placing a "reservations of rights" statement on each change, which can have the effect of holding open the option of making further requests for equitable adjustment should the contractor suffer productivity losses due to the cumulative impacts of changes in scope on the project.

Productivity loss recovery, which is sought at the end of a project phase or after the project is concluded, is called a retroactive productivity loss analysis. Such retroactive productivity loss analyses take into account the total impacts of all unanticipated categories of potential loss, such as the quantity (in terms of added craft hours) of changes, resequencing, schedule delays and disruptions, overtime and shift work and increase in crew size over the optimum level.

Many experts in the field of productivity loss analysis believe that the only means of recovering a significant portion of productivity loss is to measure such losses in their totality, at the end of the project, particularly when such losses are a result of a large number of scope changes,[4] which add a significant number of craft hours. This is believed to be true because it can be very difficult to evaluate fully the effects of productivity loss caused by one, single change in scope on the contractor's entire labor force, when it may not be known how many changes will be forthcoming in a given time period and how the aggregate of those potential impacts will increase the contrac-

[4] "Scope changes" refers to any changed condition that is outside of the contractor's scope of work. These can include added items of work over which there is no dispute (i.e., approved and pending change orders), disputed scope items, differing site conditions, and acceleration proposals.

tor's overall productivity losses. Such claims are typically called "cumulative impact" claims and are a recognized phenomenon by the major boards of contract appeals. It is understood that on projects pervasively and adversely affected by changes in scope, the only reasonable means of recovery may be through a cumulative impact claim rather than a forward priced, or individually priced, loss of productivity quantification.

Nevertheless, both methods of productivity loss—the forward priced and retroactively priced—are valid, and each project may demand the use of either, or both methods, described herein.

In terms of actually measuring a loss of labor productivity, several methods may be available to the contractor. A highly regarded method of measuring productivity loss is known as the "measured mile." This approach utilizes actual productivity measurements taken in unaffected and affected portions of a project and, from that data, a productivity ratio is established. However, many contractors do not maintain labor hour tracking and material installation records needed to support this methodology and on some projects, there are no unimpacted labor hours. In such cases, the MCAA factors can be very useful and have been accepted by courts and boards as a reliable means of estimating a contractor's loss of labor productivity.

It must be stressed that the contractor should carefully study the contract general and special conditions, the project schedule, change order forms and other, related documents to understand fully the rights, liabilities, obligations, limitations and remedies which are provided for by the documents that comprise the overall contract. These documents may dictate which method the contractor uses on a given project.

While the trend at the boards of contract appeals had been to define waiver language contained in change order forms as only waiving all impacts (direct and indirect costs) that were "knowable" at the time the change order was signed, the current trend points to much stricter and broader interpretations of waiver language on change order forms. An example of a generally "unknowable" impact is labor inefficiency caused by cumulative impacts: those impacts arising from a multitude of unanticipated labor-intensive changes in scope. Since cumulative impact labor inefficiency claims can only be quantified when all of the changes are known and the work is complete, in the recent past it was successfully argued that a contractor was not understood to have waived its cumulative labor inefficiency impact claim on executed change order forms containing "full accord and satisfaction" language since such impacts are not fully known while the project is active.

In line with the earlier cases, the recent U.S. Court of Federal Claims case of *Bell BCI Company v. United States*, 81 Fed. Cl. 617 (2008) upheld the proposition that cumulative impact labor inefficiency claims were understood to be preserved even in the presence of waiver language on change order forms. However, on appeal, this decision was vacated in part by the U.S. Court of Appeals for the Federal Circuit. The Court of Appeals did not issue a finding as to whether or not the contractor sustained a loss of productivity caused by cumulative impact. Rather, the Court of Appeals found that the broad waiver language contained on the government's change order form had released the government from any and all liability beyond the express relief provided for in the change order itself.

The Appeals Court wrote, "The language [on the change order form] plainly states that Bell released the government from any and all liability for equitable adjustments attributable to Mod 93." The Court further wrote, "if parties intend to leave some things open and unsettled, their intent to do so should be made manifest." As such, the contractor was barred from recovering its cumulative impact labor inefficiency costs for the contract modifications that contained the government's waiver language.

Based on this appeal, it would be wise for a contractor to assume that if broad waiver language is present on the change order form, such language will be viewed as a waiver of the contractor's right to later claim for any added compensation, even for those costs attributable to a cumulative impact claim that cannot be quantified until the project has been completed. Thus, if a contractor believes that a cumulative impact claim may be forthcoming due to a large volume of labor-intensive changes in scope, change order forms containing broad waiver language should only be executed after careful weighting of the potential cost impact of a waiver (i.e., waiver of future cumulative impact claims) and with the advice of experienced construction counsel.

Use of the MCAA Factors for Forward Pricing Scope Changes

The MCAA factors can be applied to a pricing sheet for a scope change on an itemized basis. Once the direct costs of the change have been estimated—the labor, supervision, material, equipment and other such costs—the contractor can apply one or more of the MCAA factors to the change order breakdown sheet. In order to evaluate properly the estimated, potential impacts to labor productivity of changes in scope, the contractor must determine if the change requires a departure from the contractor's otherwise productive work flow. A change of very limited scope, which may affect only a small crew, and which may occur in a limited and distinct area of the overall project, may have little or no measurable negative impact on productivity. However, such changes in scope are rare. Generally, changes occur in the most active areas, and at times when crews are at or near their peak. These types of changes can have a significant, negative effect on crew productivity.

In order to estimate potential losses of productivity using the MCAA factors, questions can be posed to the contractor's labor supervisor(s) by management:

1.a) Will this change in scope cause us to add craft workers to our current work force, and if so, how many workers will need to be added, when will they be added and for how long?

1.b) Answers to 1.a could lead to adding the appropriate percentage for MCAA factors such as:

Crew Size Inefficiency
Learning Curve
Dilution of Supervision

2.a) Will this change move our crews into unanticipated, severe cold, hot, rainy or windy seasons?

2.b) The answer to this question could lead to a percentage for:

Severe Weather

3.a) Will this change cause us to shift existing crews to new areas, to stop work where we are, remobilize in another area, then return to finish the original work scope?

3.b) The answer to this question could result in the addition of multiple MCAA factors to the change order pricing:

Reassignment of Manpower
Learning Curve
Dilution of Supervision
Stacking of Trades
Concurrent Operations

4.a) Will this change in scope cause us to work in areas which were unanticipated, with other trades, which were not planned for in the same area, and for how long?

4.b) Answers to 4.a could lead to adding the appropriate percentages for MCAA factors such as:

Stacking of Trades
Site Access
Concurrent Operations
Logistics
Ripple
Reassignment of Manpower
Learning Curve

These are the types of conditions, for the purposes of examples, which can result from the issuance of changes in scope, and which can cause a loss of labor productivity. The contractor must apply the appropriate factor categories and percentages.

"Factors Affecting Labor Productivity" includes three levels of potential productivity impacts—"Minor," "Average," and "Severe." Each level of impact intensity carries its own loss of productivity percentage. The three impact levels indicate the estimated effects of the changed condition on the labor hours being analyzed; i.e., specific hours within the total hours expended, or on the total hours expended on the project depending on the approach being used. Also, the three levels of intensity allow the user to more specifically assign an estimated impact for each of the MCAA factor categories being used, and like the categories themselves, should be applied with care and, if at all possible, with input by those who witnessed the conditions under evaluation.

While this chapter cannot provide for each and every condition under which contractors will choose a particular MCAA factor or factors, or the level of impact intensity, it is obvious that care must be taken to eliminate overlapping factors, to the fullest extent possible. The unrestrained and ill considered choice of multiple factors can lead to unreliable results.

For instance, the factor describing "Morale and Attitude" is a valid, but somewhat amorphous, category of inefficiency. The effects of a decline in workplace morale and attitude can be embodied in several other MCAA factors, such as stacking of trades, overtime fatigue and reassignment of manpower. It would be impossible to determine what portion the impact percentage caused by stacking of trades, overtime fatigue and reassignment of manpower is attributable to the attendant decrease in worker morale and attitude. Thus, by way of the above example, when using other factors that may already include in the loss of productivity factor a consideration for decreased worker morale and attitude, it may be advisable to avoid applying a potentially duplicative factor such as "Morale and Attitude."

Another example to consider when striving to avoid factor duplication is the "Ripple

Effect." This term of art has been used in several board decisions and is a well recognized phenomenon in the construction industry. This MCAA factor describes the downstream effect on the mechanical contractor of impacts caused to predecessor trades. For example, the mechanical contractor's schedule may be compressed because the building structure was erected late. In order to mitigate the structural delay, the general trade contractor may accelerate the follow on trades by stacking the crews of the various subcontractors, or forcing the subcontractors to work on an overtime basis. In such cases, the loss of productivity may be better classified by the events that result from the ripple effect, such as "Stacking of Trades" or "Overtime Fatigue."

On some projects, a mechanical contractor may add labor supervision in order to mitigate a loss of productivity caused by an unplanned requirement to substantially increase its work force. In such cases, the contractor generally submits a request for equitable adjustment for its added supervisory costs. Such additions of supervision usually do not totally eliminate the contractor's labor inefficiencies. The contractor may have suffered inefficiencies such as "Stacking of Trades," "Logistics," or "Reassignment of Manpower," which the added labor supervision could not mitigate or eliminate. However, where the contractor's supervisory forces are effectively increased, it may be duplicative for the contractor also to assert productivity losses arising from the MCAA factor "Dilution of Supervision."

Indiscriminate assignment of the MCAA factors can result in estimates that may be overstated and unreliable. Therefore, careful "testing" of each MCAA factor and its impact intensity must be carried out by the contractor. The description of each factor, which has remained unchanged for over 30 years, provides generally ample explanation of the type of impact described in each MCAA factor category.

It is important to understand that the MCAA factors provide a basis for developing reasonable estimates of loss of labor productivity and not for developing a loss with exactness. Thus, when the MCAA factors and their respective impact percentage are chosen, it must be with the intent to connect the cause or causes of the inefficiency with the reasonable effects. The MCAA factor descriptions represent the "cause" and the impact intensity percent represents the "effect" that can result from the conditions described by each MCAA factor. However, care must be taken to consider potential duplication and overlapping when the factor categories are chosen.

Likewise, the assignment of the impact intensity percentage must be chosen with care. For instance, if the change in scope is of a limited nature, on a project with a reasonably small crew size with little or no schedule impact (as opposed to productivity impact), then a "minor" category can be chosen. However, if the change is significant in its scope and requires major rescheduling and/or resequencing, crew size increases, overtime, shifting of work areas, piecemealing of the work and general disruption of the rhythm of the crews, then "average" or "severe" impacts could be the result.

When the factor for "Crew Size Inefficiency" is used, it is most helpful to have on hand a planned craft level chart based on the estimate or the project plan. When attempting to demonstrate that conditions beyond the contractor's control resulted in a loss of productivity, it is very helpful to show graphically what the contractor reasonably expected. Therefore, an estimated/planned versus actual craft curve is often helpful in graphically depicting the effects of unplanned crew size growth.

The percent values for each category chosen are additive in the change order pricing. Once all of the factors have been carefully evaluated for each changed condition caused solely by the proposed change in scope, the percentages are added together. The total percent is then multiplied against the estimated craft labor hours for the change. For instance:

Change order estimated craft labor hours:	2,750 hours
MCAA factor:	
Crew Size Inefficiency	10%
Learning Curve	5%
Reassignment of Manpower	5%
Total	20%
Estimated Loss of Productivity (2,750 x 20%)	550 hours
Subtotal, Craft Labor Hours:	3,300 hours

As stated previously, this methodology prices the estimated loss of productivity caused by project conditions only on the estimated change order hours. But what about the impacts of change order work on the unchanged hours? It is infrequent that a change in scope is so segregated from the base contract work that it has no effect on the crews performing unchanged, base contract work. How does the contractor recover the cost of a productivity loss caused by changes in scope to the unchanged work? There are several ways to estimate the impacts to labor productivity of changes to the unchanged work, two of which use the MCAA factors (i.e., the modified forward priced and retroactively priced methods). Another highly regarded method of measuring productivity loss is the "measured mile." This approach utilizes actual productivity measurements taken in unaffected and affected portions of a project, and from that data, a productivity ratio is established. However, as previously noted herein, many contractors do not maintain labor hour tracking and material installation records needed to support this methodology and on some projects, there are no unimpacted labor hours. In such cases, the MCAA factors can be very useful in estimating the contractor's loss of labor productivity.

Modified Forward Pricing for Estimating Labor Loss of Productivity on the Changed and Unchanged Work

It is a well understood principle that when significant changes in scope are issued to a contractor, a loss of labor productivity may affect the change order labor hours and the base contract labor hours. Previously herein, a method was described which only measured a loss of productivity on the estimated change order hours. This segment deals with estimating the effects of significant and pervasive changes in scope on the contractor's entire labor forces, both those working on the changed work and those working on base contract labor; known as "the effects of changes in scope to the unchanged, or base contract, work."

The principle is the same as is often employed to describe the overarching effects of overtime fatigue as it impacts the overtime hours and the straight time hours worked by the overtime crews. Obviously, if a crew works for eight weeks of scheduled overtime, 10 hours per day for six days per week, the fatigue and its resulting effects impact both the straight time and the overtime hours worked by that crew. There is no way to segregate the impacts of this sort of loss of productivity factor between straight time activities and overtime activities.

Similarly, if the owner issues a major scope change, or issues many changes in scope in the same general time frame, it may be impossible for the contractor to segregate the loss of labor productivity to the change order work from the loss of productivity imposed on the base contract work by the changes in scope.

As an example, a crew of nine pipe fitters is working productively on base contract work. The owner issues a change, which requires four of this crew to move to scope change work. The craft supervisor for this crew must now divert his attention from the total crew performing base contract work to setting up the new "sub-crew" performing the scope change work. The remaining five workers' productivity on the base contract work suffers because work is not being laid out as it was when the supervisor was focused only on the planned work of the single crew; answers to workers' questions take longer to resolve and materials and tools are frequently "borrowed" from contract work to perform scope change work. These impacts are defined by "Dilution of Supervision," "Reassignment of Manpower" and perhaps other MCAA factor categories. This is only one example of how a change in scope can affect the productivity of both the change order hours and the base contract hours.

When attempting to estimate and recover such losses in labor productivity when changes of a significant magnitude affect the base contract work force, a modified approach can be employed. It is called a "time specific" MCAA factor method.

The "time specific" method is used for both this modified forward pricing method and the retroactive pricing method (with slightly different rules), which will be described later in this chapter. The "time specific" method also requires significantly more information than does the standard forward pricing method, but it attempts to quantify loss of labor productivity to both the change order and base contract hours.

This method has some requirements, which may not be possible to meet because of problems inherent with the issuance of change orders. Some of the field conditions which can restrict or eliminate the effective use of this method include:

1) Unknown timing of owner's approval of the change order "notice to proceed;"
2) Lack of foreknowledge on the part of the contractor regarding pending changes in scope which are to be released by the owner for pricing;
3) Performance of the scope change work without change order execution; and
4) Not knowing what existing crews will be affected by the change order work.

Since these conditions are very prevalent on construction projects, the contractor may still be left with only three options: 1) use the method which limits loss of productivity estimates to the change order hours only; 2) wait until the project is over and perform an overall loss of productivity analysis; or 3) forego making any attempt to recover the loss of productivity costs from the party making the change.

However, if the project conditions allow the use of the modified approach, the general format is as follows:

1) The time frame of when the change order work will be performed must be known or estimated—in days, weeks, or at most, monthly increments.

2) The conditions of the change in scope must be known—what types and magnitudes of impacts are anticipated.

3) The planned craft hours for the affected period must be ascertained from estimates, labor plans or other labor forecast reports.

4) The crews which could be affected by the change must be known (i.e., some changes may only affect certain physical areas of an overall project, and therefore, not the entire work force).

5) A table is prepared with planned hours per period (day, week or month) across the top, including the estimated change order hours. The appropriate MCAA factors are listed along the "*y*" axis of the table. Under each time period, the appropriate MCAA factor percentage is estimated. The percentages may change from period to period based on the estimated impacts. The percentages are then totaled and multiplied against the total, estimated/planned craft hours.

6) An example of a resulting table follows:

In this example, a specific time frame has been evaluated for estimated impacts. This more specific method permits the contractor to make MCAA factor applications, which can vary as estimated conditions vary. This is actually more realistic and compares well with what actually happens in the field when changes are issued, or when acceleration or other impacts occur. In reality, as time and conditions in the field change, the MCAA factors can change as well and the estimate should reflect this fact.

For instance, if the MCAA factor "Learning Curve" is applied to a change, which is estimated to have a long term effect, this factor may only be applicable for the first two to four weeks of the impact, as new workers become familiar with the work area. This methodology allows for a more precise estimation of loss of labor productivity impacts.

Similar to the concept of performing time specific analyses, it is also appropriate to determine if the contractor's entire crew will be affected by the changes. If a change in scope only affects a separate and discrete area of the project, it may not be appropriate to impact the total crew hours by a loss of productivity factor. It is generally appropriate to use the MCAA factors on only those crews that will be affected by the changed condition.

C.O. Impact Period	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**
Orig Planned Hours	400	400	600	600	720	800
Est C.O. Hours	80	160	320	400	400	160
Revised Planned Hrs	480	560	920	1,000	1,120	960
Learning Curve	5%	5%	5%	0%	0%	0%
Dil of Supervision	0%	10%	10%	10%	10%	10%
Crew Size Ineff	0%	0%	10%	10%	10%	0%
Total MCAA factor	**5%**	**15%**	**25%**	**20%**	**20%**	**10%**
Est Loss of Productivity	**24**	**84**	**230**	**200**	**224**	**96**
					Total	**858**

Unfortunately, many owners simply do not recognize the effects of significant or numerous changes on the productivity of the base contract labor. However, virtually all contractors recognize this condition as a costly loss of labor productivity. Therefore, the contractor is frequently left with only one option, a post-project measurement of productivity loss caused by conditions that are not the fault or responsibility of the contractor.

Impacting the Project Schedule Using the MCAA Factors

This chapter does not deal with the development of the schedule time impact analysis ("TIA") or "fragnet." However, contractors should impact the current project schedule activities with the loss of productivity estimates derived from using the MCAA factors.

For instance, a contractor originally planned a series of activities as shown below. One of the activities was adversely affected due to a change, resulting in a 20% impact to productivity. Inefficiency can impact schedule durations and as such, the duration of the affected work must also be factored. Unless crews are added, the originally planned duration for "Piping Branches" would increase from 18 days to 22 days as a result of the 20 percent impact to productivity.

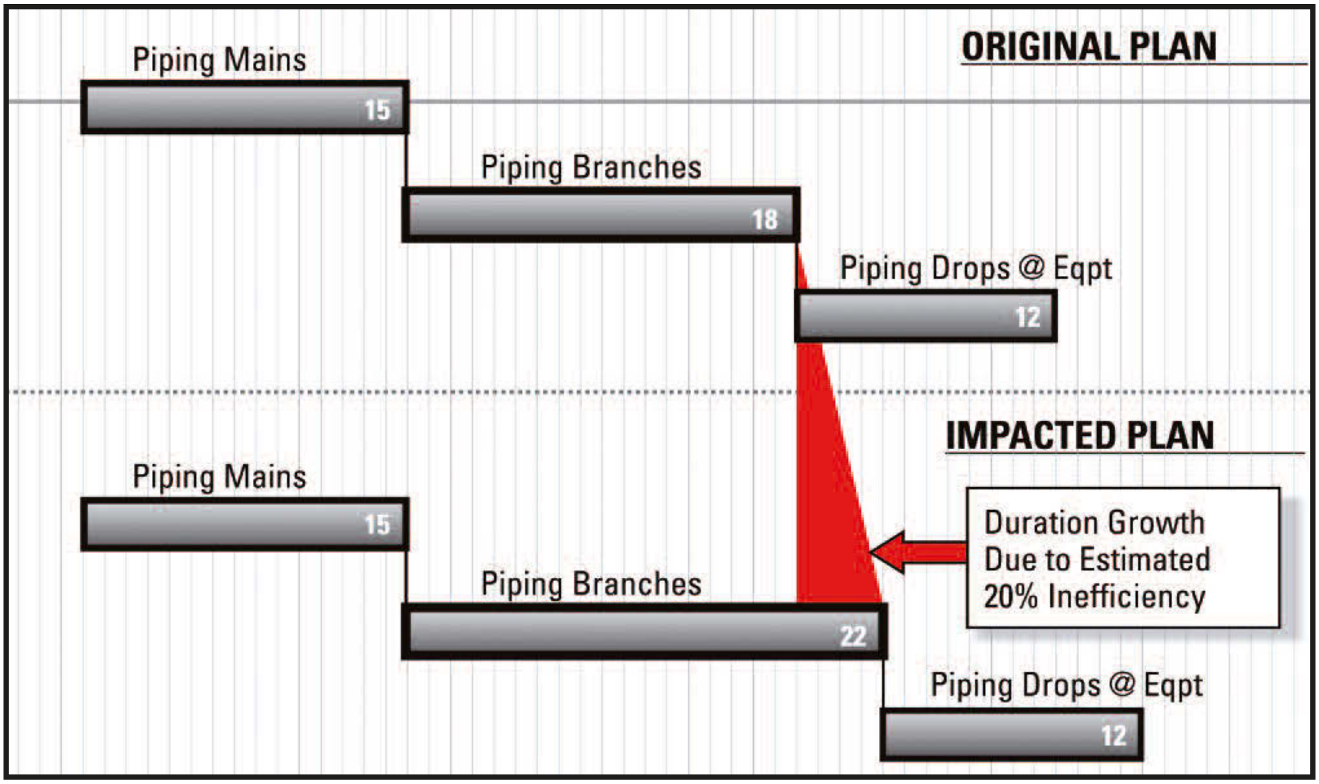
The loss of labor productivity will, in general, cause planned activities to take longer to perform, because the productivity ratio of 1:1, which was most likely used as the basis of the activity duration estimate, is no longer accurate. The contractor will no longer receive one hour's production for an hour planned, but rather some production rate less than the plan. Therefore, unless crews and supervision are added to the schedule in such numbers and with such care so as to accommodate the loss of productivity, the work activities will take longer than planned.

In this example, the 18-day planned activity in the series will take approximately 22 days each to perform, given an estimated loss of productivity of 20 percent. The adjustment of the project schedule for estimated losses in productivity can have a significant impact on the critical path, and on forecasted job costs. As can be seen in the graphic on page 115, the extension of a duration of a planned activity by adjusting the duration for an estimated loss in productivity using the MCAA factors can materially affect the schedule.

Retroactively Pricing Losses of Labor Productivity Using the MCAA Factors

In many instances, the only option for a contractor attempting to recover a loss of labor productivity caused by changed conditions is to wait until the project is over and review the actual loss; planned versus actual. Such claims are sometimes known as "cumulative impact" claims. The "plan" can be the original estimate of craft hours or the preconstruction target plan. Before a contractor makes a claim for a loss of labor productivity at the conclusion of a project, several obvious considerations must be made, including:

1. Was the estimate/plan of craft hours accurate and reasonable?
2. Were the conditions, which caused the loss of productivity, reasonably foreseeable when the project was bid/negotiated?
3. Did the contractor cause this loss of productivity?



4. Were the principal causes for the loss of productivity the responsibility of identifiable parties?
5. Will the potential cost of recovery exceed the loss?

There are a series of important legal considerations which could be added to this list which can only be addressed between the contractor and his construction counsel, and which are not the subject of this chapter. Additionally, this chapter addresses several methods of calculating a loss of productivity using the MCAA factors; however it does not address the means and methods of proving the impacts, often known as the "triad of proof," which includes proving (a) liability; (b) causation; and (c) resultant injury. This is also known as the "cause-and-effect" connection, which is necessary in linking an owner's actions and/or inactions to the contractor's injury. This chapter assumes that the contractor has already determined liability and causation, and is attempting to quantify the "resultant injury" by the use of the MCAA factors.

Assuming that the contractor is satisfied that the loss of productivity is significant and is principally the fault of another identifiable party, and that party is legally accessible for redress, then the contractor must prepare the cause and effect analysis.

Frequently, contractors use the MCAA factors to retroactively price the cumulative effects of changes in scope. Often, the method used by contractors is to multiply the cumulative percentage of losses of productivity as derived from the MCAA factors against the total, actual hours expended, sometimes with, and sometimes without, change order hours included in the total.[5]

This methodology of multiplying the MCAA factor percent against the actual hours is incorrect. The actual hours against which the MCAA factors are frequently multiplied in a contractor's retroactively priced claim for loss of productivity already include the contractor's loss of productivity; therefore multiplying the MCAA factors against the actual hours overstates the loss of productivity. Only by removing the theoretically efficient hours from the contractor's actual hours can the MCAA factors be properly applied in a retroactively priced request for equitable adjustment.

The actual hours must be further adjusted to deduct:

1. Time and materials hours;
2. Hours spent to repair the contractor's defective work;
3. Change orders on which a loss of productivity has already been calculated; (If the contractor has included "forward priced" loss of productivity in individual, executed change orders, and then seeks to recover global losses at the end of the project, these incremental, per change order loss estimates must be factored out of the computations.)
4. Hours associated with executed change orders, where it has been determined that the contractor is barred from recovering the impact caused by the executed change orders;
5. Hours expended by crews that were not affected by a loss of productivity;
6. Other types of productivity losses for which the contractor is responsible (i.e., bid errors)

Also, some contractors simply apply the total MCAA factor percentage to the total actual hours for the entire project duration. This can, in some instances, lead to inaccurate results because the effects of labor inefficiency can change during the life of the project.

The MCAA factor percentages sometimes change as actual project conditions change. Therefore, it can be useful to assign the MCAA factors to the specific impacted time frames within the overall project duration. In some cases, multiplying an MCAA factor against the total hours expended for the total duration of the project will result in a distortion (on the high side) of the forecasted loss of productivity.

The loss of productivity categories described by the MCAA factors can occur in a non-linear fashion across the entire duration of a project. To more accurately demonstrate the retroactive loss of productivity on a project, it may be desirable to divide the project into months (or, if possible weeks) and to assign loss of productivity percentages by MCAA categories by time periods, based on the accounts of eye witnesses (field managers, labor supervisors and other fact witnesses) or on documents prepared contemporaneously. Consideration of the areas of the project and the crews working in those areas is very important in performing this analysis. Only the crew hours that have been impacted by the changed conditions should be included

[5] As noted herein, it is imperative that the contractor carefully read the contract, including all general and special conditions, as well as the change order forms offered for execution by the owner. The contract terms set forth in such documents will, in most cases, dictate the contractor's rights of recovery and obligations for timely notice of delay and inefficiency claims.

in the loss of productivity computations. This is similar to the format for the modified forward pricing method, described previously.

When it is possible to apply this procedure, the types of losses described by the MCAA factors can be more accurately assigned to discrete time periods. The following table shows an example of this type of time-specific assignment of MCAA factors. Different MCAA factor categories can affect different periods of a project and at different percentages of impact intensity. As stated, it may be inaccurate to globally apply the cumulative MCAA factors against the total hours expended on a project. It may, depending on the specific circumstances, be more accurate for the contractor to evaluate the loss of productivity on a periodic, rather than on a total project, time scale.

The following table demonstrates the as-built, retroactive loss of productivity analysis using the MCAA factors, the rows indicate:

1. The actual work period being measured for impacts.
2. The actual, payroll craft labor hours (without supervision).
3. Craft hours deducted for time and material ticket work, the contractor's own deficient work (rework), any estimated, self-inflicted productivity losses, crew hours that the contractor believes were not affected by the changes in scope, such as crews working in areas of the project not proximate to the areas where the changed work was performed, and change order adjustments as described herein.
4. The resulting "revised actual hours."
5. The list of the MCAA factor categories being applied.
6. The resulting estimated loss of productivity for each time period.

Note that the total MCAA factor percentage has *not* been multiplied against the revised craft hours. Instead, the percentages have been totaled, the adjusted hours divided by one plus the decimal percent (i.e., 1.05 for the first period in the table), and that result subtracted from the total, adjusted hours. One significant difference between forward estimated and retroactively estimated productivity loss is that the contractor's actual labor hours already include the loss of productivity. Therefore, it is necessary to calculate the productive hours first to avoid overstating the loss of productivity.

Contract Period	Week 40	Week 41	Week 42	Week 43	Week 44	Week 45
Actual Payroll Hours	1,600	1,600	1,800	2,400	2,400	3,200
Deducted Hours		–80	–120	0	–120	–120
Revised Actual Hours	1,600	1,520	1,680	2,400	2,280	3,080
Reassignment of Mpw	5%	5%	5%	10%	10%	10%
Dil of Supervision	0%	10%	10%	10%	10%	10%
Crew Size Ineff	0%	0%	10%	10%	10%	10%
Total MCAA factor	**5%**	**15%**	**25%**	**30%**	**30%**	**30%**
Est Loss of Productivity	**76**	**198**	**336**	**554**	**526**	**711**
					Total	**2,401**

For instance, referencing the preceding table, during week 42, the contractor actually expended 1,800 labor hours. However, 120 hours were spent on time and materials work or repairing deficient work and were subtracted from the total, leaving 1,680 as the adjusted labor hours. After removing the contractor's self-inflicted inefficiencies, if any, hours not affected by the changes, or the hours for which the contractor was paid for the inefficiency (i.e., T&M), what remains are actual labor hours that already include the non-contractor caused losses of productivity.

After interviewing the site personnel, if it is determined that a 25 percent loss of productivity occurred, then the contractor must determine the number of hours that were efficient based on that estimated loss. Thus, taking the 1,680 craft hours and dividing that by 1.25 results in 1,344 efficient hours. Had the contractor not suffered any loss, 1,344 hours should have been spent on the work. The difference of 336 hours are those attributed to the identified loss of productivity described by the MCAA factors.

With the above analysis, the hours the contractor should have spent, if no loss of productivity had been encountered, have been calculated (1,344 hours). Since the contractor has estimated that the workers were impacted by a 25 percent loss, the resulting labor hours being claimed for recovery is 336. If the contractor simply multiplied the 25 percent times the adjusted actual hours (1,680 x 25%), the resulting loss would be estimated at 420 hours. The overstatement of loss would have been 84 craft hours (420 – 336) if the MCAA factor calculation had been misapplied.

The "Should Have Spent" Labor Hours in a Retroactive Loss of Productivity Calculation

One of the foundations of a loss of labor productivity claim is to determine how many hours the contractor *should have spent* to perform the work had the contractor not been affected by events caused by others.

The purpose of dividing the actual, adjusted[6] labor hours by 1.n, where *n* is the decimal % of the total of the selected MCAA factors, is to derive the "should have spent" hours on the project. Once the "should have spent" hours have been calculated, then these hours can be subtracted from the total, adjusted actual hours to determine the hours of lost productivity. In a hypothetical project, one without changes in scope, estimate errors and contractor-caused inefficiencies, the calculated "should have spent" hours should, theoretically, equal the original estimated hours. However, this hypothetical condition almost never exists.

The actual hours are affected by a series of inextricably intertwined events, such as impacts of changes to the unchanged work, impacts caused by the direct hours of change order work to the changes themselves, and other factors that affect the number of labor hours actually expended on a project. Therefore, it is highly unusual when the calculated "should have spent" hours equal the original estimate of labor hours. The frequent inability to match the original estimated hours

[6] Adjusted (reduced) to account for such items as the contractor's remedial work, forward priced inefficiencies contained in change orders, contractor-caused inefficiencies and in some cases, the hours directly associated with executed change orders.

with the "should have spent" hours only demonstrates that many factors can enter into the total hours expended on a construction project, some of which can be difficult, or impossible, to identify and to quantify on an individual basis.

Calculating the "*should have spent*" hours:

Example:

A contractor estimates a project to require 10,000 hours of field erection labor.

At the conclusion of the project, the contractor determines that 18,000 hours of field labor were actually expended to construct the project.

The contractor determines that approximately 3,000 hours were expended on out-of-scope work, which came in the form of change orders and/or scope changes. The contractor also determines that approximately 300 craft hours were spent removing and replacing work which was improperly installed by the contractor's own forces.

The contractor then reviews the project documents, interviews the management team, and determines that owner-caused problems, such as scope changes, disruptions and acceleration, have caused a loss of productivity on the project. A review of the change orders themselves reveals no language which could bar the contractor from recovering losses of productivity caused by the change orders.

Using the MCAA factors, the contractor interviews the management team and determines that the combined impacts caused by the owner, as described in the applicable MCAA factors, is estimated to be 30 percent. In this simplified example:

10,000 estimated/planned hours

18,000 actual hours less the remedial work of 300 hours = 17,700 hours

17,700 adjusted, actual hours divided by 1.30 (1 + 30%, or 1.30) = 13,615 hours

17,700 adjusted, actual hours less 13,615 "should have spent" hours = 4,085 inefficient hours

The 4,085 hours represent the hours of lost productivity caused by all types of non-contractor caused impacts as calculated using the MCAA factors. The 13,615 hours are the "should have spent" hours if 17,700 adjusted, actual hours were spent and the project suffered an overall productivity loss of 30 percent.

From the above example the obvious question arises—what comprises the difference of 3,615 labor hours between the original estimate and the calculated "should have spent" hours (i.e.,13,615 "should have spent" hours—10,000 originally estimated hours)? The difference will most likely be comprised of the hours expended on scope change/change order work, the loss of labor productivity caused by the change order/scope change work and all categories of contractor-caused issues other than the hours subtracted in the "adjustment" phase of the computation (in this example, the subtraction of 300 labor hours which were attributed to the contractor's own forces).

When the estimated 3,000 hours in scope change/change order work are subtracted from the "should have spent" hours of 13,615, the result is 10,615 hours. The remaining 615 hours (i.e., 10,615—the estimate of 10,000 hours) are unidentified, non-productive hours for which the contractor is not making claim.

It is often alleged by owners that contractors do not account for their own inefficiencies when calculating a loss of productivity claim. The aforementioned calculation demonstrates that the contractor has not made claim for 615 labor hours, which can be characterized as non-productive labor hours for which the contractor has taken responsibility. By whatever means chosen by the contractor, any contractor-caused loss of productivity must be deducted from the total loss of productivity hours quantified in the contractor's request for equitable adjustment.

In the above analysis, the performance of change order work, as well as the contractor's base contract work, would be performed inefficiently. Consequently, it could be appropriate for the contractor to recover losses of productivity incurred in the performance of change order work as a part of the contractor's overall retroactive loss of productivity analysis as described above. However, as is discussed herein, it may be determined by the contractor's counsel that "full accord and satisfaction" language contained in executed change orders bars the contractor from the recovery of productivity losses on the direct change order hours. In such events, the contractor may deduct the executed change order hours from the total actual hours to arrive at the adjusted, actual labor hours, as described in the appropriate section of this chapter.

In some cases, the interpretation of the "full accord and satisfaction" language is so broad that the contractor's cumulative impact claim is barred in total or in part because such impacts are claimed to arise from the change orders containing such exculpatory language. Therefore, it is *absolutely essential* that the contractor review with counsel all proposed change order forms and other contract documents[7] that seek to limit the contractor's right of recovery—before the contractor executes such documents.

In the event that the contractor, or the contractor's counsel, determines that change order hours will *not* be deducted from the total, actual labor hours, it is necessary for the contractor to remove from the contractor's retroactively developed loss of productivity claim any forward priced loss of productivity hours which were included in the contractor's executed change orders. This is true because the MCAA factor calculation should include all categories of productivity losses, including those caused to the direct hours of the change orders themselves. To leave the forward priced productivity loss estimates in place when using the MCAA factors in a retroactive computation would be "double dipping." In performing a total project, retroactive loss of productivity calculation, it is necessary to deduct the individual forward priced productivity losses, which may have been included in the contractor's individual change orders proposals submitted by the contractor to the owner. This deduction can be included when arriving at the adjusted, actual labor hour total.

The calculated "should have spent" hours may include, in addition to the originally estimated hours: (i) actual change order/scope change hours; (ii) inefficiencies caused to and by the out of scope work (subject to

[7] Other contract documents such as the monthly payment requisition lien waiver and release forms must be reviewed carefully for exculpatory language that may seek to limit or bar a contractor's claims.

other possible limitations discussed herein); (iii) contractor-caused losses of productivity; (iv) contractor's remedial work hours; and (v) estimating errors. Consequently, the comparison of the "should have spent" hours to the original estimate is generally not appropriate. What is important is that the owner is not being charged with the "should have spent" hours or for contractor-caused impacts in the retrospective productivity loss calculation as described in the above example and elsewhere herein.

Modified Total Cost Method Check of the Productivity Loss Calculations

When using the retroactive productivity loss analysis, it is prudent for the contractor to check the estimated loss of productivity, which results from using the MCAA factors against the modified total cost method of calculating the loss of labor productivity. The modified total cost method consists of a very simple calculation:

Actual expenditure in hours		A
(Less)	Estimated hours	(B)
(Less)	All types of contractor-caused problems	(C)
(Less)	Change/scope change labor hours	(D)
Claimed loss of productivity hours		E

This section will suggest a simple check on the results of the loss of productivity calculations using the MCAA factors. This very important calculation check is shown as an example below using numbers from the "should have spent" example on page 119:

Total actual hours expended		18,000
(Less)	Estimated hours	(10,000)
(Less)	Contractor's remedial work	(300)
(Less)	Change/scope change hours	(3,000)
Subtotal (hours)		4,700
(Less)	Calculated MCAA factor loss of productivity hours	(4,085)
Total of remaining hours		615

The remaining 615 labor hours would be the contractor's productivity loss not claimed in the contractor's request for equitable adjustment. These hours would remain as a potentially undefined, but unclaimed, loss of productivity. Nevertheless, it could be concluded that some portion of the 615 hours was attributable to a loss of productivity caused by the 300 hours of remedial work. Thus, with this example, the contractor has taken to its own account a loss of productivity caused by its own actions and/or inactions.

It is possible, however, for the remaining hours to be a negative number. If the remaining hours are represented by a negative number, it would indicate that the contractor expected a savings in labor, as compared with the contractor's original estimate. While it is not impossible to put forth labor savings in a loss of productivity claim, it does require an added level of confirmation that savings in labor, as compared with the original estimate, would be a reasonable expectation of the contractor.

The reasonable expectation could include a detailed analysis of the originally estimated labor hours, a presence of an historical pattern of proven labor savings by the contractor on past projects, and a verification that the subject project lent itself to a higher-than-anticipated productivity by such factors as the presence of a high degree of prefabrication or repetitive work which was not fully addressed in the original estimate. If the remaining hours indicate labor savings, the contractor will most likely have to demonstrate both the claimed losses and the reasonability of labor savings, as compared with the original estimate.

Special Considerations for "Full Accord and Satisfaction" Change Orders when Calculating the Loss of Labor Productivity

Many public and private owners are including in their change order forms language which attempts to bar the contractor from recovering, at a date after the execution of the change order, any added costs arising from the change, such as loss of productivity. The referenced language—that which attempts to bar the contractor from recovering additional costs arising from the change order after the execution of the change order—is called "full accord and satisfaction" language. The actual wording varies from project to project, and such language is best reviewed by the contractor's counsel before the execution of the project's first change order.

Boards and courts have found that when such language is included on executed change orders, the contractor may be barred from the recovery of added costs arising directly from the change, after the execution of the change order document. In some cases, the application of exculpatory language is applied very broadly to bar the contractor from any further recovery arising from a change order containing such language. It is equally important to note that, in a Veterans Affairs Board of Contract Appeals case,[8] the board found that while the "full accord and satisfaction" language contained on the executed change orders barred the contractor from recovering retroactive, direct losses in productivity on the change order work, it did not bar the contractor from the board's consideration of the alleged losses in productivity caused by the change orders *to the unchanged work*.

In the above referenced Veterans Administration Board of Contract Appeals case, the real party of interest was the electrical subcontractor. The electrical subcontractor did not include any loss of productivity "impact" costs in its change order pricing, and sought to recover loss of productivity in its claim. The VA's change order forms contained "full accord and satisfaction" language. Complicating the matter, there was "reservation of rights" language on the part of the contractor also in evidence.

The board ruled that it was the intent of the parties to resolve all costs directly associated with the executed change orders during the negotiations for change order pricing. However, the decision further stated: "We find that Dynalectric's claims for cumulative impact on unchanged work … survive the accord and satisfaction agreement." The board found that, whereas the electrical subcontractor was barred from recovery of productivity impact costs on the work directly covered by executed change orders, which contained the "full accord and satisfaction" language, it could attempt to recover the cumulative loss of productivity impacts *to the unchanged work*.[9]

[8] See: *Appeal of Centex Bateson Construction Co., Inc.*, VABCA-4613 and 5162-5165.

[9] This determination by the board was in contrast to the appellate decision in the more recent *Bell BCI* matter described at page 107 herein.

Therefore, when the contractor's counsel finds that the contractor has executed change orders which contain enforceable "full accord and satisfaction" language, the contractor may find it advisable to remove from productivity loss calculations the hours (either estimated or actual) associated with the executed change orders. This deduction would form a part of the adjusted, actual hour computation explained herein.

Many contractors do not maintain records which memorialize the actual hours expended on change orders, or which identify when the change order work was actually performed. In such cases, it is necessary to use the estimated change order hours, and to further estimate when the change order work was performed. This is best accomplished by the onsite managers, as the fact witnesses who saw the work being performed. An analysis which deducts the hours for executed change orders may appear as shown below.

By using this example, the contractor's deficient work and the change order work covered by executed change orders which contained "full accord and satisfaction" language have been factored out of the calculation. However, the impacts of productivity loss caused by changed events on the unchanged work remain.

Court Acceptance of Loss of Productivity Calculations

There are several court and board cases with published decisions which describe the use of the MCAA factors. The recent *Appeal of Clark Concrete* case, cited previously herein, clearly stated the board's acceptance of the MCAA factors publication in presenting a mechanical contractor's claim for loss of productivity. In *S. Leo Harmonay, Inc. v. Binks Manufacturing Company*, tried in the U.S. District Court, Southern District of New York in 1984 (No. 82 Civ. 6868), Harmonay sued Binks to recover several categories of project costs, including a loss of labor productivity. In the case, Harmonay's fact witness testified to a productivity loss of 30 percent based on personal observations and the use of the MCAA "manual." The court, in this portion of the case, decided for Harmonay, stating in part, that:

> "… courts have often recognized that the extent of harm suffered as a result of delay, such as the loss of efficiency claim at issue, may be difficult to prove. Thus, courts have recognized that a plaintiff may recover even where it is apparent that the quantum of damage is unavoidably uncertain, beset by complexity, or difficult to ascertain, if the damage is caused by the wrong."

Contract Period	Week 40	Week 41	Week 42	Week 43	Week 44	Week 45
Actual Payroll Hours	1,600	1,600	1,800	2,400	2,400	3,200
Change Order Hours & Other Deductions		–80	–120	0	–120	–120
Revised Actual Hours	1,600	1,520	1,680	2,400	2,280	3,080
Reassignment of Mpw	5%	5%	5%	10%	10%	10%
Dil of Supervision	0%	10%	10%	10%	10%	10%
Crew Size Ineff	0%	0%	10%	10%	10%	10%
Total MCAA factor	**5%**	**15%**	**25%**	**30%**	**30%**	**30%**
Est Loss of Productivity	**76**	**198**	**336**	**554**	**526**	**711**
					Total	**2,401**

This is an important case which established that even though the loss of productivity cannot be computed with exactness, the impossibility of reaching an exact proof of loss does not bar recovery.[10] Also, in the Stroh case, which was previously cited, the General Services Board of Contract Appeals restated two important principals of productivity loss claims; that exact measurement of productivity loss is not a condition precedent for recovery, and in loss of productivity claims, the claimant bears the burden to clearly demonstrate that the cause (for which the claimant was not responsible) resulted in the effect (loss of productivity).

It is fortunate that courts and boards have recognized the difficult nature of quantifying with exactness construction productivity losses and have not found the absence of precise measurements as a bar to recovery. Furthermore, the MCAA factors publication has been recognized as a useful and reliable tool by which loss of productivity impacts can be estimated, particularly when their use is coupled with credible fact-witness testimony.

When a Contractor Must Litigate an Inefficiency Claim

It is usually in a contractor's best business interest to settle, or at least to mediate, a construction dispute rather than to litigate or to take the matter to arbitration. The decision to litigate, or to arbitrate, means handing over the destiny of your case to others. It is usually a better business decision to control your destiny and bring a contentious matter to an amicable settlement, if at all possible.

When a contractor has utilized the MCAA's labor inefficiency factors and then decides to take its loss of labor productivity claim forward for a hearing at arbitration, in a court or before a board of contract appeals, it is helpful to know how the courts and boards have viewed this method of calculating labor inefficiency. As noted previously in this chapter, the MCAA factors, if properly applied, have gained broad acceptance as a reasonable means of estimating a contractor's loss of productivity. However, that does not mean that boards of contract appeals automatically find persuasive contractors' inefficiency claims prepared using the MCAA factors. A contractor should expect probative questioning regarding the factual basis of such claims, how the claim was prepared, who prepared it, and the qualifications and independence of the person testifying on the issue of labor inefficiency.

From time to time, the source of the MCAA factors may be questioned. This issue has been addressed by the MCAA in a Declaration filed in 1999. While the records of the polling and data collection process were not retained in MCAA's files, through historical research, the means of preparation of the factors have been memorialized. Pertinent excerpts from MCAA's Declaration follow:

> The MCAA Factors apparently were developed by the MCAA Management Methods Committee beginning in the late 1960s and continuing into the early 1970s. It is (MCAA's) informed belief that the committee was comprised of MCAA Member representatives who were experienced mechanical contractors. MCAA records show that in April 1969 a "rough draft on the subject of Change Orders in the Construction Industry" was presented to MCAA's Board of Directors…. In May 1970, the Management Methods Committee reported to the MCAA's Board of Directors on a

[10] Luria Bros. & Co. Inc. v United States, 369 F.2d 701, 712, 177 Cl.Ct 676 (1966).

> "complete 'in-depth' study of the whole Change Order concept as it affects the construction industry." It is (MCAA's) informed belief that this is the predecessor of the current MCAA Factors. It is also (MCAA's) understanding that the substance of this document has not changed since that time. It is now known as the "Factors Affecting Labor Productivity."…the available documents indicate that the committee and its members were responsible for selecting the titles and descriptions for each of the factors and formulating the percentage values that are set forth in the document. To the best of MCAA's current knowledge, the information contained in the MCAA Factors was gathered anecdotally from a number of highly experienced members of the MCAA's Management Methods Committee. MCAA does not have in its possession any records indicating that a statistical or other type of empirical study was undertaken in order to determine the specific factors or the percentages of loss associated with the individual factors.

The process of collecting data such as that which appears in the MCAA factors' table using a polling process is not unusual or proscribed. Such methods have been used to establish losses of labor productivity by many trade associations other than MCAA. The factor descriptions were prepared in advance by the Management Methods Committee. A form was created listing the factor descriptions and three levels of potential impact: "Minor," "Average," and "Severe." The form was then made available to the MCAA member firms for careful review. The intensity data, in the form of the expected impacts percents, were filled in by the MCAA member firms. From this broad polling process, the factor descriptions and the expected impact percentages were reviewed and finalized by the Management Methods Committee and then formalized in the MCAA's publication.

Not only were the factors prepared by experienced and knowledgeable leaders in the mechanical construction industry, the factors have constantly been vetted in the industry for the past 40 years and found to be reasonable and reliable. They have remained unchanged since their first publication and have been accepted by courts, various boards of contract appeals and arbitration panels as useful in estimating a contractor's loss of labor productivity. Moreover, the MCAA factors have been formally adopted by the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) and have been utilized by the National Electrical Contractors Association (NECA) and the Electrical Contracting Foundation in its publication entitled *Factors Affecting Labor Productivity for Electrical Contractors*.

In terms of preparing to utilize the MCAA factors in a litigation or arbitration to establish a claim of lost labor productivity, it is vital that the contractor retain an experienced and independent expert to perform the inefficiency analysis, prepare the expert report, and testify as an independent expert if necessary. In several recent cases in which the MCAA factors were utilized, the Armed Services Board of Contract Appeals has indicated that the testimony regarding labor inefficiency quantification should not be performed by an employee or principal of the claimant, but rather by an *independent* labor productivity expert. That is not to say that credible fact witnesses, such as foremen, superintendents, and project managers should not testify as to the causes and effects of issues adversely affecting labor productivity. Credible fact-witness testimony is very important to establishing the cause and effect nexus. However, if various formulae are to be applied during testimony in litigation or arbitration, including utilization of the MCAA factors, then the use of an independent expert is highly recommended and may be mandatory if an analysis utilizing the MCAA factors is to be credible and reliable.

Even when an independent expert is utilized, it must be underscored that the MCAA factors should be applied in a reasoned manner, relying on the methodology set forth in this chapter. Outlandish and unsupportable inefficiency analyses will draw deserved skepticism from courts and boards of contract appeals. If the MCAA factors are not applied in a proper manner as described in this users' manual, a contractor can expect to face a high bar in its attempts to recover its loss of labor productivity.

Conclusion

The loss of labor productivity is often difficult to quantify with exactness. The MCAA factors can be highly useful to contractors seeking to recover losses in labor productivity due to events not the fault of the contractor. The contractor facing a project that shows the symptoms of delays and inefficiencies should ensure that the contract terms and conditions for timely notice and impact quantification are followed with care. Many otherwise meritorious claims for which the contractor is entitled to recover its fair and reasonable costs are barred because the contractor failed to follow the contract terms as to notice and quantification, or failed to reserve the right to file a delay or inefficiency claim at a point in time after the execution of a change order.

The use of the MCAA factors in forward pricing change orders can result in an overall acceptable recovery of potential loss of productivity in addition to the direct costs of the change. Also, the use of the MCAA factors can result in a more accurate forecast of potential schedule impacts when durations of activities are factored for the estimated productivity loss.

It is essential that contractors weigh the value of recouping reasonable amounts for the indirect costs of change orders along with the direct costs against the potential of gaining a greater recovery by waiting until the end of a project to assess the cumulative effects of all changes issued during the life of the project.

As described herein, in some instances, the only option available to the mechanical contractor may be a retroactively quantified loss of productivity claim. In such cases, the MCAA factors can be applied to the adjusted, actual hours expended by the contractor.

Productivity loss caused by changes in scope, including defective design, unforeseen site conditions, delay and acceleration and change orders, can be real, provable and recoverable. Using the MCAA factors correctly can materially improve the contractor's ability to recover from such losses.

Prepared by Paul L. Stynchcomb, CCM, PSP, CFCC of Vero Construction Consultants Corp. and Jarad Kriz, CCM, LEED® AP (BD+C), PSP of FTI Consulting, with peer review performed by: Wayne Day of John J. Kirlin, Inc.; Raymond Jung of The Poole & Kent Company; Robert Gawne and Richard Freeman of Stromberg Metal Works, Inc.; Herman Braude, Esq. of Braude & Margulies, P.C.; Robert Windus, Esq. of Moore & Lee, LLP; and Henry Danforth, Esq. of Watt, Tieder, Hoffar & Fitzgerald, LLC.

How to Apply the Measured Mile Method of Productivity Analysis

Introduction

When the labor on a project exceeds the estimate or job plan, the mechanical contractor often commences an analysis of the causes for, and quantification of, its labor loss. This sometimes leads the contractor to seek relief from a third party, such as a prime contractor or owner. Frequently, the third party's first line of defense will focus on assertions that the mechanical contractor's original labor estimate was flawed. When properly applied, the "measured mile" analysis is a very effective means of quantifying the loss of labor productivity. This method relies on a comparison of the contractor's actual unit rate ratios on the subject project, thus eliminating concerns over bid errors.

The measured mile method compares actual labor productivity in an impacted period or area with productivity in an unimpacted (or less impacted) labor period or area in order to establish what the labor production rates "should have been" in the impacted labor periods or areas. To be effective, the work performed in each area or period needs to be of a reasonably similar nature. The work performed in the unhindered or less impacted area or time frame is frequently known as the "baseline" or "measured mile" labor. The process of calculating the difference between the "should have spent" labor hours and the actual labor expended in the impacted areas or time frames is referred to as the measured mile method of labor productivity analysis.

The more detailed and accurate the contractor's labor expenditure records, the more persuasive the measured mile analysis will be. Contractors are advised to evaluate their record keeping procedures to ensure that the information necessary for a measured mile analysis is being collected and maintained on a regular basis.

This chapter offers a description of the measured mile method of productivity analysis, discusses record keeping and provides examples of the analysis process itself, along with ways in which the results can be presented. When used properly, the measured mile analysis can offer a compelling case for recovering a mechanical contractor's loss of labor productivity.

Applying the Measured Mile Method to Quantify a Loss of Labor Productivity

The measured mile method provides for a differential productivity comparison between actual production rates achieved on the same project.[1] Because this methodology relies on actual production rates, no reference or reliance upon the contractor's estimate or labor plan is required. This fact is one of the most important sources of credibility for this methodology.

Identifying the Measured Areas or Time Frames

In order to perform a measured mile analysis, different areas or time frames must be identified. These should be contrasted, one from another, by the inefficiency factors that have been alleged to be the root cause of the contractor's loss of labor productivity. The choice between utilizing physical areas of a project or time frames is at the discretion of the contractor based on the specific project conditions. The fact pattern may be such that similar sections of a building are definable with one or more definable areas having been less adversely affected by the productivity impact factors and with one or more definable areas having been more affected. These same conditions could be ascribed to discrete time frames.

For instance, a project could progress to the 50 percent complete point with reasonable productivity and then be subjected to a substantial acceleration effort resulting in overtime work, stacking of trades, crew size inefficiencies and reassignment of manpower for the duration of the project. The aforementioned case would suggest a time frame approach.

[1] While this chapter focuses on the use of labor hours in quantifying labor inefficiencies, some contractors have chosen to use unit costs. The measured mile method does not proscribe the use of costs as a surrogate for labor hours, however if costs are utilized, the claimant must be careful to remove all factors, such a wage increases, that would inherently unbalance the measured mile comparison.

On another project, one or more discrete areas could be constructed with reasonable productivity while other, similar areas were affected by substantial changes in scope, trade stacking, lack of owner-supplied materials (logistics), site access limitations and other identifiable factors. The differential measurement between such areas can form the basis of a measured mile analysis.

One means of determining which method is best for a project under study is to interview the site management (i.e., project managers, superintendents, and foremen) and seek their input into what took place (or is taking place) and what areas or time frames were more productive and less productive. This interviewing process will also form the basis of the cause-and-effect connection that will be required when proving and explaining the production rate differential.

Once this interview process has taken place, the observations of the staff can be tested against the actual labor production records. At this time, it may become obvious as to which format will be most effective: an area measurement or a time frame measurement. After the contractor has decided on whether the measured mile analysis will be made on an area or time frame approach, the collection and analysis of the actual payroll labor hour and material/equipment installation data can commence, as described in greater detail below.

Reasonable Similarity between Materials and Work Environment

The measured mile method measures the difference in actual productivity rates between sets of productivity impact conditions, one having little or no impacts and one having representative[2] impacts. For this measure to be “exact”[3] (which is ***not*** a condition precedent to use this methodology), the same material and/or equipment would have be to installed by the same crew, under the same management, in the same work environment, as measured between two areas or time frames that are similar in space and time; with the remaining difference being the influence(s) of inefficiency being claimed by the contractor. The aforementioned conditions virtually never exist on a construction jobsite. Only in an academic or laboratory setting would these precisely matched conditions be found.

The courts and boards of contract appeals only expect that the areas or time frames under measurement be ***reasonably similar***. These reasonable similarities between the data being measured include: 1) material and equipment types; 2) installation equipment and/or means and methods; 3) experience, quality and quantity of supervision; 4) experience and quality of the work force; 5) inherent work environment including exposure to weather factors and height of the work being installed; and 6) any other factor that would inherently imbalance or skew the productivity study.

For instance, comparing the installation of 4”, 6” and 8” standard weight A-53 carbon steel butt weld pipe to the installation of 8”, 10” and 12” pipe of the same or similar material would be considered as reasonably similar. Comparing the production rate for 2” carbon steel threaded pipe to large bore mechanically welded stainless steel pipe, if utilized in the analysis, offers inherent dissimilarities that will require a carefully considered production adjustment and/or thorough explanation of why the comparison is reasonable.

Installing pipe under a roof slab 30′ from the finished floor in a mechanical room can be more challenging than installing the same type of pipe system in a room with a 15′ ceiling. Installing straight lengths of pipe on pipe racks in an open area can be inherently more efficient than installing the same type of pipe in a crowded mechanical room where the pipe system has frequent changes in direction and may have valves and other appurtenances that could represent a lower production rate. Installing equipment during the winter in an area open to the elements with exposure to lower temperatures and wind will most likely be inherently less productive than installing similar equipment in a heated mechanical room (this assumes that the work was not delayed into an unanticipated adverse climatological period).

Installing material with a seasoned journeyman crew with proven competent supervision in an unobstructed area will most likely be inherently more productive than installing the same types of material in a congested area with a measurably higher ratio of inexperienced workers, less effective supervision or in more crowded or constrained conditions.

All of the potentially inherent differences must be identified and evaluated when performing a measured mile analysis. The goal of the analyst is to measure the differences in

[2] The term “representative” is used herein to mean impacts representing a reasonable and consistent level of productivity loss arising from the alleged causes as opposed to choosing a limited, particular area or time frame that exhibited the most drastic impacts without averaging or weighing the resulting inefficiencies with other impacted areas or time frames.

[3] Luria Bros. & Co. Inc. v United States, 369 F.2nd 701, 712, 177 Cl. Ct. 676 (1966)

productivity rates caused by the productivity impact categories identified in the analysis (i.e., stacking of trades, overtime inefficiency, disruption and other such categories), and to be confident that the segment is reasonably free of differences that would have, on their own, caused a measurable variation in the contractor's labor performance.

The Project Records

An essential feature of the measured mile method is its absence of reliance on the contractor's estimate or labor plan. This method relies on the contractor's actual unit rate ratio of production achieved on the project in different areas or time frames of the same project or, in some cases, highly similar projects. In order to establish the contractor's actual unit rate ratio, or productivity rate, records that set forth the actual labor hours expended to install a definable quantity of material and/or equipment is very helpful. They are not absolutely required, however, as explained herein.

A minority of contractors track, in a contemporaneous fashion, the amount of material and/or equipment installed by hour of labor. This sort of contemporaneous labor productivity tracking is very meaningful, however it usually requires a very substantial and costly effort to track the actual material installed by type and by labor hour. In some industries, such as the sheet metal industry, the difficulty of tracking actual material installed by labor hour is being overcome by electronic means of bar coding duct sections and tracking the duct from manufacture to pre-assembly to final installation in the field. Assuming the contractor's systems allow coding of actual labor to a section of duct, its actual manufacturing, pre-assembly and installation can be tracked with a reasonable degree of accuracy.

Such contemporaneous labor-tracking record keeping provides for valuable and timely productivity monitoring that requires little or no further adjustment in order to apply this data to a measured mile analysis. However, most mechanical contractors do not contemporaneously track the actual labor hours required to install lengths of pipe, supports, fittings and appurtenances or pieces of equipment in discrete areas or time frames on a project. The absence of contemporaneously maintained actual labor installation records does not preclude the use of a measured mile method.

Many contractors maintain labor performance reports. These are an earned value type of reporting because the actual hours expended to install a known quantity of work are compared to a plan or estimate. These reports typically provide a variance between discrete activities of work comparing the planned and actual hours on a regular basis, such as each payroll period, or monthly. Such labor performance reporting is described in greater detail within the chapter on "Maintaining Control of Labor Productivity," and a sample is shown on the next page.

In the sample labor performance report shown on the next page,[4] current actual payroll hours "C Act Hrs" are compared with an updated plan "Rev Plan"[5] to provide for weekly variances. The "Earned Hours" are a function of

[4] For an explanation of the data columns shown in this sample report, refer to the chapter entitled "Maintaining Control of Labor Productivity" herein.

[5] Many mechanical contractors do not track actual change order hours by activity code. Some mechanical contractors do not update the plan on an activity-by-activity basis for estimated change order hours. There is no established standard in the industry in this regard. However, at some level, the contractor must know if the production rates estimated to perform the work are being met on the project, either at the activity level or at the bottom line.

The Labor Performance Report (Example of Detailed Activities)

Activity ID Code	Activity Description	Planned Hours	CO Hrs	Rev Plan	Last % C	Current % C	Earned Hours	PT AH	C Act Hrs	Wk -2	Wk -1	Cw
7550	Inst CHWS&R Mains Area B	500		500	30	50	250	300	450	–75	–150	–200
7570	Inst CHWS&R Brnchs Area B	700	50	750	10	20	150	120	200	–40	–45	–50
7590	Connections @ Mech Equip	100		100	10	15	15	10	12	0	0	3

earned or reported percent complete multiplied against the updated planned hours. Thus, the contractor's measure of performance using an earned value reporting system is based on reported progress and the contractor's estimate, adjusted to incorporate changes in scope in order to compute a current, revised plan. This system enables the contractor to divide the overall plan into identifiable units of work, called activities. These activities usually have work boundaries that are defined by the description of the activity, as shown in the example on the next page.

Assuming the contractor has a labor performance reporting system that sets forth definable features of the work (i.e., activities), the contractor can locate the activity boundaries on a set of contract drawings and from that information, take off the material contained in the activity. Provided the contractor has coded the actual labor hours by discrete activity, the contractor can assign actual hours expended to a definable quantity of installed material and/or equipment.

Due to the differences in expected production rates between different piping and equipment systems, it is helpful if the contractor has defined its activities by pipe size (i.e., small bore versus large bore) and general material type (i.e., butt weld versus threaded, carbon steel versus cast iron, pipe installation versus equipment setting). Such differentiation will enable the contractor to assign the actual hours by general categories of pipe system, pipe type, equipment setting and other definable features of the work.

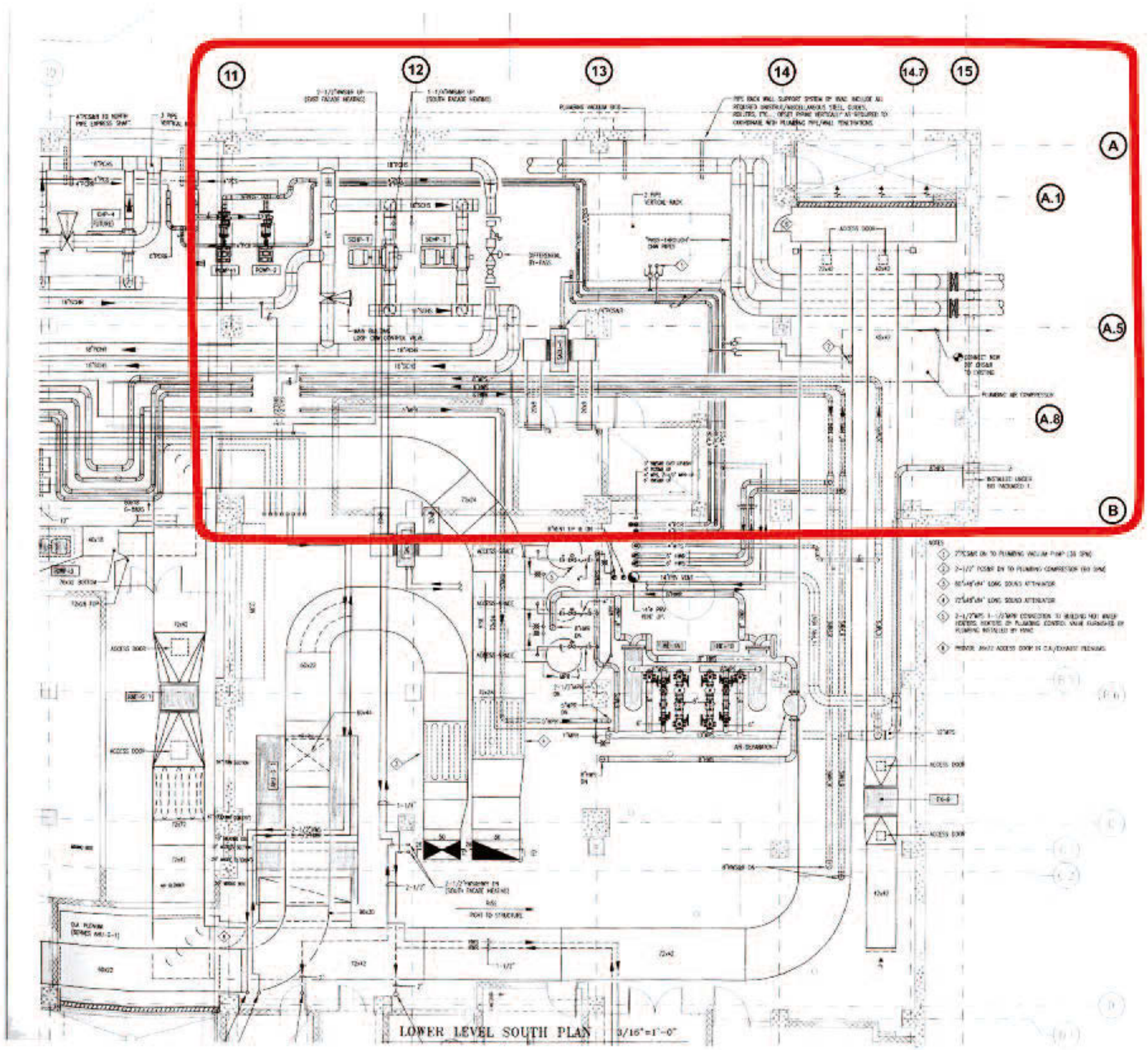
The goal of an exercise such as that described above is to assign actual labor hours expended to discrete elements of the construction process. This area-by-area comparison method is one manner of preparing a measured mile analysis. Once the actual labor hours have been defined and the material and/or equipment have been quantified, a production rate ratio can be computed.

Assuming the contractor has been able to identify a nonimpacted or less impacted area or time frame, then the actual labor hours and installed units can be measured. For example, a contactor measured 1,000 linear feet of 6" and 8" carbon steel butt weld pipe that required 575 labor hours to install[6] in a definable area or time frame. From this data,

[6] "Installation" needs to be uniformly defined within the analysis such that categories of work such as material handling and pipe support erection are consistently included or excluded.

Activity Boundaries Marked on the Contract Drawings

Activity 7550 - Mechanical Room Mains Column Lines 11-15/A-B



the contractor can compute a labor rate of .575 hours per linear foot, or 1.74 linear feet of pipe per hour of labor actually expended. Although the contractor was unable to differentiate the labor required to install the 6″ system from the 8″ system, the pipe systems were sufficiently similar to arrive at a blended production rate.

The contractor must now identify a reasonably impacted area or time frame in which similar work was performed but was adversely affected by the conditions the contractor has identified during the interview process described herein. For example, it was found that 1,500 linear feet of 4″ and 10″ carbon steel butt weld pipe required 1,250 hours to install. Once again, the contractor could not differentiate between the 4" and 10" pipe as to actual labor hours required to install the pipe systems. The blended production rate equals .83 hours per linear foot or 1.2 linear feet of pipe per hour of labor actually expended.

The measured mile method comparison would be .575 hours per linear foot in the non/less impacted area or time frame versus .83 hours per linear foot in the reasonably impacted area or time frame. Similarly, the methodology would compare an actual production rate of 1.74 linear feet per hour with an actual production rate of 1.2 linear feet per hour. The productivity factor would then be computed as 31 percent. Those calculations appear as:

0.575 ÷ .83 = .69; 1 - .69 = .31 x 100 = 31%

or

1.2 ÷ 1.74 = .69; 1 - .69 = .31 x 100 = 31%

The loss of productivity factor of 31 percent is then multiplied against the actual labor hours expended in the impacted area or time frame for the work being measured, or 1,250 actual hours x 31 percent = 388 labor hours lost due to the productivity factors that impacted the less productive area or time frame.

The results of this calculation also can be used to compute the "should have spent" labor hours between areas or time frames. From the example above, the contractor demonstrated that it actually installed butt weld carbon steel pipe at a rate of 1.74 linear feet per hour of labor in a less impacted area or time frame. There were 1,500 linear feet of pipe in the affected area. Absent the productivity factors being complained of in the affected areas, the contractor should have achieved approximately the same production rate in the impacted area or time frame as was achieved in the more productive area or time frame; 1,500 linear feet of pipe ÷ 1.74 linear feet per hour = 862 hours. The actual hours expended in the impacted area; 1,250 less the "should have spent" hours of 862 = 388 hours of lost productivity.

When more than one sampling segment of work is included in the measured mile analysis, particularly when the amount of material (i.e., pipe lengths) varies significantly between the segments of work being compared, it may be advisable to use a weighted average, weighted on pipe lengths or other material considerations. This process weights the production averages based on the amount of material being evaluated. Examples that follow include a weighted average computation. Depending on the data, some samples using a simple arithmetic average will produce the same, or nearly the same, results as using a weighted average. However, in analyses with multiple and relatively large sample groups, and with significant variances in the quantities of materials, a weighted average approach based on material quantities or other measurement metrics can yield measurably different results as opposed to a simple arithmetic average.

Unusual Study Observations Caused by Inconsistent Project Conditions

One of the goals of a measured mile analysis study is to evaluate differential productivity rates by comparing similar work being performed under similar conditions, with the exception of identifiable categories of inefficiency that affect one set of labor hours but not the other set of labor hours, or at least to the same extent. Sometimes when performing a measured mile analysis, an area or time frame under study shows a productivity rate that is either much greater or much lower than other unimpacted or less impacted areas or time frames. The contractor should carefully review these apparent anomalies and take appropriate action. One appropriate action could be to exclude these apparent outliers as shown in the example below:

Step 1. Identification of Areas and Production Rates
Assume all areas contain a mix of 4", 6" and 8" Std. Wt. B.W. pipe, 8-hour workday, 5 days per week, at approximately the same elevation and work environments, but production anomalies exist in one of the "better productivity" areas of the study (i.e., Area C).

Areas that are expected to be more productive and less productive can be calculated as shown in the example at the bottom of the page.

Step 2. Weighted Average Method
In the example at the top of the next page, Area C has been excluded from the weighted average because of its unusually high rate of productivity. This type of exclusion is known as an "outlier" due to its unusually high rate of productivity compared with the other less impacted areas and thus was not included in the weighted average. The second box on the following page provides sample calculations used in determining the weighted average of the less productive areas.

Step 3. Example Loss of Productivity Calculations Using the Weighted Averages
The contractor demonstrated a weighted average production rate of 2.54 linear feet of pipe installed per labor hour expended in the less or nonimpacted segment of work.

The contractor did not include Area C due to apparent dissimilarities (an exceptionally high production rate in comparison to the other less impacted areas)

The contractor's demonstrated production rate in the impacted areas averaged 1.82 LF/MH for 5,800 LF of pipe.

Step 4, Option 1: Calculate the "Should Have Spent" Hours
In the impacted areas, 5,800 LF of pipe should have been installed at the proven rate of 2.54 LF/hour. Samples of these calculations are provided on the facing page.

Step 4, Option 2: Calculate the Inefficiency Factor
A calculation of the production rate ratio would look like the example on the next page.

Sample Calculations to Identify Expected More Productive Areas

Area A: 3,000 linear feet of pipe – crew of 4 for 38 days = 2.47 LF/MH
Area B: 4,300 linear feet of pipe – crew of 4 for 52 days = 2.58 LF/MH
Area C: 2,500 linear feet of pipe – crew of 2 for 30 days = 5.21 LF/MH

Example of Calculations Used to Identify Expected Less Productive Areas

Area D: 3,800 linear feet of pipe – crew of 4 for 68 days = 1.75 LF/MH
Area E: 2,000 linear feet of pipe – crew of 2 for 63 days = 1.98 LF/MH

Determining the Weighted Average of the More Productive Areas, Less Any "Outliers"

Area A: 3,000 linear feet of pipe – crew of 4 for 38 days = 1,216 hours = 2.47 LF/MH
Area B: 4,300 linear feet of pipe – crew of 4 for 52 days = 1,664 hours = 2.58 LF/MH
Area C: 2,500 linear feet of pipe – crew of 2 for 30 days = 480 hours = 5.21 LF/MH
7,300 2,880
Weighted Average = 7,300 ÷ 2,880 = 2.54 LF/MH

Calculating the Weighted Average for Less Productive Areas

Area D: 3,800 linear feet of pipe – crew of 4 for 68 days = 2,176 hours = 1.75 LF/MH
Area E: 2,000 linear feet of pipe – crew of 2 for 63 days = 1,008 hours = 1.98 LF/MH
5,800 3,184
Weighted Average = 5,800 ÷ 3,184 = 1.82 LF/MH

Sample "Should Have Spent" Hours Calculation

5,800 LF in the impacted areas ÷ 2.54 LF/hour = 2,284 "should have spent" hours
3,184 hours actually spent – 2,284 hours = 900 hours of productivity loss

Sample Inefficiency Factor Calculations

1.82 LF/Hour ÷ 2.53 LF/Hour = .72; 1.0 – .72 = .28 x 100 = 28 percent inefficiency
3,184 hours in the impacted areas x 28 percent inefficiency = 892 hours of productivity loss

The mechanical contractor's result may vary depending on the option selected in Step 4. In the examples shown above, Option 1 results in 900 hours of productivity loss, while the number of hours of lost productivity in Option 2 is 892.

As can be seen from the example, the contractor has removed the one study area that demonstrated an unusually high level of productivity. This may have been caused by having assigned a particularly experienced or hand selected crew to perform the work, or perhaps the physical work environment allowed the installation of the material to be performed much more efficiently than in other areas of the project. While there is no set guide as to how much variance in a particular study segment should disqualify it from a measured mile method analysis, findings that approach doubling or halving of productivity in particular segments suggest that such segments could be outliers in the study. However, there can be incidences where vastly different productivity rates have a reasonable explanation, thus these sorts of apparent anomalies must be analyzed on a project-by-project basis.

Additionally, if the contractor finds that its own management problems or crews caused portions of the inefficiencies in the impacted areas or time frames, such self-inflicted inefficiencies must be identified, quantified and removed from the contractor's request for equitable adjustment (REA). For example, a mechanical contractor may have experienced delay caused by its own forces and, to mitigate these impacts, embarked on unplanned overtime. This overtime schedule, depending on its intensity and duration, can on its own cause labor inefficiency. In its measured mile analysis, the contractor finds that it sustained a substantial loss of productivity caused by owner changes and disruptions in a particular time frame of the project schedule. The contractor also finds that this period of owner change and disruptions is concurrent with the time period of contractor-initiated overtime. Assuming the same crews involved in the contractor-initiated overtime were also affected by the owner changes and disruptions in the same time period, the contractor must factor out of its claim the inefficiencies caused by the overtime it chose to undertake to mitigate its own delay.

Another adjustment that must be considered is the payment by an owner or prime contractor to the mechanical contractor for change orders that include a loss of productivity that occurred in the impacted segment of the project. To the extent that the contractor has been compensated for labor and/or equipment inefficiencies during the impacted segment, these labor and/or equipment hours must be identified and removed from the measured mile REA.

Area Measurement

Area-based measurements are often used in a measured mile analysis to quantify the loss of labor productivity on a construction project. Area-based analyses can usually be derived from earned value reports that divide the project into are spatially-based activities. Assuming that the productivity impacts can be segregated by building or project area, spatial dividing lines between impacted and less impacted areas make logical study segments. It is important that the work environments be similar from one area to the next, which includes the height of the work off the finished floor elevation, if applicable. There should not be any inherent features of any of the areas that make them more productive or less productive—only the inefficiency impact categories should form the significant differences between the areas, to the fullest extent possible.

As with a reasonable amount of time in a time frame-based measured mile quantification, there is debate within the construction industry and in academia regarding how large an area should be in order to offer a credible measure of actual productivity. As of this writing, there does not appear to be any firm agreement on this question nor have the courts offered any judicial guidance. Generally, the area should be representative of the overall work, not an isolated segment of the work that would, by its nature, exhibit a much higher production rate than the balance of the project areas.

The space within the areas should be reasonable—that is, the area should be large enough for the crews to perform a sufficient amount of work to establish a measurable pattern of performance. Furthermore, the spaces between the areas used in the comparison should be similar or, if dissimilar, such differences should not have had an adverse effect on the underlying productivity.

Time Frame Measurement

In terms of utilizing time frames rather than physical areas, the application methodology is the same. Also, similar considerations have to be made when comparing the different time frames. Adverse weather may be a factor to consider; if the various measurement time frames fall into different climatological periods and weather impacts are not one of the categories of inefficiency being claimed, this may require adjustment of the study. In fact, any measurable inconsistencies between the time frames that could represent inherently more or less efficient performance need to be carefully evaluated. Reasonable care must be taken to eliminate from the study any effects that are materially different between the time frames being evaluated.

As with the proper amount of space when considering an area-based measured mile quantification, there is an unresolved debate within the construction industry and in academia regarding how long a measured mile time frame should be in order to offer a credible measure of actual productivity. In the writer's opinion, the time frame should be long enough for the crews to perform a sufficient amount of work to establish a measurable pattern of performance. The less impacted or unimpacted time frames should not include periods that experienced unusual or isolated spikes of high productivity that are not representative of the work on the overall project.

For instance, the learning curve commences with lower productivity as workers arrive on the project at the outset of the contract, or begin work in very different surroundings. As workers become more accustomed to the project, or to an area, the productivity of the crews is expected to increase. If the time frame is limited to the opening days or weeks of a project, it may encompass this time of lowered productivity due to the effects of learning curve. Conversely, if the measurement period is at the height of the project such that workers have gained the benefit of the learning curve effect, this alone could increase productivity. The effects of the learning curve, both negative and positive, can in some instances be very slight and may not affect the measured mile comparison, however it should be taken into consideration when choosing the time frames to be measured. If necessary, explain in the written narrative that will accompany the measured mile quantification why the learning curve was, or was not, considered as a variable that could affect the outcome of the study.

What if the Contractor's Earned Value Records Are Not Available?

Most mechanical contractors do not track material and equipment installed by labor hour on a contemporaneous basis. The reasons this sort of detailed tracking does not usually occur include the level of complexity of most mechanical piping systems, the mix of materials within areas or systems, and the

[7] We note that the trend among many of the larger sheet metal contractors is to track the labor required to manufacture, pre-assemble and erect duct work on a contemporaneous basis. This trend has been facilitated by computerized sheet metal detailing and cutting systems and bar coding on the duct segments that allow for efficient tracking of the material and correlation of the material installed with the labor required to perform the work. This mechanization has resulted in many sheet metal contractors being able to perform measured mile analyses while the project is on-going and with little additional effort in data collection and labor hour correlation.

cost of having a "clerk of the work" tracking the physical amount of material or equipment installed during each day of work, tied to the hours spent to install those materials or equipment.[7] Where mechanical contractors do perform this sort of contemporaneous productivity measurement, the contractor has already gathered the information it needs to conduct a measured mile method analysis. There is little or no need to refer to earned value reports or to other data since the actual production data is being collected on a daily or weekly basis.

The absence of contemporaneous labor and material tracking is not an unusual condition in the construction industry. While many contractors maintain some form of earned value reporting, on some projects the contractor may not have maintained any reports that segregate the hours actually expended by physical areas or time frames within the project. There are other means of extracting the needed information, albeit means that are much more time consuming and that may be more subjective in nature. An alternate method of data segregation involves the use of the contractor's payroll system, time cards, daily reports[8] and/or field diaries. The CPM schedule also may be used to determine when work was performed.

In such cases, the interview process is very important in order to locate the areas and/or time frames of better and lower productivity. If the site management is available, a list of the categories of inefficiency impacts should be compiled. If necessary, refer to the list of inefficiency categories contained in the chapter that addresses "Factors Affecting Labor Productivity." Discuss what areas or time frames were adversely affected by these impact categories and what areas or time frames were less impacted. Once the differential areas and/or time frames have been identified, have the knowledgeable individuals review the payroll time cards and other contemporaneous project data to see if the labor hours expended in those areas and/or time frames can be identified using the workers' names or crew coding. Often, area foremen or superintendents know the workers by name and can identify which workers performed the various activities on the project. This is more subjective than using a well-maintained earned value report, however it may enable a measured mile method analysis to be performed.

If the labor hours can be extracted from the payroll system by identifying the workers by name and assigned to specific areas or time frames, then the materials installed in discrete areas can be taken off and quantified in that manner. As to time frame measurements, it may be necessary to review progress records such as daily reports, progress photographs, project schedules or site diaries for descriptions of the work being installed. Some daily reports allow very specific entries of such progress information and can be useful references to allow for the identification of workers and the material being installed by time and area. The payment applications or CPM schedule updates also may reveal vital information regarding when and where work was performed, and to what extent it was complete on a weekly or monthly basis. While this

8 From the outset of a project, the contractor's management should review the superintendent's or foreman's daily field reports and/or progress diaries to ensure that the contemporaneous entries contain sufficient detail, are accurate and are in the proper format. At a minimum, daily reports or diaries should specify what work is being performed, where the installation activities are taking place by physical area of the project and by which crews.

sort of investigative analysis is very time consuming, it may be the only way to extract the labor hour and material quantity information that is necessary to perform a measured mile method analysis.

What if the Less Impacted Area or Time Frame was Adversely Impacted?

On some projects, there is no reasonably "unimpacted" area or time frame. This is not unusual. Projects with pervasive defective design impacts can experience labor inefficiencies from the outset of the work, and in virtually all areas of the project. Projects that are the subject of enormous scope growth by way of scope changes (i.e., cumulative impact) can be similarly affected such that no area or time frame can be found that was immune from measurable productivity impacts.

One method of removing labor inefficiencies from the less impacted area or time frame is to perform an MCAA labor inefficiency factor analysis on those labor hours (reference the chapter entitled, "How to Use the MCAA Labor Factors"). If the less impacted area or time frame has been impacted by others as a result of unplanned trade stacking, disruption, overtime or other recognized categories of labor impacts, appropriate MCAA factors can be applied to the less impacted area or time frame to set a revised baseline to be used in the measured mile comparison. All adjustments to the less impacted baseline labor hours should be fully explained and justified. If the contractor was responsible for its own inefficiencies in the baseline segment of the project, those have to be quantified and explained as well to demonstrate that the contractor has not claimed inefficiencies arising from its own mistakes and corrections.

Can Similar Projects Serve as Surrogates for Areas/Time Frames on the Project Under Study?

The farther a contractor moves from comparative measurements on the same project, the less likely the analysis will be considered a valid measured mile analysis. That does not necessarily disqualify the use of very similar projects to produce the comparative areas or time frames. The two-project measured mile approach is used when the baseline, or less impacted area or time frame on the project under study simply does not exist, or would have to be significantly adjusted to explain the inefficiencies in the less impacted area or time frame.

In some cases, it may make sense to offer two measured mile analyses: one utilizing a modified baseline comparison as explained above and one utilizing two very similar projects. However, there will be a need to demonstrate that the crews, supervision, work environments, types of productivity impacts and other factors on the two projects were indeed highly similar, one to the other. While a two-project method is not proscribed, it is worth the extra effort on the part of the contractor to find similar areas or time frames on the single project under study.

Productivity Impacts to BIM/ Coordination and Pre-Fabrication/ Sub-Assembly Operations and Equipment Inefficiencies

On projects that suffer from the effects of multiple and significant changes in scope (i.e., cumulative impact), defective designs, overall disrupted "start-stop-start" operations and/or delays to the schedule, the BIM/coordination and pre-fabrication/sub-assembly operations can sustain significant labor inefficiencies. The measured mile method can be used to quantify inefficiencies in these areas of a project.

When a mechanical contractor bids a project, labor hours are usually included for traditional coordinated drawings or, on larger projects, computerized Building Information Modeling (BIM) drawings. The production of these drawings or computer models usually leads to some amount of prefabrication or sub-assembly of systems. A mechanical contractor can expect substantial labor savings if this process is reasonably free of impacts from large quantities of requests for information (RFI), changes, disruptions and delays.

Many mechanical contractors include coordination/BIM hours performed on change work within the change proposal itself by way of percentages or direct hours required to address the changes. However, many of the issues that affect coordination/BIM labor and the downstream prefabrication and sub-assembly operations never become a part of the contract as a change order. It is not unusual to find that a large percentage of RFIs issued by a mechanical contractor during the coordination/BIM stage never become change orders, thus the added time and disruption to the coordination/BIM process are not equitably compensated to the mechanical contractor. The result is an undefined overrun in the coordination/BIM efforts. The disruption and inefficiency of the coordination/BIM operation then trickles down to the prefabrication and sub-assembly operations, which can be additionally impacted by having to start, stop and then restart operations due to the flow of the drawings, or due to "holds" placed on prefabrication or sub-assembly work caused by delays, RFIs and changes to the work.

In order to capture measured mile information for use in the coordination/BIM, prefabrication and sub-assembly operations, the mechanical contractor should ensure that the workers are coding time to individual projects and, if possible, to discrete segments of the erection work or drawing. To the extent that there are areas of a project or discrete time periods which represent reasonably productive work, actual hours required to produce a representative drawing or set of drawings, or to prefabrication or sub-assemble a known quantity of material should be maintained. This becomes the baseline set of hours. As with the erection work, the baseline productivity should be based upon a representative sample and not on unusually simple drawings or assemblies.

Similarly, actual hours should be coded and collected on drawings by area or systems, or during time periods which represent the effects of the disruptions, RFIs and changes. The goal is to establish a differentiation between the labor hours required to produce coordinated or BIM computerized drawings without the adverse effects of inefficiencies not caused by the mechanical contractor and the labor required to produce the drawings given impacts on the project.

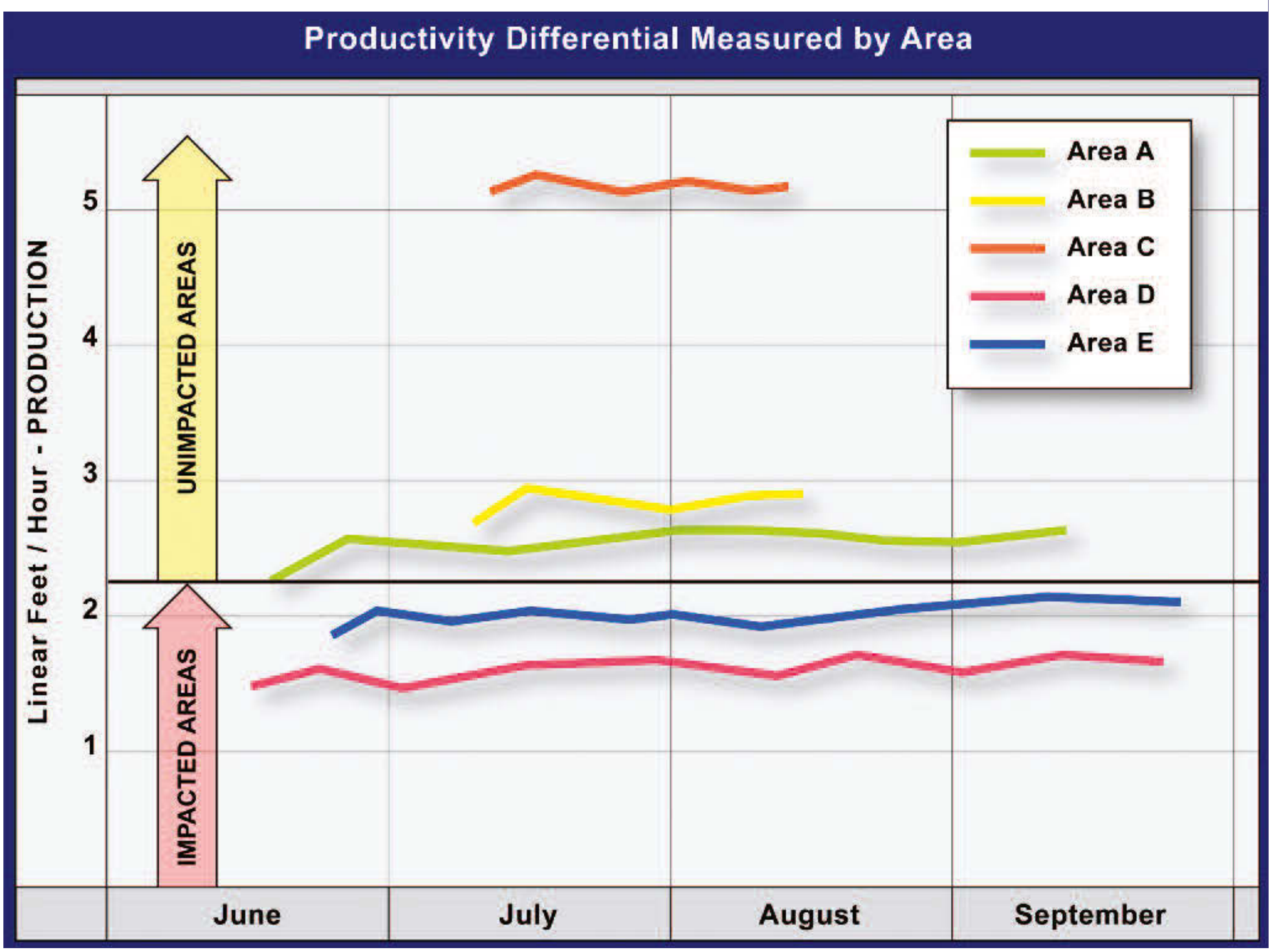
Actual prefabrication and sub-assembly operations can be measured for inefficiencies in the same fashion as field erection activities. In order to perform the comparative analysis, the contractor should have records of the time required to perform prefabrication and sub-assembly work by definable segment, comparing the production rates between more efficient and less efficient areas or time periods.

Construction equipment can also be subject to a loss of productivity. Depending on how equipment has been estimated, the inability to utilize equipment in an efficient fashion can add to the cost of construction. If the inefficiency of construction equipment is the result of delays, disruptions, stop work orders or other adverse conditions outside of the control of the mechanical contractor, this component of added cost can be the subject of an REA.

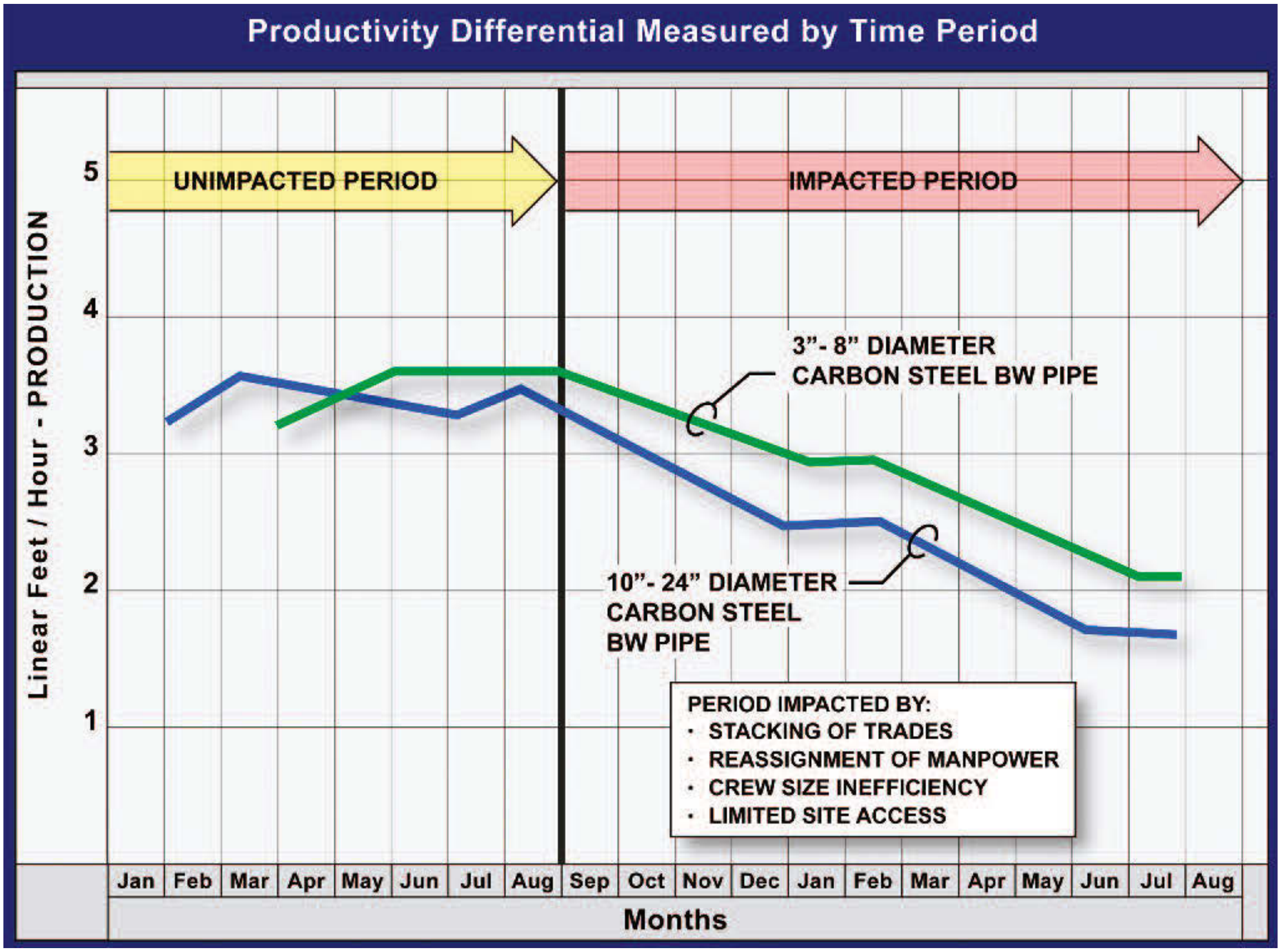
To the extent that usage records can be maintained for any mechanized or motorized equipment, such as gas welding rigs, bulldozers, track hoes, electrical welding packs and similar items, these records can be coordinated with the contractor's measured mile labor analysis to demonstrate the less efficient and/or delayed nature of the equipment usage on the project. A measured mile analysis can be performed on the equipment itself, by way of example contrasting the amount cubic yards of excavated materials that were moved in unimpacted and impacted segments of the project.

As with the erection activities, any appreciable inherent differences between segments being measured, other than the inefficiency categories themselves, must be identified and factored during the preparation of the measured mile method analysis. Also, any contractor-caused inefficiencies occurring in the impacted

Sample Productivity Chart by Area



Sample Productivity Graphic by Time Period



areas or time periods must be identified, quantified and removed from the contractor's REA along with any inefficient hours paid for in change orders or by time and materials tickets.

Presentation of the Analysis and Graphic Charts

When presenting a change order proposal, or REA, for loss of labor productivity, the claimant has the burden of proof regarding the cause-and-effect nexus and the damages resulting from the causative events. Therefore, it is helpful to prepare a comprehensive written narrative report describing the conditions that the mechanical contractor is asserting caused the harm and how the resulting damages were quantified.

One effective means of communicating the comparative variances that are at the center of a measured mile analysis are graphic charts depicting various productivity curves. These curves can convey the time lines and differences between the productivity that was measured in the analysis. Two examples are provided, one on the previous page, and one above.

Oftentimes, the acceptance or rejection of a mechanical contactor's REA for loss of labor productivity can be affected by the quality of the narrative describing the cause-and-effect nexus, the supporting schedule analysis (if appropriate), payroll and other project reporting, and the form and content of the measured mile quantification. Presentation graphics, supported by well-prepared documentation, also can be persuasive in depicting the differential productivity unit rate ratios derived by the measured mile investigation.

Conclusions

The measured mile method is, without question, a very effective means of quantifying a contractor's loss of labor productivity in the construction industry. In order for the measured mile method to be reliable and successful, however, it must be applied in an appropriate manner. The inappropriate application of the measured mile method may result in a significantly reduced recovery or, in the worst case, no recovery at all. However, many contractors have properly applied sound and reasoned logic to prepare measured mile method analyses that contain comparisons of similar materials, equipment, environments, and crews and also contain any required adjustments between the segments as described herein.

Contractors who consistently pre-plan their work and create a mechanical schedule in close coordination with the general contractor's schedule can significantly improve tracking of the measured mile data. The mechanical contractor, in coordination with its developed schedule, can create an area-specific labor-coded schedule of activities that follows the logical construction sequence of the project. Whenever possible, this area-specific data should be divided and identified by individual system or piping material.

The general guideline for the duration of activities is from between 3 and 22 working days in order to allow for optimal tracking. Mechanical activities should be created that can usually be accomplished by a single crew in the time period noted above. Collection of the payroll input then gives the contractor timely data as to how each area performs in comparison to the original project plan, and in comparison with other similar areas on the project.

Since the contractor's estimated/planned hours are used to populate the area-specific labor-coded activity schedule and labor performance report, the contractor has a record of performance compared to its estimate/plan and to other similar work on the same project. Such record keeping can allow a mechanical contractor to perform a measured mile analysis while the project is still ongoing, and with that information, to work proactively to mitigate productivity losses, if at all possible.

When mitigation is not feasible or achievable, the mechanical contractor may be placed in a position of recovering its productivity losses by way of an REA. In its REA, the contractor will have to identify, justify and quantify its loss of productivity component.[9] A contractor has several choices in the selection of a method to quantify labor inefficiencies. Where possible, the contractor should consider the measured mile method as the

[9] The contractor should also endeavor to measure the potential time impacts to the project schedule arising from labor inefficiencies and, if applicable, include those time impacts it its REA. The subject of potential time impacts arising from labor inefficiencies is covered elsewhere in this manual.

one that will, if properly applied, produce the most compelling and acceptable results.

Additionally, when a mechanical contractor anticipates that it will sustain a loss of labor productivity on a project and such labor productivity losses will, more than likely, not be equitably compensated in change orders, the contractor must preserve its rights to collect its damages by other means, such as an omnibus REA. Many change order forms issued by public and private sector owners contain "full accord and satisfaction" restrictive language. On many projects, the prime contractor may include waiver language on the monthly payment application release forms that attempt to bar a mechanical subcontractor from recovery of any impacts that are not expressly excluded from the waiver provisions. These "full accord" and waiver provisions are explained in greater detail in other chapters within this manual, however the mechanical contractor is reminded to avoid executing any document that seeks to limit the mechanical contractor's rights to recover its delay and labor productivity impact costs, unless such terms have been reviewed and accepted by the mechanical contractor's senior management or construction counsel.

Finally, the more credible the measured mile analysis, the greater the contractor's REA recovery will be. To be credible, the contractor must carefully apply the test of reasonability—reasonably similar comparison areas or time frame, reasonably similar types of material and/or equipment being installed, reasonable record keeping or source data, reasonable adjustments that may be required to the unimpacted and/or impacted segments, such as the removal of the contractor's own inefficiencies and inefficient hours compensated in change order in the impacted segments, and reasonable conclusions drawn from the analysis. The analysis should be accompanied by a cogently written narrative that connects the causes with the effects of the analysis and discusses why such impact causations were not the fault or responsibility of the mechanical contractor. A well-prepared and well-documented measured mile REA can be an important factor in averting costly litigation and can offer the potential for a positive recovery of a mechanical contractor's loss of labor (or equipment) productivity.

Appendix

Support at the Courts and Boards of Contact Appeals for the Measured Mile Method

Reported decisions from the boards of contract appeals and other tribunals can be instructive in the preparation of a measured mile quantification of labor productivity loss. One of the frequently cited cases in favor of the use of the measured mile method is the *Appeal of P.J. Dick*[1] at the Veterans Administration Board of Contract Appeals. This decision stated the following, in part:

> …the efficiency factor calculated from the feeder work was used to adjust the budget for the branch work. …the VA's labor productivity expert, took exception to use of the measured mile analysis using the feeder-branch circuit comparison because it violated a fundamental precept of a measured mile analysis in that [the electrical subcontractor's expert's] analysis does not measure the productivity for an activity in an unaffected period against the productivity for the same activity in the affected period. …[the electrical subcontractor's expert] indicated, there was

[1] *Appeal of P.J. Dick* VABCA Nos. 5597, 5836-37, 5839-50, 5951-65, 6017-24, 6483, 01-2 BCA ¶ 31,647

> no period of branch conduit installation that was not impacted by either the design problems or acceleration. [The VA's expert's] principle objection to comparing feeder work to branch work was the difference in crews and crew continuity.

Note that the government's expert criticized the electrical subcontractor's alleged improper use of feeder conduit installation as compared with branch conduit installation to form the measured mile as being too dissimilar to support a reasonable comparison. The Board rejected this criticism and the electrical subcontractor was awarded inefficiency damages based on its measured mile analysis comparing feeder conduit production with that of branch conduit.

Moreover, in the *Appeal of P.J. Dick* the Board underscored the favored standing of the measured mile method to quantify a contractor's loss of labor productivity and also recognized that measured mile quantification was not required to be exact in order to be acceptable as a basis of recovery. This decision mirrors the oft-cited *Wunderlich Contracting Co.*[2] decision wherein the Court decided that a "claimant need not prove his damages with absolute certainty or mathematical exactitude…it is sufficient if he furnishes the court with a reasonable basis for computation, even though the result is only approximate …."

However, the *Wunderlich Contracting* Co. decision cannot be taken to extremes and the requirement for establishing "a ***reasonable*** basis for computation" [emphasis supplied] cannot be ignored with impunity. Other cases underscore the need for the claimant to adjust its measured mile analysis to take into account inherent dissimilarities between the segments under study. *Danac, Inc.*[3] and *W.G. Yates & Sons*[4] confirm the necessity for the claimant to make productivity adjustments for differences in materials and joint types in the segments being compared.

The decision in *W.G. Yates & Sons* underscoring the acceptance of the measured mile method stated, in part:

> Yates, using the measured mile methodology, computed its alleged additional labor inefficiency costs by comparing performance costs incurred prior to the defective specification disruption with performance costs after the defective specification disruption. …In *DANAC, Inc.*, ASBCA No. 33394, 92-2 BCA ¶ 29,184 **this Board endorsed the use of the measured mile methodology** to measure the cost for labor inefficiency caused by Government delay and disruption holding:
>
> For labor inefficiency claims, "good period vs. bad period" analysis, comparing the cost of performing work during periods both affected and unaffected by disrupted events "**is a well established method of proving damages**." *U.S. Industries, Inc. v Blake Construction Co. Inc.* 671 F.2d 539, 547 (D.C. Cir. 1982) [emphasis supplied]

The contractor's measured mile analysis may be significantly reduced or even rejected by a court or board of contract appeals if the contractor does not adjust the underlying productivity rates for differences in the installation of the materials or other conditions not associated with the inefficiency categories upon which the claim is based. Such inherent differences can include material types, joint types, elevation of the work, spatial limitations or other physical conditions that would make the com-

---

[2] *Wunderlich Contracting Co. v U.S.* 173 Ct. Cl. 180, 351 F.2d 956 (1965)

[3] *Danac, Inc.*, ASBCA No. 33394, 97-2 BCA ¶ 29,184 (1977)

[4] *W.G. Yates & Sons Construction Co.*, ASBCA No. 49398, 01-2 BCA ¶ 31,428 at 29 (2001)

parisons imbalanced. The goal of the measured mile method is to measure labor productivity between two segments of reasonably similar work with the variable being the labor inefficiency factors identified by the contractor.

The principal of "reasonably similar" comparisons in a measured mile analysis was clearly defined in *Clark Concrete Contractors, Inc*. wherein a concrete contractor offered a measured mile analysis. The aforementioned decision was cited, in part, in the *P.J. Dick* decision:

> We find no basis to conclude that either the productivity of the same crew or that exactly the same work is a prerequisite for a valid measured mile analysis to establish the amount loss of productivity. We agree with the GSA Board of Contract Appeals when it held in *Clark Concrete, Inc*., 99-1 BCA ¶ 30,280:
>
> [The Government] is correct in asserting that the work performed during the periods compared by [the Contractor] was not identical in each period. We would be surprised to learn that work performed in periods being compared is ever identical on a construction project, however. And it need not be; the ascertainment of damages for labor inefficiencies is not susceptible to absolute exactness [citation omitted]. **We will accept a comparison if it is between kinds of work which are reasonably alike, such that the approximations it involves will be meaningful.** [emphasis supplied]

However, in *P.W. Construction, Inc*.[5] the contractor's measured mile productivity analysis was rejected because the contractor failed to take into account very different pipe joining methods between the segments being measured. While different materials and installation methods do not necessarily prohibit the use of a measured mile comparison, the claimant must make suitable adjustment in the computations to account for inherent differences in the segments being compared. This decision stated, in part:

> The record shows that welding in the impaired period was butt-welding on polyethylene pipes, which takes only 15 seconds to 2 minutes per weld, whereas the welding done in the pre-disruption period was steel welding, which may take up to 2.69 hours per weld. …this evidence suggests that a comparison of the pre- and post-disruption periods must take into account the difference in welding …
>
> Because the impaired rate accurately reflects productivity during the impaired period, but does not accurately reflect productivity during the ideal period, the court vacates the damage award on lost productivity. The rates must account for the differences in welding and trenching costs for the different pipes.

What can be taken away from the aforementioned cases and the other measured mile cases in the industry is that the concept of *reasonable similarities* is crucial in prevailing when utilizing a measured mile analysis. Also, these cases affirm the fact that the measured mile method is the most widely accepted form of productivity measurement in the construction industry.

---

5 *P.W. Construction, Inc. v. The United States* 2002 WL 31780958 (Fed. Cir. 2002

Prepared by Paul L. Stynchcomb, CCM, PSP, CFCC of Vero Construction Consultants Corp. with peer review performed by: Robert Beck, President of John W Danforth Company; Michael R. Cables, Executive Vice President of Kinetics Systems, Inc.; Stephen R. Dawson, President, Harrell-Fish, Inc.; Richard Freeman, Vice President of Stromberg Metal Works; Michael A. Mack, Executive Vice President, John J. Kirlin, Inc.; Charles F. Mitchell, General Counsel of The Kirlin Group; Adam Snavely, President and CEO of The Poole & Kent Corporation, An EMCOR Company; and Thomas Williams, President of Sustainable Builders.

How to Estimate the Effects of Cumulative Impacts

Executive Summary

This chapter has been written as a resource for the subcontracting industry with the purpose of helping the reader identify when cumulative impact has affected labor productivity and how to quantify the adverse effect in terms of inefficient labor hours. To the extent that questions arise, contractors are encouraged to seek the expertise of their legal and claims consulting resources.

Definition

Cumulative impact of changes to a construction contract is the unforeseeable disruption of labor productivity resulting from the effect of multiple changes to the contractor's pool of labor. Cumulative impact is referred to as the "ripple effect" of changes on unchanged work, and on the change work itself, and causes a decrease in labor productivity. This loss of productivity is usually not subject to analysis in terms of spatial or temporal relationships because its source is not a single event, but arises from the multiple changes issued on the project.[1]

Contractors have long understood that when a project is subjected to a large number of changes in terms of labor hours, not necessarily dollar amounts, the productivity of the contractor's labor force can decrease substantially, even more so than the contractor may foresee at the time any single change is priced. It is not the effect of a single change, but the *cumulative effect* of numerous labor-related changes in scope that disrupts the rhythm of the project and frequently results in stacking of trades, unplanned crew size increases, piece-meal performance, and other types of inefficient operations.

The resulting loss of labor productivity may be recoverable as an added cost of the multiple changes affecting the contractor's labor pool. This loss is not attributable to a single change and cannot be tied to a specific change by a traditional cause and effect analysis. Rather, the contractor's loss of labor productivity is the result of the myriad changes radiating disruption and other adverse effects outward, resulting in a decrease in the contractor's overall labor productivity on the project.

The contractor may quantify the effects of cumulative impacts in several ways. The simplest means of quantification is the total

[1] Paraphrased from the Veterans Affairs Board of Contract Appeals reported decision in the matter of *The Appeal of Centex Bateson Construction Co., Inc.* VABCA-4613 and 5162-5165.

cost method. This entails subtracting from the contractor's total labor hours its estimate and change order labor hours. A variation on this, called the modified total cost method, subtracts from the total actual hours any of the contractor's bid errors or field retrofit caused by the contractor. These are the least accepted methods of quantifying the contractor's losses. The contractor may employ the MCAA labor inefficiency factors to quantify the labor inefficiencies caused by cumulative impact. The most widely accepted method of recovering loss of labor productivity is the measured mile method, where the portion of the project impacted by others (i.e., change) is compared with an undisrupted or less disrupted portion. The measured mile is the favored methodology because it is an empirical, project-specific method of quantifying all types of labor productivity impacts. However, the conditions permitting the use of a measured mile analysis may limit the projects on which it can be applied.

Only recently have methods been made available for a contractor to quantify the adverse productivity effects of cumulative impacts utilizing statistical analyses performed on other construction projects. William Ibbs, PhD, Professor of Civil and Environmental Engineering at the University of California, Berkeley, has performed studies of over 170 individual construction projects covering a wide variety of project types. Those data have been assembled into forecasting curves that predict, with reasonable accuracy, a contractor's loss of labor productivity given the labor intensity and timing of the implementation of the labor changes.

Professor Ibbs' studies have confirmed the critical role of the timing of the performance of changes as correlating to the degree of impact caused by change to a construction contract. The Ibbs studies show that when change is implemented early in a construction schedule, the effects of these early changes can be less than the effects of changes introduced during the "heat of battle"—at a time when crew sizes and the number of activities being worked are at their maximum, and when much of the physical base contract work may have been installed and may require modification or removal and replacement as a result of changes in scope. The resulting studies and the statistical analyses have now been published by the MCAA in a form that allows contractors to utilize the data to quantify the effects of cumulative impact.

In the following chapter, contractors will learn what constitutes cumulative impact, how to explain the phenomenon, and, using the Ibbs curves, how to quantify the resulting loss of labor productivity. Examples are provided that guide the contractor in selecting the appropriate timing curve, computing the necessary categories of labor hours and percent of change, and reaching a reasonable result in terms of the loss of labor productivity, expressed in labor hours. The graphic curves presented in this chapter allow the contractor to plot percent change against the resulting loss of labor productivity percentage. That correlation, derived from the graphic curves, is then utilized by the contractor to compute an estimated number of inefficient labor hours resulting from the effects of cumulative impact. The Ibbs methodology has been accepted by triers-of-fact and thus, can be helpful in resolving disputes arising from cumulative impact.

Introduction to Change and Cumulative Impact

There are few subjects in the construction industry as widely discussed in the context of identifying and quantifying losses in labor productivity as the subject of cumulative impact. A principal reason for this discussion regarding cumulative impact stems from the fact that cumulative impacts are, in most instances, virtually impossible to identify while they are taking place.[2] In many cases, the effects of cumulative impact only become evident at, or near, the conclusion of a project, when the effects of the individual changes have been recorded in the contractor's labor and cost reports. Reasons for this may arise from a lack of detail in contemporaneous labor tracking and trending reports, the manner in which labor reporting was maintained, or the late issuance of scope changes such that negative trends do not appear in the labor reporting until the project is at, or near, completion.

Another cause can be attributed to the notion that a significant number of small to medium-sized changes are difficult, if not impossible, to connect as causes to quantifiable and specific effects on an individual, change by change basis. It is not until these almost invisible and individual impacts of changes mount into a tidal wave that the effects begin to become evident in the project records.

Because today's construction projects are complex, expensive, and sometimes risky investments for project owners, many owners seek to impose strict bidding or proposal conditions and tight controls on their projects. Projects sometimes have to go to market by way of competitive bidding early in the development process, with plans and specifications that are latently incomplete or have errors, such as lack of a coordinated design among the trades. Often the additional costs associated with incomplete design and/or design errors do not become apparent until the project is under construction. At the same time, there is fierce competition in the marketplace as evidenced by the large number of contractors pursuing the projects released for bidding. The result is an industry that is competitive and which creates tight profit margins for the builders. Moreover, some projects are "economically fragile" and susceptible, so when even modest change occurs, contractor profit margins and owner value propositions can be jeopardized, or even evaporate.

Thus, in a challenging marketplace, it is important for the contractor to monitor the status of contract changes on a construction project. An important step in this process is for the contractor to attempt to fully understand the scope of work in the contract. Only by being aware of the base contract scope can a contractor know that an owner is requiring out-of-scope work to be performed. Unfortunately, at times contractors perform out-of-scope work without realizing that the labor hours they are expending are actually for work that is out of scope. They incorrectly assume that the labor hour overruns recorded on the labor reporting system must be caused by their own issues in the labor plan or by inherently inefficient workers.[3]

---

[2] The impact of the cumulative effects of multiple changes on a construction project has been described in one Board of Contract Appeals decision as *amorphous* (i.e., all but invisible, lacking definite form, shapeless). Reference the *Appeal of Centex Bateson Const. Co. Inc.*, 99-1 BCA ¶ 30153 (1998).

A second step in monitoring the change process is for the contractor to track the magnitude and timing of change. Many contractors do not record actual labor hours expended on change orders or scope changes (i.e., by charging actual hours to separate change work codes on labor reports) nor are actual start and finish dates for changed work tracked in the contractor's contemporaneous records. When changes are performed, the contractor should create some form of documentation (e.g., RFIs, daily field reports, or superintendent's diaries) that will denote when and where change work is being performed and by what crew size. In the absence of this contemporaneous data, change work files should be maintained that document the estimated labor hours required to perform the work, and, at a minimum, when the change work was estimated to have commenced and when it was completed.

However, even with identification and monitoring of the work scope accompanied by reasonable efforts to segregate and account for job costs, the cumulative impact of multiple changes often cannot be accurately captured within the contractor's cost reporting system. As noted by legal and accounting experts:

> The advisable practice for capturing and reporting claimable costs is to segregate the costs that are a direct result of the events that impacted the project.…This argument has merit in theory but in practice may be difficult to achieve. If the claimed event relates to additional activities or expanded scope of work that is readily identifiable and segregated from the original scope of work, then discrete cost accounts can be established to capture the additional costs of direct labor, purchase orders, or subcontractor change orders. Conversely, if the basis of the claim is…acceleration within the same activity, or changes affecting multiple work packages, then the associated extra costs may not be captured from the originally established cost accounts. Because separating the additional costs may be difficult or impossible, the basis for substantiating these costs must be accomplished by other means.
>
> …Even with optimal planning and cost control systems, contractors can still experience difficulty in capturing all of their discrete cost damages… .Hidden costs may occur with a significant number of changes to a project…and such delay and disruption costs can snowball and not be discretely captured.…The quantification of each change order will fail to identify the cumulative impact or "ripple effect" associated with multiple changes. These…will have a negative compounding effect on construction productivity and are usually difficult to quantify discretely in the cost report.[4]

This chapter will describe methods for establishing a reasonable recovery of costs arising

[3] At times the contractor will perform out-of-scope work that is not identified as such until late in the project, when a major labor overrun has been identified and the contractor's management team undertakes a detailed comparison between the base contract work scope and the work actually performed on the project. This comparison can identify large quantities of labor expended on work not contained in, or contemplated by, the base contract but which was required to actually build the project. A common example is labor expended to install extra pipe and fittings not shown on the contract drawings but which are necessary to overcome design deficiencies such as improperly coordinated drawings. Because the labor was not associated with a change in the contractor's cost system, it was never submitted for compensation as changed work. Such lapses in the contractor's control of the work taking place on a project is lamentable, but should not *necessarily* bar the contractor from an equitable recovery of its reasonable costs, subject to the terms, conditions, and limitations set forth in the contract documents.

[4] A. Overcash and J. Harris, "Measuring the Contractor's Damages by 'Actual Costs' – Can it Be Done?" *The Construction Lawyer*, Vol. 25, No. 1 (2005), pp. 34-36.

from the adverse effects of cumulative impact. As a starting point, *change* is defined by the Construction Industry Institute (CII) as "any variation in a project's scope, whether physical, administrative, commercial, or schedule."[5] For the purposes of this chapter, change will refer to changes in the contract scope, whether existing as formally approved change orders or unapproved scope changes submitted by the contractor to the appropriate contractual party (e.g., owner or prime contractor). As will be discussed more fully herein, unapproved scope changes used in the computations contained in this chapter must have a reasonable likelihood of being approved as a change order, or have a reasonable chance of being recognized as valid changes by a neutral or trier of fact.

When many changes occur, the situation is further complicated and may result in what is known as a cumulative impact condition. This term has, perhaps, been best defined by recent decisions issued by the major boards of contract appeals and which are cited elsewhere in this publication (reference "How to Use the MCAA Labor Factors" herein). Two such definitions bear repeating here:

> Direct impact is generally characterized as the immediate and direct disruption resulting from a change that lowers productivity in the performance of the changed or unchanged work. Direct impact is considered foreseeable and the disrupting relationship to unchanged work can be related in time and space to a specific change.

> Cumulative impact is the unforeseeable disruption of productivity resulting from the "synergistic" effect of an undifferentiated group of changes. Cumulative impact is referred to as the "ripple effect" of changes on unchanged work that causes a decrease in productivity and is not analyzed in terms of spatial or temporal relationships.
>
> This phenomenon arises at the point the ripple caused by an indivisible body on two or more changes on the pond of a construction project sufficiently overlap and disturb the surface such that entitlement to recover additional costs resulting from the turbulence spontaneously erupts. This overlapping of the ripples is also described as the "synergistic effect" of accumulated changes. This effect is unforeseeable and indirect. Cumulative impact has also been described in terms of the fundamental alteration of the parties' bargain resulting from the change.

The second paragraph of this board of contract appeals decision defines several key elements of cumulative impact: 1) changes in scope that can result in decreased labor productivity can be "undifferentiated" (i.e., the loss of productivity cannot be attributed to a specific change); 2) the effects of such changes can "ripple" outward adversely affecting the base contract, or unchanged work, as well as other change work; and 3) changes in scope that affect labor productivity need not be related spatially or temporally—they need not occur in the same time frame and/or in the same physical area of a project. As a result of the inability to tie the features of cumulative impact to a specific event, time frame, or area of the project, it is difficult, if not impossible, to capture the additional costs associated with a specific impacting event even with standard project control and accounting systems being utilized by the management team.

[5] The Construction Industry Institute (CII) is an organization comprised of more than 100 leading owner, engineering-contractor, and supplier firms that sponsor research into construction-related topics. Founded in 1983, it has earned a reputation for conducting high quality, impartial research that enhances business effectiveness and capital project sustainability.

Finally, in the third paragraph, the board found that these "ripples" of inefficiency flow from the changed work onto the pond of the base contract, or unchanged work, as an indirect effect of the changes. Since these "ripples" are an indirect result, they may not be foreseeable at the time the change events are taking place.

It follows that cumulative impacts—the destructive effects of multiple changes in scope on a construction project—cannot be measured as the work moves forward, nor can such adverse effects be measured in individual changes in scope. An estimator attempting to forward price changes may not be able to foresee, let alone quantify, with reasonable accuracy the productivity impacts to the overall project arising from individual changes.[6] Indeed, such impacts may not be identifiable or quantifiable until the end of a construction project, when measured within the entire universe of change that was encountered during the construction process.

Another definition of cumulative impact offered by a major board of contract appeals is also instructive:

> Among other things, 'impact' includes: inefficiencies due to overcrowding, over or under manning, skill dilution, extended overtime, shift work, and local and cumulative disruption.
>
> 'Local [or direct] disruption' refers to the direct impact that changed work has on other unchanged work going on around it. Conceptually, for purposes of this appeal, 'cumulative disruption': Is the disruption which occurs between two or more change orders and base work and is exclusive of that local disruption that can be ascribed to a specific change. It is the synergistic effect….of changes on the unchanged work and on other changes.

While this chapter is not intended to serve as a legal treatise on the subject of cumulative impact, it is frequently the published decisions from the Boards of Contract Appeals and the U.S. Court of Federal Claims that can provide some understanding regarding critical issues in the construction industry. It is apparent from these and other Board of Contract Appeals decisions that there is general agreement as to the existence and effects of cumulative impact. However, there is less agreement regarding how to actually measure the effects of cumulative impact. Addressing this challenging issue in the construction industry is the primary purpose of this chapter.

Underlying Causes and Nature of Cumulative Impact

Cumulative impact occurs when multiple changes in scope unforeseeably ripple out to cause disruption and a loss of productivity to changed work and, potentially, to the base contract work itself. However, it is understood in the construction industry that some change is inevitable on larger construction projects—the question is how much change to expect. It is generally agreed in the construction industry—and substantiated by research—that projects with multiple, unanticipated labor hour changes often suffer a considerable loss of labor productivity.

[6] This chapter focuses on inefficient labor hours; however, losses of productivity can also affect other facets of construction costs, such as equipment that supports the work effort being analyzed (e.g., cranes, welding machines and excavation equipment for underground installations). Thus, productive use of equipment, which is typically charged to the project in hourly units, can also be adversely affected by cumulative impact.

Thus it is important to establish what general magnitude of change an experienced contractor should expect when bidding a construction project of any size or complexity. Studies conducted in the construction industry by governmental agencies have resulted in the data shown in Figures 1-A and 1-B regarding expected changes in scope on construction projects.

From the data shown in Figures 1-A, 1-B, and 1-C,[7] it is clear that contractors should expect some amount of change on a sizable construction project. Obviously, the exact percentage of contract growth is not foreseeable at the time of bidding each individual project. However, ranges of potential change growth can be evaluated based on historical data available in the industry.

Cumulative impact arises from multiple labor-related changes (whether directed or constructive) being issued on a construction project. The more labor intensive the project, the greater the impact that can be expected. This impact may result from design changes, differing site conditions, third party actions or inactions, weather, or other causes that are not the responsibility of the labor-intensive contractor.

Regardless of the source of the change, it is generally not the dollar value of the change, or the number of executed change orders, that are the critical factors in determining whether change may cause or contribute to cumulative impact. Rather, it is the number

[7] Figures 1-A through 1-C were extracted from the publication entitled "Construction Contract Modifications—Comparing the Experiences of Federal Agencies with Other Owners" published in 1986 by the Committee on Construction Change Orders, Building Research Board and the National Research Council. As of the date of this publication, no more recent studies on the subject of expected change have been identified by the authors.

Figures 1-A & 1-B

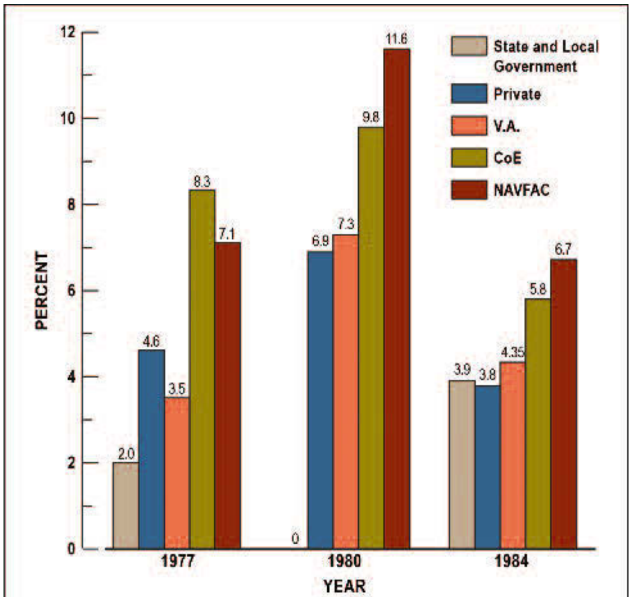


FIGURE 3 Yearly contract modification rates for state and local government projects, private projects, VA construction, CoE construction, and NAVFAC construction for 1977, 1980 and 1984.

TABLE 7 Statistics on Modifications to Veterans Administration Construction Contracts, 1974 to 1985

Calendar Year	Number of Projects Physically Completed per Year	Original Amount of Completed Contracts, Yearly Totals ($, thousands)	Net Amount of Changes to Complete Contract, Yearly Totals ($, thousands)	Rate of Cost Growth (percent)
1974	56	16,470	803	4.87
1975	128	91,928	8,162	8.88
1976	159	163,046	8,672	5.32
1977	202	132,717	4,706	3.55
1978	197	149,068	12,394	8.31
1979	204	183,267	9,091	4.96
1980	224	210,962	15,445	7.32
1981	259	245,654	15,297	6.23
1982	211	209,513	11,901	5.68
1983	214	495,199	19,322	3.90
1984	257	281,896	12,256	4.35
1985 (thru June)	89	96,517	4,411	4.57
Total	2,200	2,276,237	122,460	5.38

SOURCE: Veterans Administration.

Figure 1-C

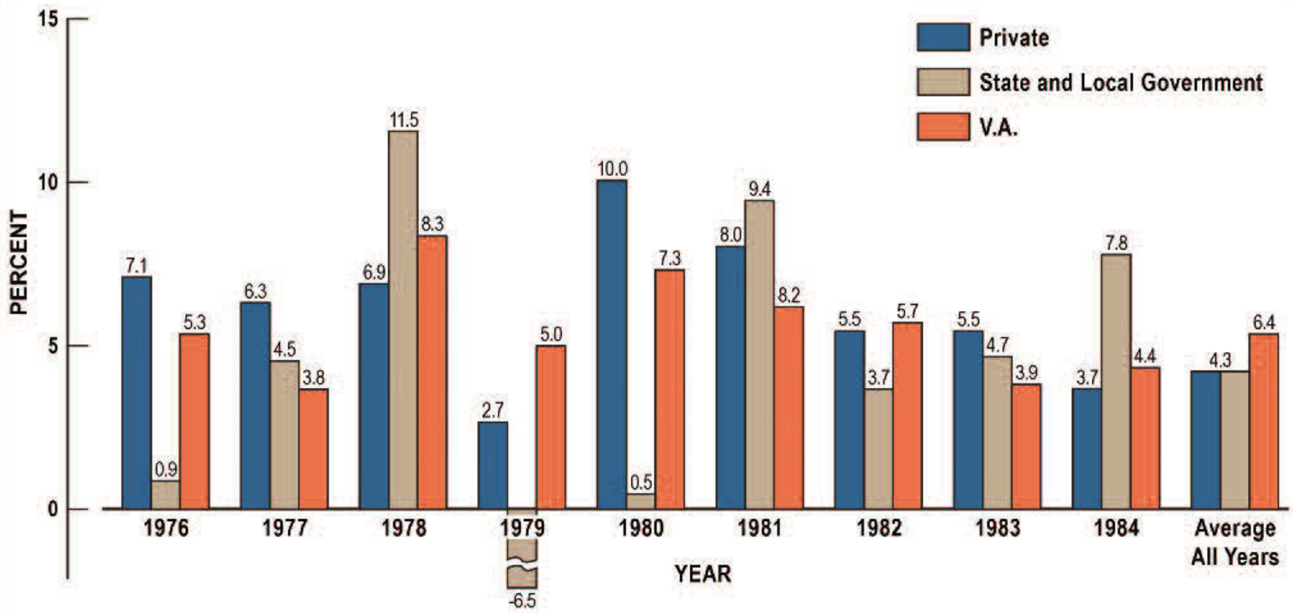


FIGURE 2 Yearly contract modification rates for private hospitals, state and local government hospitals, and VA construction for 1976 to 1984.

of labor hours that will be required to perform the changed work. A change order presented to a mechanical contractor could have significant dollar impact to the overall contract value, but could be "all material" and have little or no meaningful impact on labor productivity. Thus, it is usually the labor hours that really matter when attempting to identify and quantify cumulative impact.

Another characteristic of change, not just of cumulative change, is that it can be either additive or deductive. That is, a given change may enlarge a project's scope or reduce it. Many owners find it difficult to accept, but research clearly indicates that there are many instances where a deductive change can be so disruptive that the number of labor hours and costs actually increase despite the fact that the physical quantity of work may be reduced by the change. This situation must be evaluated on a case-by-case basis.

Cumulative impact cannot be measured on individual, discrete changes as each change by itself may not have a significant impact. Usually, cumulative impact is best measured near, or at, the conclusion of a project because its adverse impacts do not dissipate until the project is completed, or is nearly completed.

Waiver Language in Contract Documents

This chapter does not offer a comprehensive review of the potential legal obstacles associated with recovery of damages arising from cumulative impact. However, it is important to note that owners such as the federal government (e.g., GSA, VA) and many local agencies and private developers are including waiver language in the various contract forms (e.g., change orders, payment releases, or in the contract itself) that seeks to limit a contractor's right to recover any costs of change that are not expressly included in the executed change order. Recent trends at the federal level suggest that a contractor must use extreme caution when executing any contract document, including the contract itself, if the contractor expects to preserve its rights to recover the cost of change (i.e., cumulative impact) that was not included in the executed change order.[8]

Since cumulative impact is usually quantified near, or at, the conclusion of a project, by that point in time the contractor may have executed a host of monthly payment application forms and change orders containing some form of waiver language. In many cases, these forms contain "full accord and satisfaction" language or other waiver provisions that may seriously limit, or even bar, the contractor from a cumulative impact claim arising from the adverse effects of changes that have been previously negotiated and bilaterally executed.

Before executing the original contract or any of the various contract forms, such as monthly payment applications and change orders, the project management team should review these documents with its executive management team and seek legal advice if deemed appropriate. Executing such forms containing the aforementioned waiver provisions, without an assessment of long term risk to the contractor, is not prudent project management. In general, the contractor should assume such waiver clauses are enforceable unless advised to the contrary by competent construction counsel.

In the alternative to executing payment applications and change order forms that have comprehensive waiver provisions, the contractor may seek to bilaterally negotiate with the prime contractor or project owner alternative language that will appear on the forms themselves. Such alternative language often seeks to preserve a portion of the contractor's rights to recover, at some future date, "unknowable" (i.e., "unknowable" at the time individual, "stand alone" changes are priced and executed as change orders) impact costs such as those arising from cumulative impact.

In the alternative, on projects where cumulative impacts are expected to be substantial, and where the owner refuses to alter the waiver provisions on the various contract forms, the contractor may decide to accept unilateral change orders that pay for a portion of the change but do not require the contractor to execute documents that may waive the right to later claim for unforeseeable or unknowable impact costs such as those arising from cumulative impact. Another option is for the contractor to proceed with the changed work without payment (most contracts give the owner the right to direct the contractor to proceed without a settled change order) while the parties address the change through the contractor's dispute clause.

The waiver of a contractor's right to claim for cumulative impact costs after the execution of changes bearing full accord and satisfaction language is a very serious financial and legal issue. It is strongly recommended that mechanical contractors review all con-

[8] Reference *Bell BCI Company v. United States*, U.S. Court of Appeals, Federal Circuit No. 2008-5087 570 F.3d 1337, 2009. For a related decision regarding cumulative impact following the decision in *Bell*, reference *Walsh/Davis Joint Venture v General Services Administration*, Civilian Board of Contract Appeals 1460, March 13, 2012.

tract documents with competent legal counsel prior to mobilizing on the project and certainly prior to executing any document that could potentially bar the contractor from receiving full equitable adjustment to its contract for all forms of impacts, including the cumulative impacts of change.

The Measured Mile Analysis Methodology

The measured mile method of quantifying a loss of labor productivity on a construction project is considered a project-specific, empirical analysis methodology. Productivity data is collected on the project under study comparing the production rates of similarly skilled workers installing similar materials, but under different conditions; productive (or partially productive) and impacted. The role of the analyst is to identify the causes of the reduction in productivity between a less impacted and a representatively impacted area or time frame on the project. The comparative production rate data produces the productivity loss quantification.

Since the measured mile methodology is a project-specific means to quantify a loss of labor productivity, it is highly favored by courts and arbitration tribunals. The cumulative impact data provided in this chapter are not studies of the productivity rates actually achieved on your company's project. The graphic models presented herein were prepared under statistical controls to offer accurate predictions of productivity loss given a set of circumstances that existed on over 170 individual construction projects.

As will be described herein, the data lines shown on the graphs have a "good fit" as to their ability to statistically predict with reasonable accuracy outcomes given certain input (i.e., the project data described in the examples contained herein). However, the data collected to produce the curves shown in this chapter were not prepared from the specific project to which the reader will apply the methodologies described herein. Thus, before a statistical approach is attempted, the claimant should attempt to prepare a measured mile analysis that derives its data directly from the affected project under study. The description of the measured mile methodology is provided in detail within this publication in the chapter on "How to Apply the Measured Mile Method of Productivity Analysis."

There may be a host of valid reasons why a measured mile analysis cannot be applied on a construction project that is beset with multiple changes in scope. In order to prepare a measured mile analysis, there must be a non-impacted or less impacted area or time frame in which, or during which, the contractor's actual productivity can be compared with the contractor's actual production in an impacted area or time frame. On many projects, change begins at the outset of the project and continues almost to the time of commissioning or demobilization, thus yielding no unimpacted or less impacted area or time frame for the comparison. On other projects, the labor tracking records may not exist to perform a measured mile analysis. However, there are ways to modify the measured mile approach to accommodate some of the obstacles often encountered with the lack of a less impacted area or time frame, or with the lack of robust recordkeeping.

Before any other type of productivity quantification methodology is applied, the claimant should first seek to utilize the measured mile method to quantify the loss of labor productivity. A successful measured mile analysis will capture the vast majority of the types of labor inefficiencies that occur on construction projects. If a measured mile analysis cannot be performed and the project has been adversely affected by change, the methodology described in this chapter may assist the contractor with the preparation of a loss of productivity analysis that is derived from statistically reasonable project studies as will be described herein.

Defining "Scope Change" and "Change Order"

When reviewing the available literature on the subject of cumulative impact, the terms "scope change" and "change order" are frequently used interchangeably when discussing the hours attributable to contract changes in scope.[9] "Change" includes unapproved scope change labor hours and approved change order hours, presuming these unapproved changes will stand the test of scrutiny regarding their validity. Including labor hours arising from questionable scope changes will reduce the contractor's credibility and potentially affect the inefficiency computations and estimates.

If scope change hours (which by definition have not been formally approved as contract change orders) are included in the contractor's cumulative impact loss of productivity computations, some special considerations have to be made. If, during the process of vetting scope changes, the contractor withdraws a scope change and performs the work under its base contract, or the scope change is determined by an authoritative tribunal or board to have been within the contractor's base contract scope, the total "change" hours must be adjusted accordingly in any of the cumulative impact models that are presented in this chapter.

As will be discussed herein, the actual number of change orders issued on a project may not be relevant to the issue of labor inefficiency. On some projects, an owner may bundle many, perhaps 10, 20 or more, individual scope changes into one omnibus change order. Thus, it is not the number of executed change orders, or necessarily the timing of the issuance of the formal change order documents, that most adversely affect field labor productivity. It is the number of change labor hours and their timing (in terms of when the work is actually performed) that most profoundly affects a contractor's labor productivity.

Identifying Labor Overruns in the Construction Industry

Labor overruns can have a variety of causes as their origins. One cause of labor overruns could be an inaccurate estimate. However, on projects fraught with a multitude of labor intensive changes, labor overruns are frequently the result of cumulative impact. As noted, a simple labor overrun shown in a labor production report is not necessarily an indicium of an inefficient project. Similarly, labor overruns on construction projects do not necessarily arise from inaccurate labor estimates. A project which was based on an accurate, reasonable and carefully reviewed labor estimate can have substantial labor overruns. Therefore, it is necessary to investigate such labor overruns carefully to ensure that the root cause is not an inaccurate labor estimate and is, in fact, the result of labor inefficiencies caused by identifiable events on the project.

Labor overruns that result from an inaccurate estimate usually arise from missed work scopes,

[9] "Design development" changes, a type of change common in design-build projects, are a different type of change for which the design-build contractor is responsible.

such as material and equipment items, not being identified during the estimating process. As such, when it comes time to assign labor hours to material and equipment items, the labor hours required to install items that were missed in the estimate are not included in the total of labor hours required to construct the project. Another possible source of an improper labor estimate is the labor factor(s) utilized by the contractor as the achievable productivity on a particular project and that will result in the expenditure of the planned labor hours.

For instance, if an estimator applies a 0.65 MCAA estimating labor factor for the installation of pipe, valves, and fittings on a project because the field forces are known to the estimator as productive, and these forces become unavailable when the project actually commences, the actual labor forces may only achieve a 0.75 or higher MCAA estimating labor factor. While this represents a form of labor inefficiency (i.e., the actual labor force was inherently less productive than the estimated labor force), such misassumptions in the estimating process may not constitute a claim for labor inefficiency under most construction contracts.[10]

When a project has been properly estimated in terms of quantities and the original labor factors applied at the time of the bid, and the project sustains a measurable labor overrun, then a condition resulting in a potentially recoverable loss of labor productivity may have occurred. Such conditions should initiate a careful analysis of the project by the contractor's management personnel.

A potentially recoverable[11] loss of labor productivity condition is one that was not caused by the contractor in its estimating, management of the project, or other factors ascribable to the contractor. Put another way, but for the conditions that caused the inefficiencies—conditions not caused by the acts or omissions of the mechanical contractor—the mechanical contractor's labor would have at least met the planned production rates.

Loss of productivity cannot be defined simply as actual labor hours for a specific scope of work, minus change hours, minus estimated hours, equals inefficient labor hours for a particular scope of work. Consider that a contractor planned to install 40 linear feet of 10″ diameter ASTM A53 schedule 40 carbon steel butt weld pipe and fittings in 8 labor hours. However, it actually took 12 labor hours. The labor overrun cannot be ascribed to a loss of labor productivity without the benefit of a productivity cause and effect analysis. The overrun of 4 labor hours could have been caused by a bid error, an inherently less efficient labor force, or the introduction of the ripple effect of change to the project.

When cumulative impact occurs, it is the effect of multiple changes to the work that causes the majority of the loss of labor productivity, not each independent change itself. In such cases, it is usually impossible to connect an individual, single cause to a specific effect—on a change by change basis. However, the contractor still must prepare a cogent narrative that provides the respondent with a logical

---

[10] An excusable delay to the commencement of the mechanical contractor's work, such as by a differing site condition that delays foundation and vertical construction, may justify such a loss of productivity claim based on an assumed, reasonable overall production rate.

[11] "Recoverable" is a term that can be highly qualified or restricted by the terms and conditions of the contract. Many contracts attempt to limit, or eliminate, a mechanical contractor's right to recover labor inefficiencies. Such contract terms should be the subject of a careful legal review.

and factual basis for the contractor's productivity losses.[12] If the cause can be identified as arising from the impacts of multiple changes on the project and not from the contractor's self-inflicted acts and omissions, then the contractor should consider the application of the studies and examples contained in this chapter to quantify the loss of labor productivity.

If the contractor is tracking its field erection labor by use of activity tracking or cost account codes that divide the project into identifiable segments, such as by buildings, floors, rooms, or site facilities, management can determine if the losses are project-wide or limited to certain specific areas or time frames. This sort of labor performance reporting is discussed in much greater detail in the "Maintaining Control of Labor Productivity" chapter of this publication. Such contemporaneous labor tracking is an important tool in forecasting inefficient labor trends on a construction project and can assist the management team in their efforts to connect causes with the effects in terms of lost labor productivity.

Once a contractor determines that its crews have sustained a measurable loss of labor productivity, and that such losses are not solely the result of the contractor's own acts or omissions, the contractor should seek to identify the source(s) of the productivity loss, mitigate where practical, quantify the losses, and, if appropriate, seek recovery for those losses.[13]

[12] "…it is clear that demonstrating an overrun in labor and the existence of numerous changes without some evidence linking the changes to the overrun is insufficient proof of causation. Finally, there must be some proof of a causal connection established showing that the undifferentiated group of contract changes affecting the changed and the unchanged contract work resulted in the loss of productivity on that work." Reference the *Appeal of Centex Bateson Const. Co. Inc.*, 99-1 BCA P 30153 (1998).

Evaluating the Potential Productivity Impacts of Changes in Scope

What are the potential constituents of cumulative impact as we presently understand them in the construction industry? In terms commonly used in the construction industry, cumulative impacts arising from a multitude of changes can include, without limitation, the following components:

- **Stacking of Trades**—congestion of unplanned trades simultaneously working in limited spaces;
- **Reassignment of Manpower**—also known as labor disruption—the start-stop-restart condition frequently resulting from the introduction of new scopes of work into the existing labor plan, or the resequencing of activities to accommodate the introduction of other trades in an unplanned fashion, or new activities (i.e., the scope change activities);
- **Crew Size Inefficiency and Learning Curve**—resulting from the addition of unplanned resources brought on site to address the magnitude of the changed work and their need to "learn" the project and assimilate into existing crews;
- **Concurrent Operations**—congestion caused by the stacking of the contractor's own forces to address the added change activities;
- **Dilution of Supervision**—redirection of field labor supervision's attention from

[13] Even if the contractor determines that all or a portion of the loss of productivity has been caused by the contractor, it is still essential for the contractor to identify the cause and to mitigate the loss wherever possible.

managing base contract work to solving change scope issues—such as preparing RFIs, directing crews performing changed work and ordering of materials arising from the changes; and

- **Overtime**—inefficiencies arising from an unplanned overtime schedule required to mitigate the delaying factors arising from changes to the work.[14]

The aforementioned categories, taken from the widely accepted MCAA table entitled "Factors Affecting Labor Productivity" at pages 99 through 100 herein, are among the list of possible components of cumulative impact. On a project with multiple changes, it can be difficult, or in some cases impossible, to segregate the individual impact categories that caused the loss of productivity arising from cumulative impact. Thus, the data provided in this chapter is presented to allow a contractor to estimate labor inefficiencies arising from cumulative impact in a more holistic fashion based on the manner in which the underlying data was collected and analyzed.

In addition to reviewing the labor tracking records and interviewing the field supervision in its investigation, the contractor should carefully assess the size, quantity in terms of labor hours, and timing of changes in scope that have been issued. As will be described below, the timing of changes in scope is important in the evaluation of the impacts of those scope changes to the base contract labor. Changes in scope that are issued early in a project and sufficiently prior to the planning, coordination, fabrication, and installation of the affected work can be expected to have less impact than changes that are issued in the heat of battle and while the affected work is about to commence or is already in progress. The importance of the timing of changes has been borne out by the research performed by the researchers at the University of California at Berkeley and is demonstrated by the data contained in this chapter.

It is helpful for contractors to record when scope change work commences and is performed. While the majority of contractors do not code their actual field labor to scope change or change order account codes, in some cases it is possible to track generally when changes are directed or otherwise authorized to commence and when the changed work is performed.[15] By tracking when scope change work is performed, a bar chart can be compiled demonstrating the timing of the scope change work. Such charts can temporally depict the concurrent nature of multiple changes on a construction project and aid in the preparation of a cumulative impact request for equitable adjustment.

It is a generally accepted axiom in the construction industry that the timing of changes is important when considering the potential effect of changes on labor productivity. Changes that occur early in the project and which affect downstream activities may not adversely affect the overall labor productivity. For example, if a scope change/change order is issued near the outset of a two year project

[14] The contractor should differentiate between short-term "spot" overtime required to address immediate scheduling needs and long term and unplanned overtime that can cause a substantial loss of labor productivity. Reference the chapter entitled "How to Estimate the Impacts of Overtime on Labor Productivity" herein on the subject of overtime inefficiency.

[15] When the cumulative impact arises from constructive changes that are not recognized until after their performance or, in some cases, until the conclusion of the project, it may not be possible to track the start and stop dates of the change.

to modify piping on a vessel that is not planned to be fabricated, installed, and piped until the middle of the second year of construction, such changes may have a negligible effect on productivity because the influence of such changes can be assimilated into the normal flow and rhythm of the work more easily.

However, most changes in scope are not issued far enough in advance of the planning, coordination, prefabrication, and installation of the work to allow the influences of the change to be managed into an efficient work flow. Most often, contractors are deluged with changes in scope as the work affected by those changes is being installed. When changes in scope are identified and are required to be performed during the "heat of battle," when the crews are ramping up or are at or near their peak, the effects of such changes in scope on labor productivity can be devastating.

Figure 2 on the next page depicts the temporal relationship between change, resource usage and a value known as the Actual Contract Labor Hours (ACLH). The ACLH calculation and consumption curve will be explained in the next section of this chapter. The actual crew size is shown on the *z* axis and, if desired, the planned labor curve can be superimposed to show a contrast between planned and actual. This is optional, but potentially very helpful information to show how the craft levels responded to the addition of change work. On the line graph, the contractor has plotted the dates on which scope change work actually commenced and was performed[16] and the rate of consumption of the ACLH.

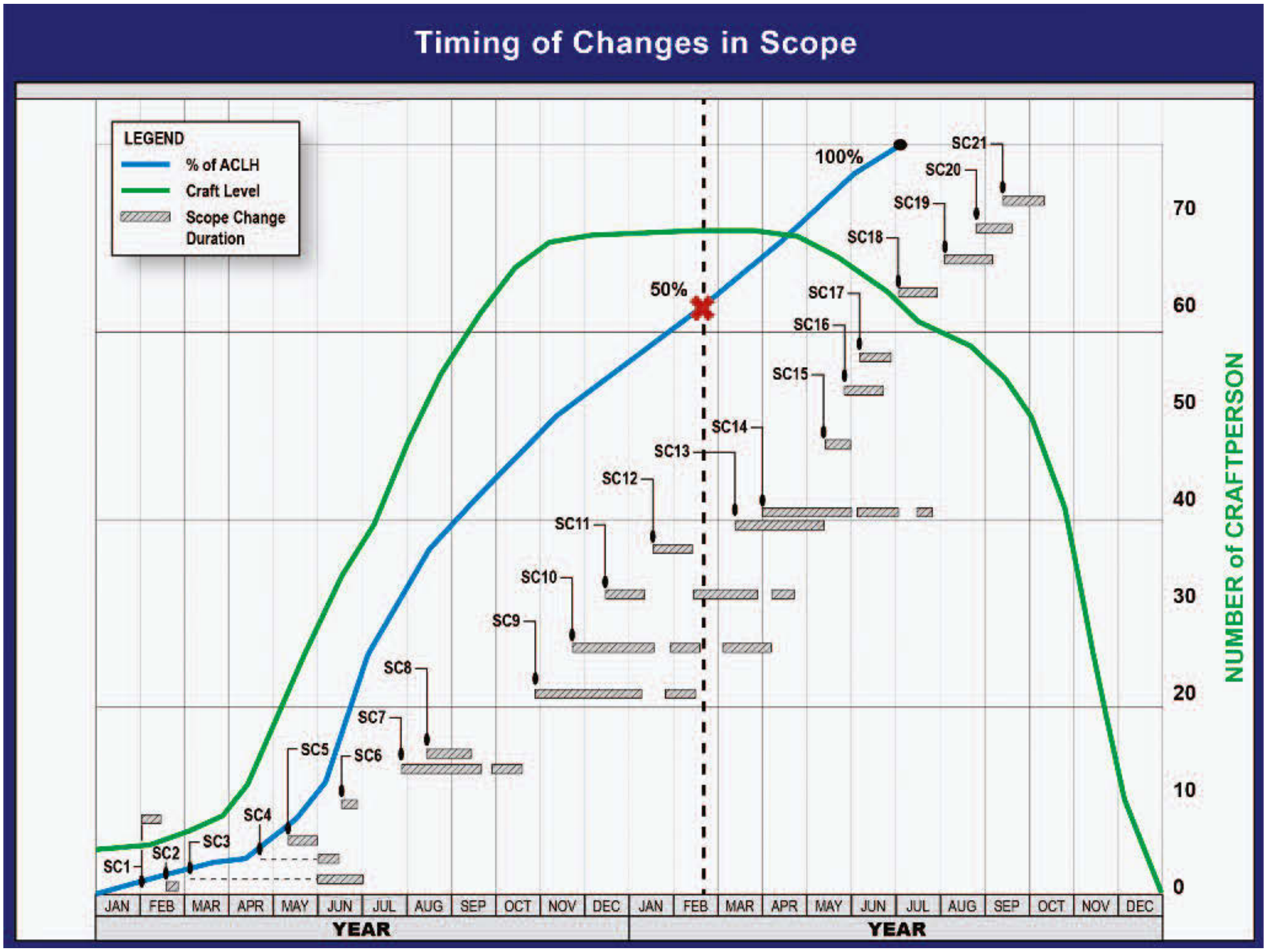
Figure 2[17] shows that certain scope changes (SC), or interchangeably, change orders, were directed to commence when the project was in its early stages and when the crews were at minimal levels. Assuming these early changes allowed the contractor to easily incorporate the new or changed work into its planning, coordination, fabrication and installation steps, an attenuated impact would be anticipated as compared with changes issued during the peak crew periods. However, as the contractor increases its crews and prosecutes multiple work activities on several work fronts, changes could be expected to have a substantial and increased adverse impact on the contractor's labor productivity. It is the labor-hour intensity of the change in scope, and its timing, that are the important considerations regarding the effects of the change on labor productivity. The actual dollar value of the change is not the determining factor as to its potential impact on labor productivity.

An important feature of the inefficiency study that underlies this chapter is its measurement of inefficiencies arising from the *timing* of the changes in scope. The studies and resulting data that underlie this chapter (i.e., the *University of California at Berkeley Ibbs Study)* were evaluated to determine the effects of timing of the changed work, as

[16] These change work start and finish dates should be as accurate as reasonably possible. As previously noted, the date on which a change order is executed may be totally irrelevant to the issue of labor productivity. A formal, executed change order may "roll up" dozens of individual scope changes and may not be approved until very late in the project, thus shedding no light on when the changed work scope was actually directed and performed. On some projects, an owner may never actually execute any change orders and may direct the contractor to perform added or changed work scope under the applicable terms of the contract.

[17] ACLH shown in this figure refers to Actual Contract Labor Hours. This value is not simply direct payroll hours; rather it is a computation of adjusted labor hours that is fully described in the "Change and its Quantitative Effect on Productivity" section of this chapter.

Figure 2: Example of Scope Change Timing Chart with Craft Level Curve



well as the effects of the magnitude of the ratio of changes to the base contract labor hours. In a following section of this chapter describing the use of the Ibbs cumulative impact curves, the manner by which the user can categorize a change as "early," "median," or "late" will be defined in detail.

Change and its Quantitative Effects on Productivity

Despite the fact that change clearly has measurable and oftentimes adverse impacts on a construction project's labor productivity, until recently there was little authoritative and reliable research into the quantitative relationship between change and loss of labor productivity.[18] This dearth of information led CII to fund an extensive, two-year study led by Professor William Ibbs, PhD, a co-author of this chapter, and his University of California at Berkeley research team.

The study was funded by large, sophisticated owners and contractors and was reviewed and overseen by a balanced audience. The published results were endorsed by representatives of a majority of the stakeholders in a typical construction project. The Berkeley researchers collected extensive amounts of data from 172 projects and tested various research hypotheses by sophisticated statistical methods. Follow-up interviews were conducted with the project participants to provide quality control on the data and to understand the contexts of the projects.

The projects ranged in size from $3.2 million to $15 billion, with a median value of $62 million, and included both domestic and foreign worksites. Ninety-two percent of the sample projects were constructed in the United States. Sixty-two percent of the sample projects consisted of private sector projects and the remaining 38 percent were public sector projects. Of the public sector projects, 31 percent were highway and bridge, 20 percent rail systems, 19 percent commercial and school buildings and 15 percent hospitals, with the balance consisting of airports and canals.

Forty-one percent of the sample projects were design-build and the balance of the projects utilized a design-bid-build contract delivery system. Fifty-two percent were fixed price (either lump sum or unit price) and 48 percent were cost reimbursable projects. Eighty three percent of the public projects were design-bid-build with a general contractor or construction manager at risk and 17 percent utilized a design-build delivery system. Seventy six percent of the private projects were design-build, with 20 percent using a design-bid-build delivery system and 4 percent utilizing a hybrid contract delivery system. Of the public projects, 65 percent were lump sum, 31 percent were unit price and 4 percent cost plus. Of the private projects, 53 percent were lump sum and 40 percent were cost plus. Eleven percent of the public projects were multi-prime as were 8 percent of the private sector projects. Fifty-seven percent were new, greenfield projects and the balance renovation or expansion projects.

The private projects in this database contained the following types of construction:

- Petrochemical 27%
- Power generation 19%
- Heavy manufacturing 16%
- Light manufacturing 12%
- Commercial buildings and other types 26%

Labor hour and labor, material, subcontractor, and overhead cost data were collected for the projects at the 25 percent, 50 percent, 75 percent, 80 percent, 85 percent, 90 percent, 95 percent and 100 percent completion points in the design and construction phases.

The data points representing each of the 172 total projects were analyzed and plotted as can be referenced in Figure 3 on the next page. The curved line represents the best-fit, regression for the total projects under study and the equation for that line is represented by the mathematical expression shown in the figure. The R^2 value[19] is a measure of the line

[18] Over 15 years ago, a cumulative impact study was authored by Charles Leonard (the "Leonard Study") and was widely circulated in the construction industry. The Leonard Study found that the cumulative impact of multiple changes on a construction project adversely affected a contractor's labor productivity. This study also found that the timing of changes affected labor productivity. This study was later criticized in several court cases, primarily for its manner of data collection and statistical analysis. The study utilized in this chapter was carefully composed and monitored in order to avoid, and then to correct, those data collection and statistical analysis errors for which the Leonard Study was criticized.

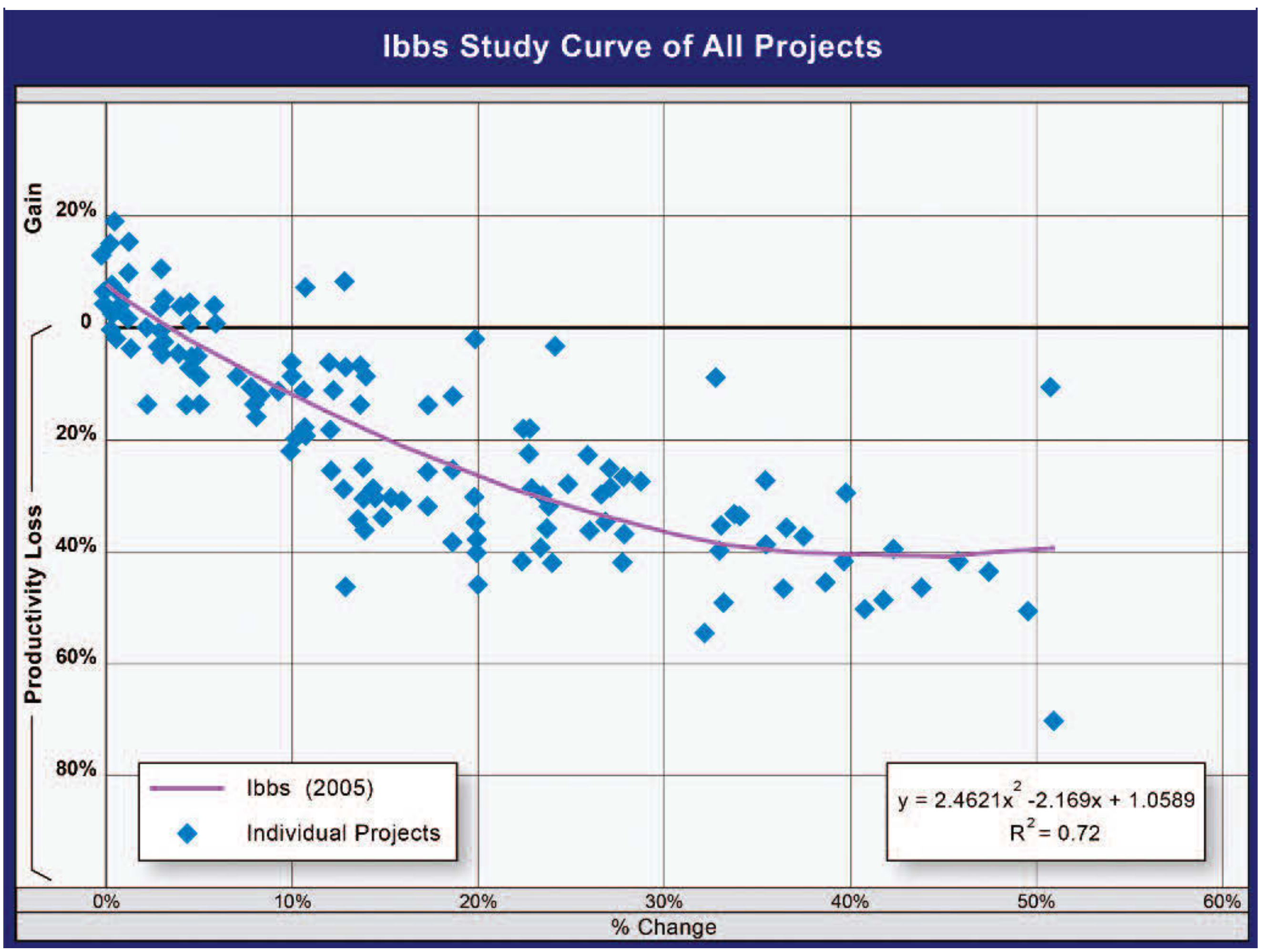
goodness for fit for the universe of projects in the study; $R^2 = 0.72$ indicates a good fit.

Percent Change as used in this chapter is defined as: change labor hours[20] ÷ Actual Contract Labor Hours (ACLH). Actual Contract Labor Hours are the total number of actual payroll field labor hours minus change labor hours and minus all appropriate contractor adjustments. These adjustments would include, without limitation, bid errors and contractor field mistakes. Examples of such potential downward adjustments will be provided later in this chapter.

As described above and as shown in Figure 3, the data collected and analyzed by the Ibbs Study research team were transferred onto charts for use in the construction

[19] The R^2 value is known as the *correlation coefficient* and is used in statistical models whose main purpose is the prediction of future outcomes based on other related information. This value states the proportion of variability in a data set that forms a statistical model, such as regression analyses as utilized in the Ibbs models. The R^2 value provides a measure of how well future outcomes are likely to be predicted by the model, thus within the range of 0 to 1, the closer the value is to 1, the more likely it will be that the prediction will resemble the result.

Figure 3



industry. From the extensive data that was gathered, the research team identified three separate data curves based on the timing of the issuance of changes in scope. The data presented herein represent the estimated impacts to labor productivity when changes at a particular level are issued early, at a median point, or late in the project. These terms, and the means by which projects are categorized as "early," "median," or "late" models, are fully defined and explained in a later section of this chapter. The data resulted in the following three curves.

These two variables, percent change and percent productivity, were compared, as can be seen in Figures 4 A-C. Each of the data points in these figures represent a project in the Ibbs study. The R^2 values for the three curves shown in Figures 4 A-C are as follows: 0.81 for the "early" timing curve, 0.63 for the "median" timing curve and 0.76 for the

[20] In order to offer a more conservative inefficiency estimate, the labor hours contained in T&M tickets are not included in the percent change computation for the purpose of this chapter. By virtue of the way T&M charge tickets are maintained, they usually have the direct inefficiencies embedded within the T&M entries. We have taken the conservative approach of not including these hours in the computation of the percent change value. However, if a significant portion of the total change hours were recorded on T&M tickets, this exclusion of T&M hours in the percent change computation may be revisited by the contractor, since the exclusion of a major portion of the change hours recorded on T&M tickets could unfairly affect the outcome of the labor inefficiency estimate.

Figure 4-A

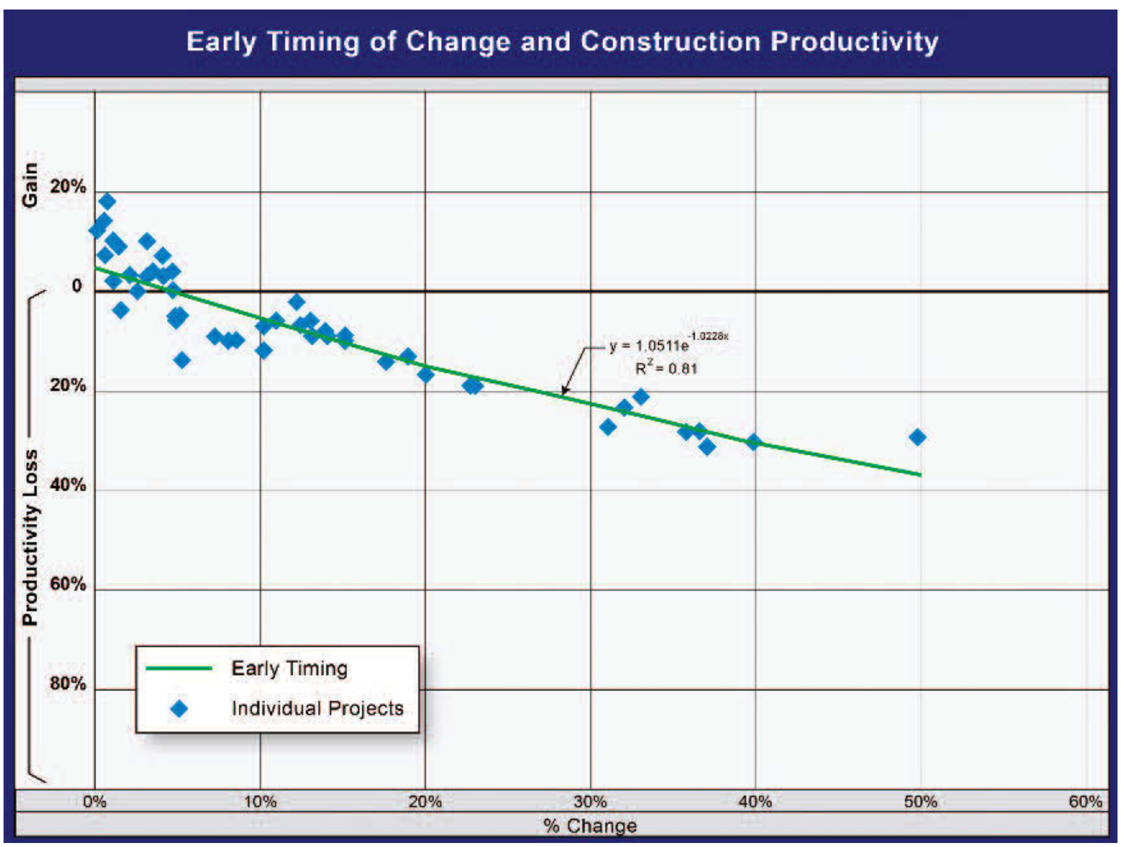


Figure 4-B

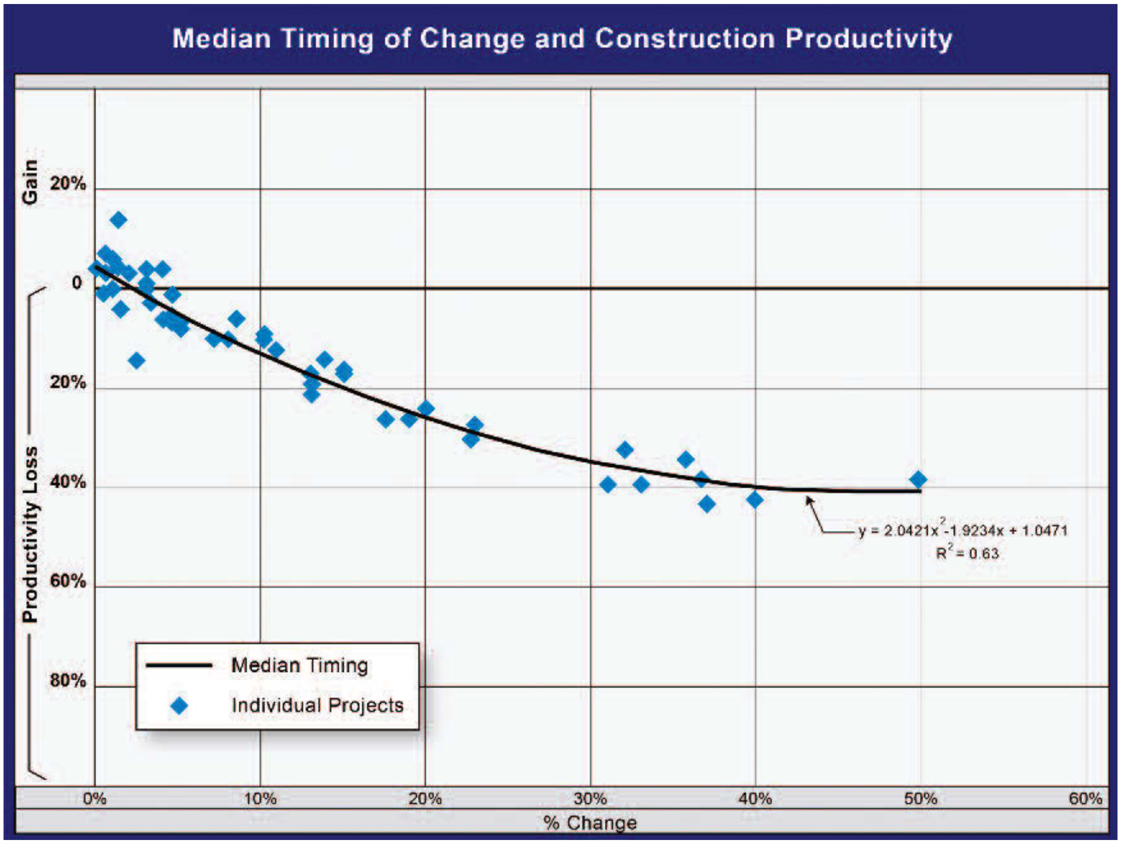
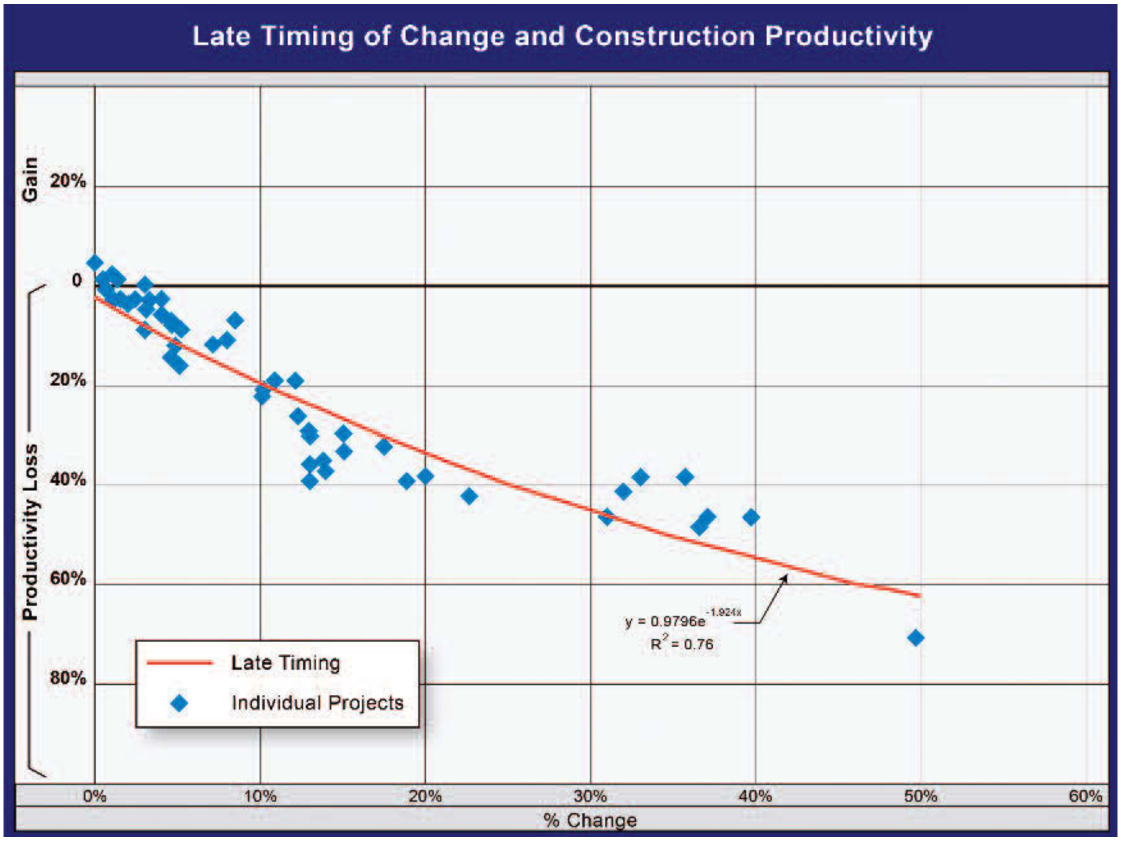


Figure 4-C



"late" timing curve. All provide for reasonable forecasts of labor inefficiencies that can be expected at various ratios of changes to adjusted base contract hours.

Several points emerge. First, larger amounts of change result in greater loss of productivity. For instance, a project with 20 percent change (measured on the horizontal axis of the median curve) results in a loss of labor productivity of approximately 25 percent. In other words, the cumulative impact of changes causes a reduction in the contractor's planned productivity of approximately 25 percent.

In this portion of the Ibbs Study projects were ranked as having change at an early, median point or late stage of the project. As to the timing of change, this study utilizes the total ACLH by establishing the mid-point of the project based on the actual utilization of one half of the ACLH, as depicted in Figure 6 on the next page and as described below.

The Change Timing Designation Chart in Figure 6 demonstrates how each of the three timing models is defined. Follow these steps:

Figure 5

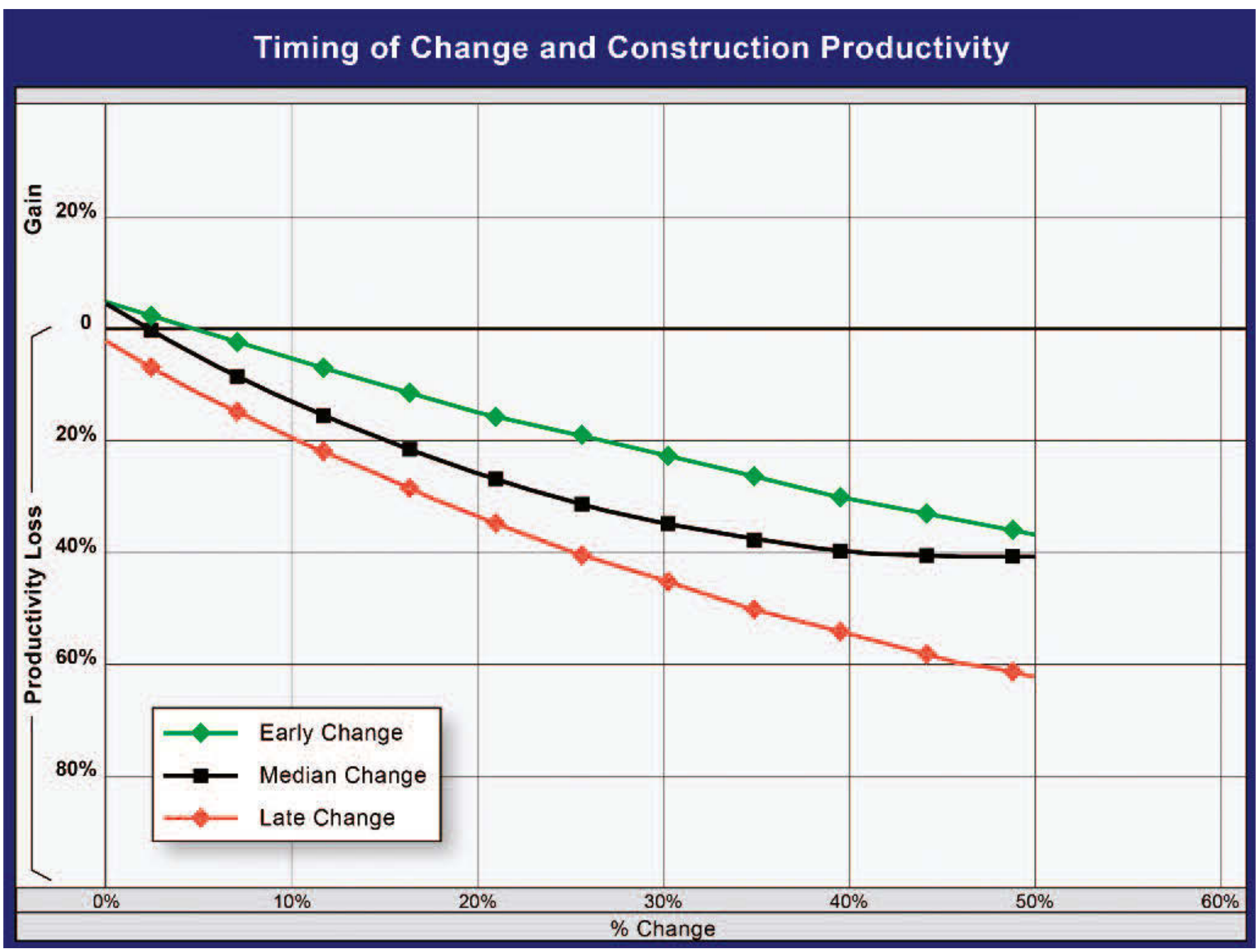
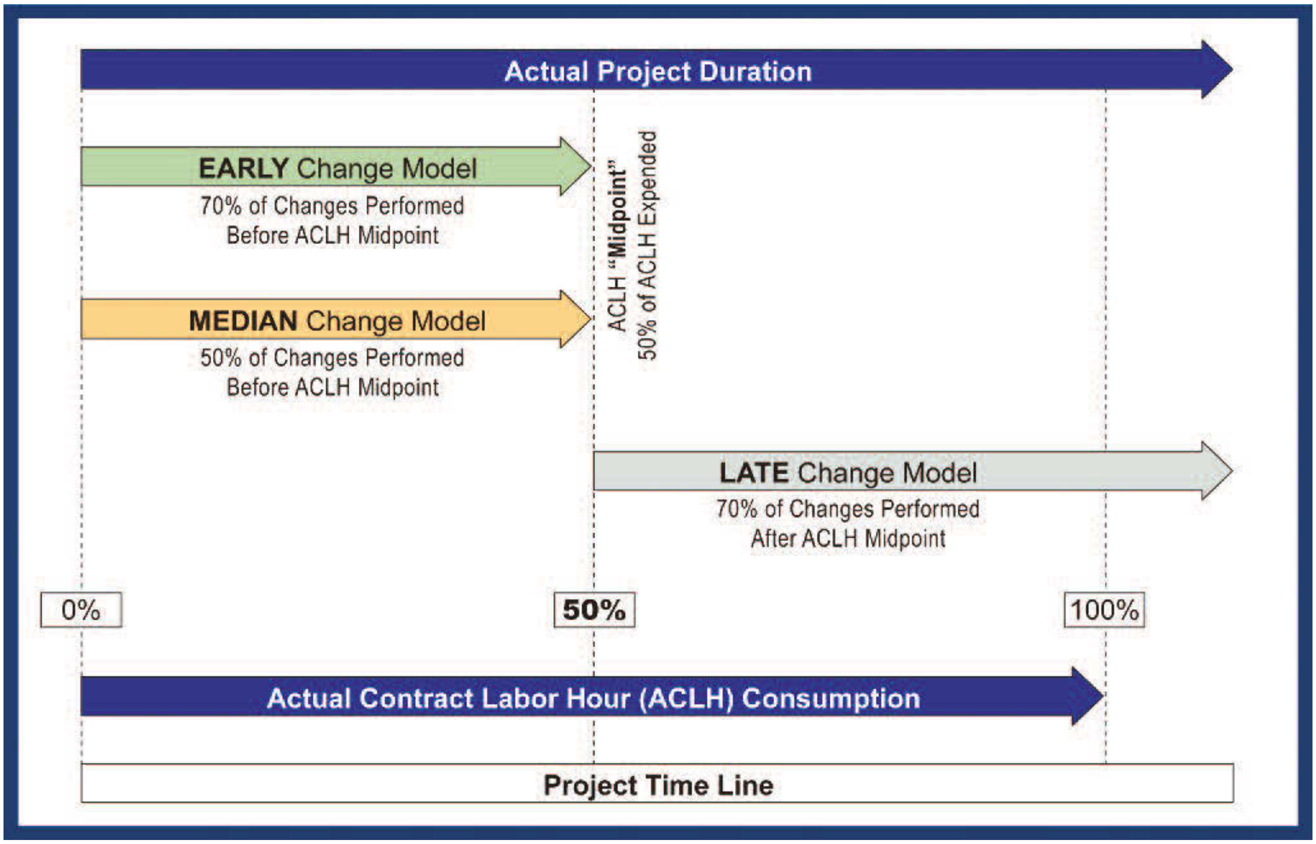


Figure 6: Change Timing Designation Chart



1) compute the ACLH as described in this chapter, we will call that labor hour number X; 2) by referencing payroll or other labor hour data,[21] determine when, in time, one half of X was actually expended, this is known as the ACLH midpoint; 3) by referencing change pricing folders, time sheets or other data, determine when change work was performed; 4) from that data, determine how many change hours were expended before, and after, the ACLH midpoint; and 5) compute the percent of change hours expended prior to, and after, the ACLH midpoint.

By way of example, the ACLH on a project was calculated to be 16,000 field craft labor hours. The claimant would refer to payroll records to determine when 8,000 field craft hours had been expended on the project. The date on which 8,000 field craft labor hours had been expended would mark the ACLH midpoint for the purpose of determining the timing categories of change. The claimant would then determine when change hours were expended and from that data, compute the percent of change hours that were expended before, and after, the ACLH midpoint.

[21] For the purposes of this chapter, field craft labor hours should not include non-working labor categories. Such non-working categories could include superintendents, general foremen and foremen, depending on the size of the project, local union requirements and custom and practice of the contractor.

Early change means that about 70 percent of change hours were expended before the ACLH midpoint, median change means that about 50 percent of the change hours were expended before the ACLH midpoint and "late" change means that about 70 percent of change hours were expended after the ACLH midpoint.

Note that in most cases, 100 percent of the ACLH hours will be expended before the project has been completed. That is because the ACLH hours exclude various components such as bid labor hour mistakes, field retrofit caused by the contractor and the change work, thus the ACLH will achieve 100 percent before all of the labor hours are consumed on a project. Also note from Figure 6 that the ACLH midpoint will probably not match the midpoint of the overall project timeline measured by other indices, such as billing values, total hours consumed or work days accomplished. This is to be expected. As previously noted, 100 percent of the ACLH will be consumed prior to the actual completion of the project.

As can be seen in Figure 5, projects with early recognition of change incurred less loss of productivity than projects with median or late changes. For example, at 20 percent change, the "late" projects suffered about twice as much productivity loss as the "early" projects. These curves reinforce the notion that it is better to address change earlier in a project than to postpone resolution of the issues causing change.

Examples of Cumulative Impact Quantification

Below are three examples of the use of the cumulative impact studies. These studies provide a basis to estimate a contractor's loss of labor productivity caused by cumulative impacts. The results gained from applying the Ibbs Study are not represented to be precise computations. They are represented to be *reliable estimates* of productivity losses when properly applied.

Example No. 1: A project was planned to utilize 16,500 field craft labor hours (excluding non-working supervision). At the conclusion of the project, the payroll reports show an actual expenditure of 30,000 field craft labor hours, excluding non-working supervision. Upon careful investigation it was discovered that there was a bid error of 1,500 field craft labor hours, errors in construction that required 900 field craft labor hours to repair, and 500 hours were recorded via T&M tickets. Moreover, the contractor estimated that 5,500 hours were expended on scope change work, other than the T&M time tickets noted above. Based on the formula described above, the Actual Contract Labor Hours would be computed as follows:

Total field craft labor hours actually expended on the project:	30,000
Bid error:	(1,500)
Field errors:	(900)
T&M ticket time:	(500)
Scope changes/change order labor hours:	(5,500)
Actual Contract Labor Hours	21,600

From the example above, it is clear that the Actual Contract Labor Hours are not simply the actual payroll hours; the ACLH value has been derived by reducing the actual payroll hours by various factors such as bid errors or field retrofit. The factors will vary from project to project and must be determined by the contractor's management team. Once the Actual Contract Labor Hours have been computed, the timing of the labor expenditure must be plotted using the payroll or labor performance reports. The date at which 50 percent of the ACLH were expended (10,800 hours of payroll labor expenditures out of the total of 21,600 ACLH hours) is considered the midpoint of the project for purposes of assigning the proper curve to the inefficiency analysis that follows.

The next step would be to identify from the actual records, or estimate if such records are not available, the dates during which the change work was performed. Also, the actual (or estimated) labor hours of each change must be determined utilizing payroll reports, field records or an estimate. By determining change hours performed before and after the midpoint, the appropriate curve can be selected.

In this example, it was determined that approximately 74 percent of the change hours were expended by the midpoint, thus the first graph (early) on the curve is chosen to calculate the impact to the labor productivity.

Figure 7

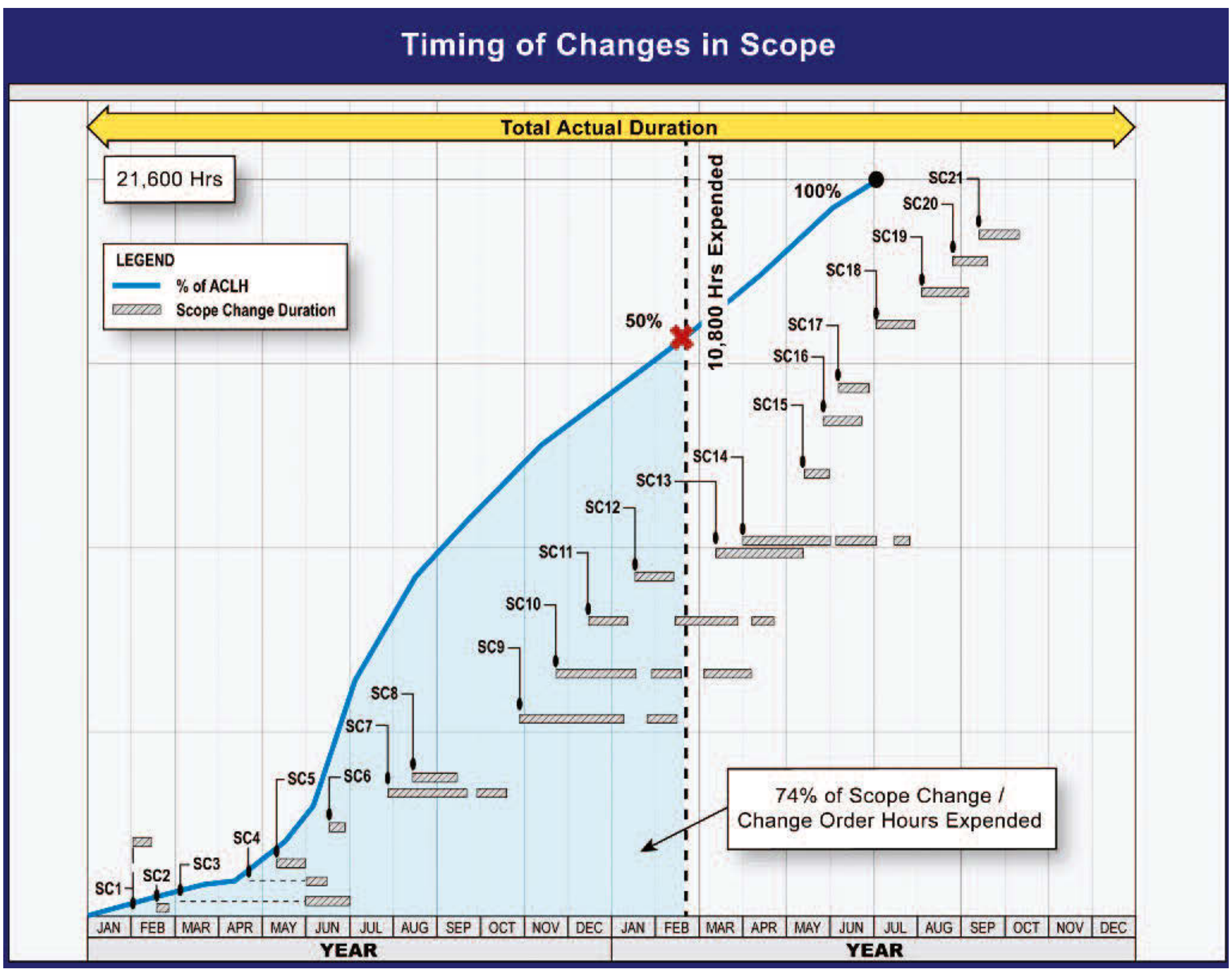
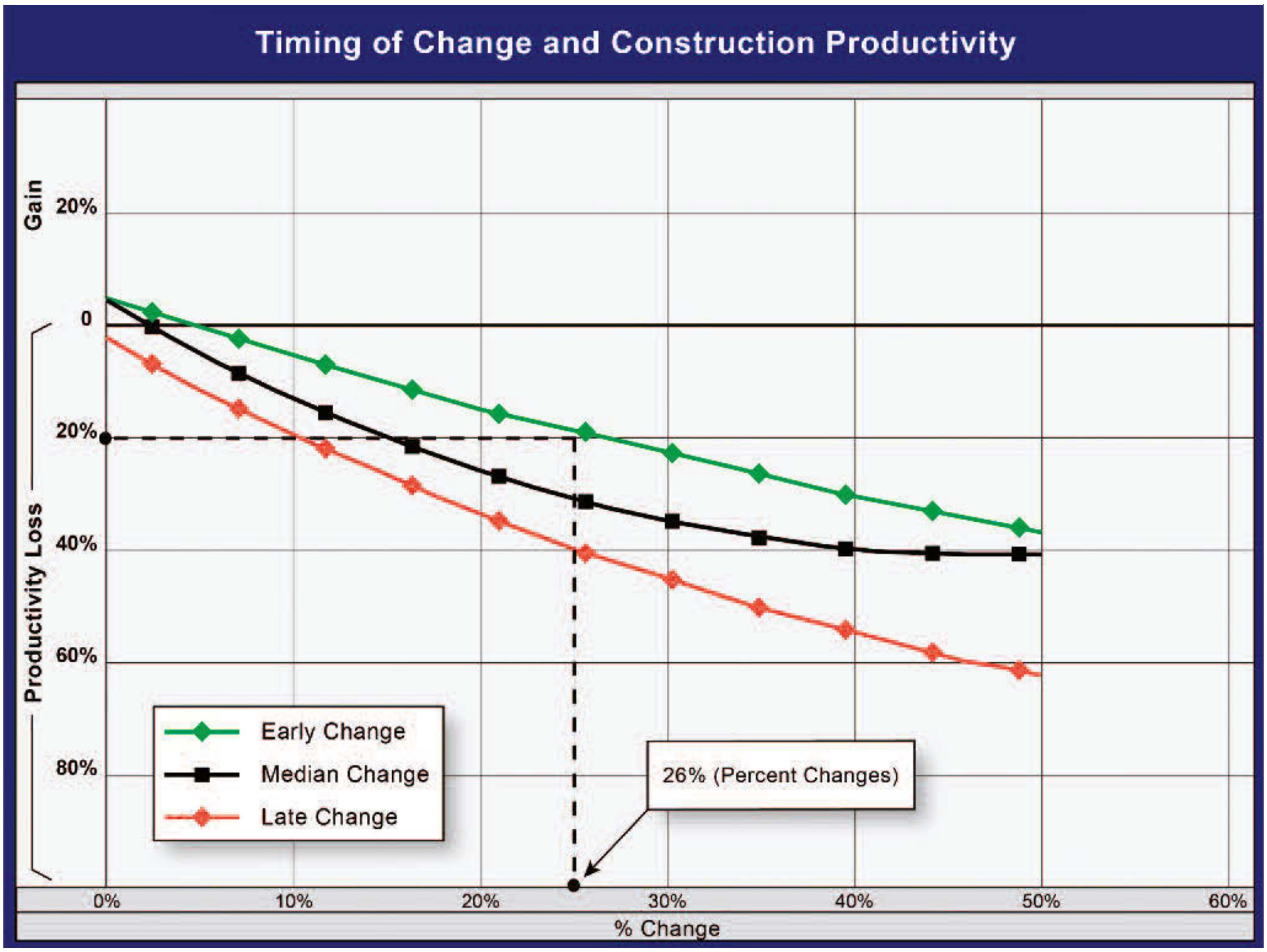


Figure 8



From the formulas provided above: Percent Change = Change Labor Hours ÷ Actual Contract Labor Hours. Percent Change = 5,500[22] ÷ 21,600 = 25.46% = 26%. The percent change for this example is 26 percent.

From the example above, it was determined that the project sustained a 26 percent cumulative change impact. From the "early" curve on Figure 8 it can be seen that 26 percent intersects the "early" curve at a productivity loss of approximately 20 percent. A loss of 20 percent of the ACLH of 21,600 equals a loss of productivity of approximately 4,320 field craft labor hours.

Special Note: When performing a loss of productivity computation from industry studies, it is advisable to test the results by way of a "modified total cost" evaluation (in this case, labor hours are substituted for the "cost" value). This will allow the contractor to analyze the amount of labor hours being claimed as cumu-

[22] The change hour totals in the examples included in this chapter for the calculation of the percent change value do not include T&M ticket hours, as previously explained herein.

lative impact inefficiency in comparison with the total unallocated labor loss on the project. From Example No. 1 above, a modified total labor hour calculation would appear as follows:

Total field craft labor hours actually expended on the project: 30,000

Original estimate: . . . . (16,500)

Bid error: . . . . (1,500)

Field errors: . . . . (900)

T&M ticket time: . . . . (500)

Scope changes/change order labor hours: . . . . (5,500)

Unallocated labor loss due to all causes: 5,100

Since the cumulative impact recovery computed in this example was 4,320 hours, there remains 780 hours of unallocated loss of labor productivity. This unallocated labor loss can be explained in the contractor's narrative as potential unclaimed losses caused by the contractor's own acts or omissions (so as not to assert an otherwise perfect performance) or simply as an undefined, and unclaimed, amount of lost labor hours.

Example No. 2: A project was planned to utilize 8,000 field craft labor hours (excluding non-working supervision). At the conclusion of the project, the payroll reports show an actual expenditure of 20,000 field craft labor hours, excluding non-working supervision. Upon a careful investigation, it was discovered that there was a bid error of 1,200 field craft labor hours, errors in construction that required 1,000 field craft labor hours to repair, and 300 hours were compensated by T&M tickets. Moreover, the contractor estimated that 4,000 hours were expended on scope change work (net of the T&M ticket hours). Based on the formula described above, the Actual Contract Labor Hours would be computed as follows:

Total field craft labor hours actually expended on the project: 20,000

Bid error: . . . . (1,200)

Field errors: . . . . (1,000)

T&M ticket time: . . . . (300)

Scope changes/change order labor hours: . . . . (4,000)

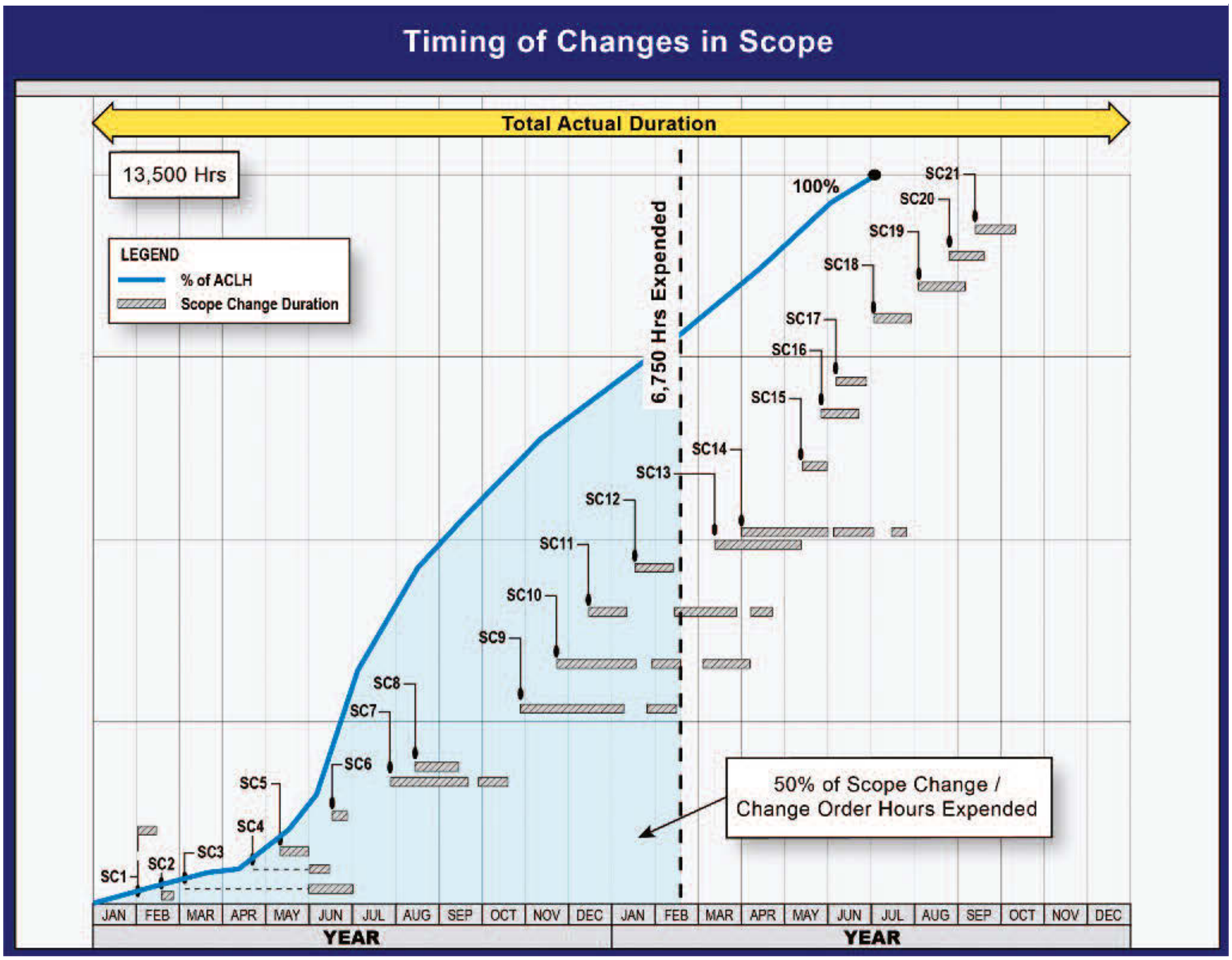
Actual Contract Labor Hours 13,500

Once the Actual Contract Labor Hours value is computed, the timing of the labor expenditure must be plotted using the payroll or labor performance reports. The date at which 50 percent of the Actual Contract Labor Hours were expended (6,750 hours of actual payroll-supported labor was expended of the total of 13,500 hours) is considered the "midpoint" of the project for purposes of assigning the proper curve to the inefficiency analysis that follows.

The next step would be to identify from the actual records, or to perform an estimate if such records are not available, the actual performance dates of the change work. Also, the actual (or estimated) labor hours of each change must be determined. As described in Example No. 1, the timing component is thereby computed and the appropriate curve is chosen from the timing chart.

As shown in Figure 9, it was determined that approximately 50 percent of the scope change hours were expended by the "midpoint," thus the second graph (median) on the curve is chosen to calculate the impact to the labor productivity. Note on this example that the scope change timing has been taken from field records or has been estimated by the project staff. Further, the number of field craft labor hours

Figure 9



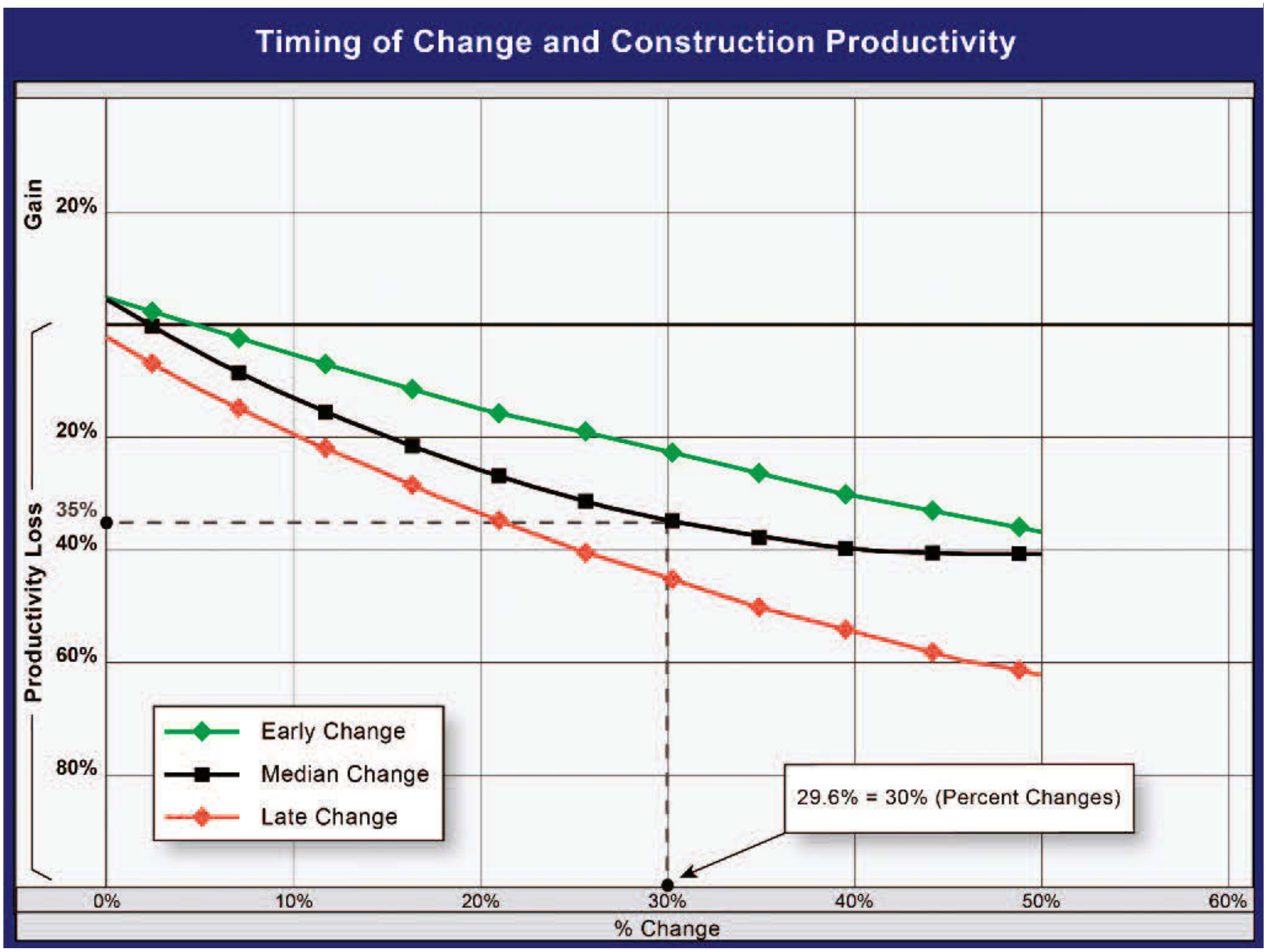
(actual or estimated) has been determined for each change. Thus, at the time approximately half of the change hours have been expended, the contractor has expended approximately half of its Actual Contract Labor Hours.

From the formulas provided above: Percent Change = Change Labor Hours ÷ Actual Contract Labor Hours. Percent Change = 4,000 ÷ 13,500 = 29.6% = 30%.

From the above example, it was determined that the project sustained a 30 percent change impact. From the "median" curve on Figure 10 on the next page it can be seen that 30 percent intersects the median curve at approximately 35 percent. A loss of 35 percent of the Actual Contract Labor Hours of 13,500 equals a loss of productivity of 4,725 field craft labor hours.

Example No. 3: A project was originally estimated to utilize 8,200 field craft labor hours (excluding non-working supervision). At the conclusion of the project, the payroll reports show an actual expenditure of 40,000 field craft labor hours, excluding

Figure 10

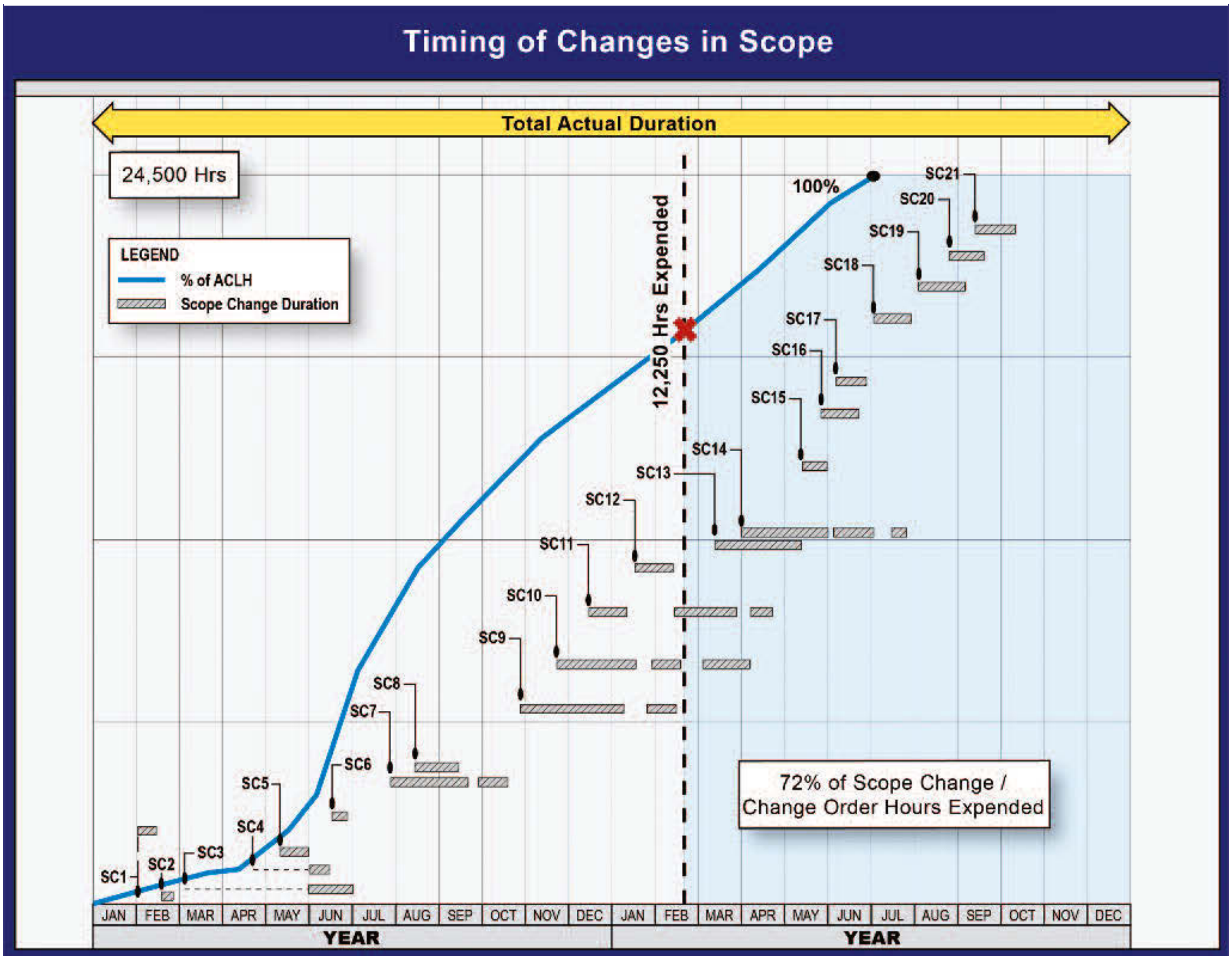


non-working supervision. Upon a careful investigation, it was confirmed that the bid was accurate and complete, errors in construction required 2,500 field craft labor hours to repair, and 1,000 hours were compensated T&M tickets. Moreover, the contractor estimated that 12,000 hours were expended on scope change work. Based on the formula described above, the **Actual Contract Labor Hours** would be computed as follows:

Total field craft labor hours actually expended on the project:	40,000
Field errors:	(2,500)
T&M ticket time:	(1,000)
Scope changes/change order labor hours:	(12,000)
Actual Contract Labor Hours	24,500

Once the Actual Contract Labor Hours are computed, the timing of the labor expenditure must be plotted using the payroll or labor performance reports. The date at which 50 percent of the Actual Contract Labor Hours were expended (12,250 hours of actual payroll-supported labor was expended of the

Figure 11



total of 24,500 hours) is considered the "midpoint" of the project for purposes of assigning the proper curve to the inefficiency analysis that follows.

The next step would be to identify from the actual records, or to perform an estimate if such records are not available, the actual start date of the scope changes. Also, the actual (or estimated) labor hours of each change must be determined. From this data applied to the timing chart, it can be determined if the change model is "early," "median," or "late."

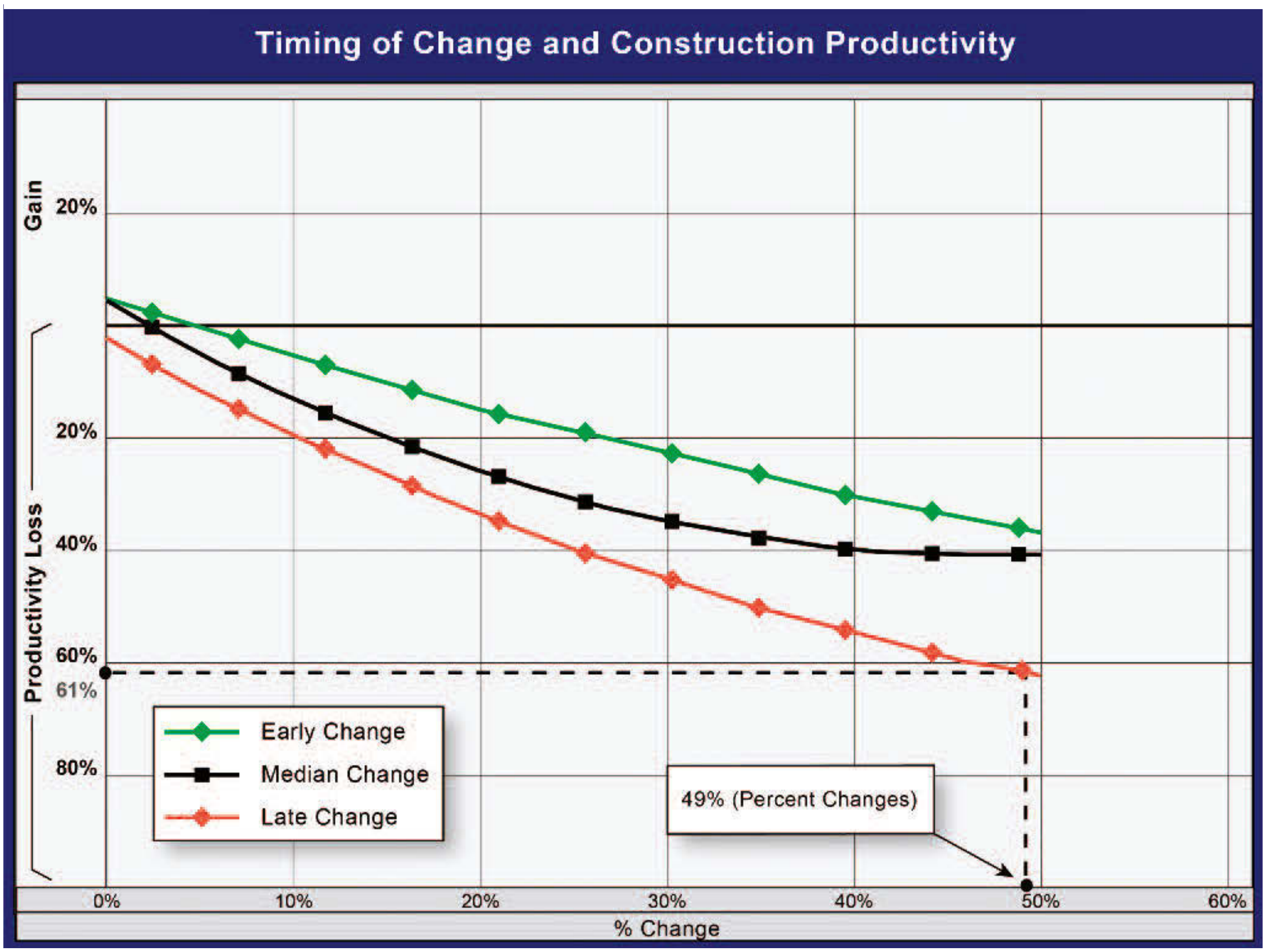
In this example from Figure 11, above, it was determined that only approximately 28 percent of the scope change hours were expended by the "midpoint," thus the third graph (late change) on the curve is chosen to calculate the impact to the labor productivity. Note in this example that the scope change timing has been taken from field records or has been estimated by the project staff. Further, the number of field craft labor hours has been determined (from charge records such as time sheets, contemporaneous field reports, or estimated) for each change. Thus, at the time approximately half of the Actual Contract Labor Hours had been expended, only 28 percent of the change hours had been expended. Therefore, in the last half of the project, 72 percent of the change hours were expended, making this example a late change project.

From the formulas provided above: Percent Change = Change Labor Hours ÷ Actual Contract Labor Hours. Percent Change = 12,000 ÷ 24,500 = 48.9% = 49%.[23]

From the above example, it was determined that the project sustained a 49 percent cumulative change impact. From the late change curve within Figure 12 it can be seen that 49 percent intersects the late change curve at a productivity loss of approximately 61 percent.

[23] Note that the data points do not support a Percent Change value greater than 50 percent. No extrapolation of the data lines should be performed to allow for Percent Change values in excess of 50 percent.

Figure 12



A loss of 61 percent of the Actual Contract Labor Hours of 24,500 equals a loss of productivity of 14,945 field craft labor hours.

Special Consideration for Projects with Substantial Bid Mistake Adjustments Not Identified Early in the Project Schedule

Today's computerized estimating and BIM coordination processes that are undertaken before a contractor mobilizes on a project make it more likely that bid mistakes will be discovered before the actual fabrication and construction phases of the project commence. In the past, usually the only way a contractor could verify an estimate was to have the project team perform a re-estimate of the project prior to mobilization. That process is still utilized by some contractors who are not fully adapted to the more advanced technologies.

When bid labor errors, even serious ones, are recognized at the outset of a project such that the labor hours that were omitted from the bid are able to be assimilated into the labor plan before work commences, or very early in the project, the labor productivity impacts should be mitigated to a greater extent. Certainly, the contractor will feel the direct financial impact of having to provide the labor hours that were missed in the estimate; however, such estimating errors would not be expected to diminish the contractor's overall field labor productivity.

However, if a serious labor estimating error were to occur that was not diagnosed early in the project and that required the expenditure of a material number of labor hours in the midst of the project, the contractor's productivity would be expected to suffer in the same fashion as if a change, or series of unanticipated changes, were introduced into the project during the same performance period. The contractor would usually not be able to recover such losses from a prime contractor or owner. In cases where this type of bid error has been identified, it is reasonable to treat this bid error in the same manner as a scope change or series of changes when preparing a cumulative impact analysis.[24]

Example 4 offers an illustration of how a contractor might address the impact of this type of bid mistake:

Example No. 4: At the conclusion of a project, the contractor's payroll reports show an actual expenditure of 34,500 field craft labor hours, excluding non-working supervision. This amount exceeded the contractor's labor plan by many thousands of hours. Upon a careful investigation, it was discovered that there was a bid error of 2,500 field craft labor hours. Moreover, the contractor estimated that 5,500 hours were expended on scope change work. Based on the formula described above, the Actual Contract Labor Hours would be computed as follows:

Total field craft labor hours actually expended on the project:	34,500
Bid error:	(2,500)
Scope changes/change order labor hours:	(5,500)
Actual Contract Labor Hours	26,500

As described in Examples 1 through 3, the next step is to identify from the actual

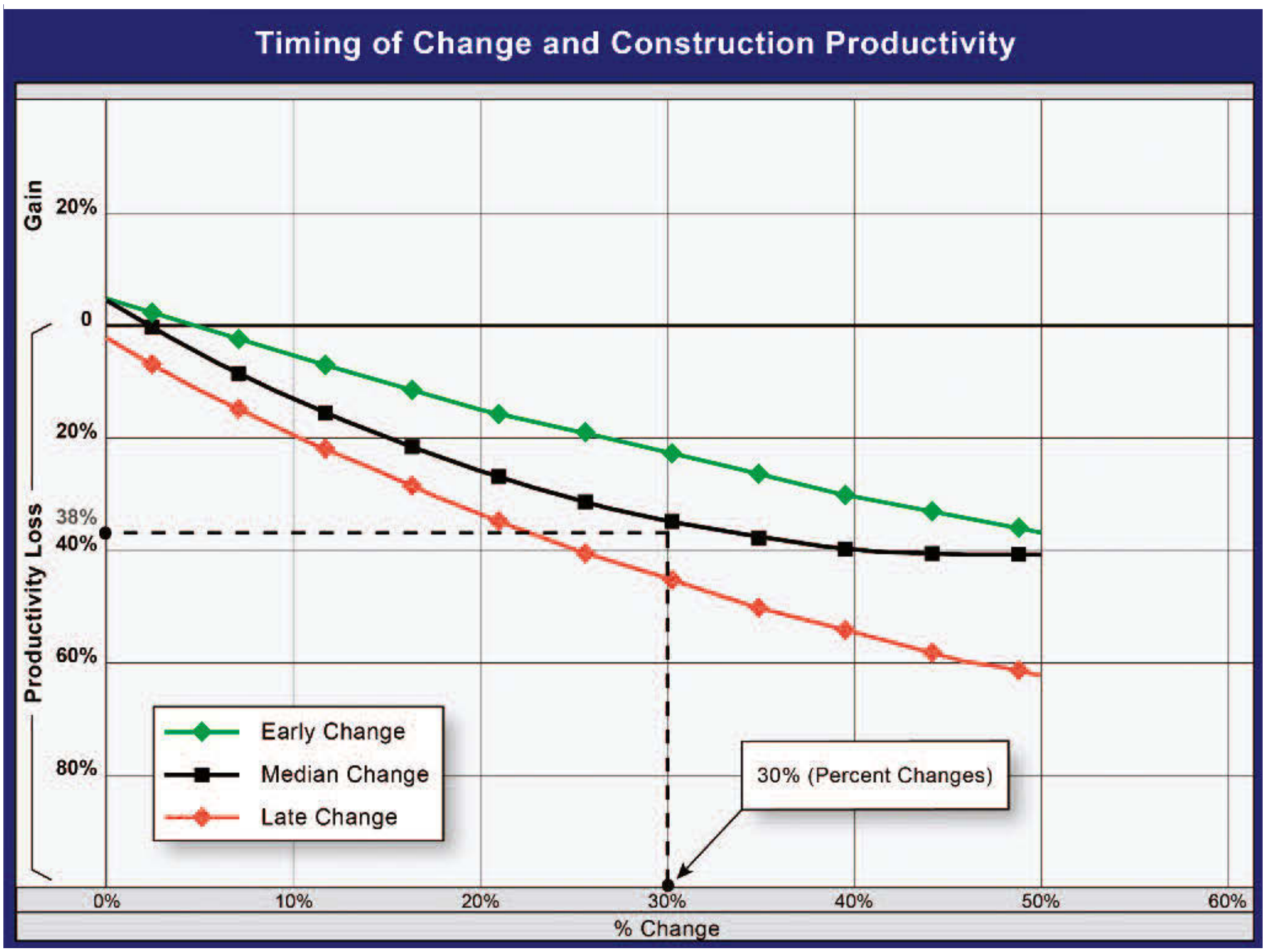
[24] The claimant would compute the loss of labor productivity arising from such types of bid error and demonstrate, in its request for equitable adjustment, that these labor hours were not being claimed in the total labor hours sought in the claimant's recovery.

records, or to perform an estimate if such records are not available, the dates during which the change work was performed. This special example also requires the contractor to know, or to estimate, the dates when the "missed" bid labor hours were added into the project schedule. In this case, the contractor's bid error labor hours are treated just as if those hours were the result of change.

In this example, it was determined that approximately 50 percent of the change hours and the "missed" labor hours were expended by the "midpoint," thus the "median" curve is chosen to calculate the impact to the labor productivity.

A revised formula can be applied in the case of a major bid labor hour estimate error that was not discovered until the labor to perform the "missed" work was actually required: Percent Change = (Change Labor Hours + Bid Error in Labor Hours) ÷ Actual Contract Labor Hours. Percent Change = 8,000 ÷ 26,500 = 30.2% = 30%. The Percent Change for this example is 30 percent. This percent represents the *total* loss of productiv-

Figure 13



ity caused by change and the contractor's bid error.

From the above example, it was determined that the project sustained a 30 percent change ratio. From the "median" curve on Figure 13 it can be seen that 30 percent intersects the "median" curve at a loss of productivity of approximately 38 percent. A productivity loss of 38 percent of the ACLH of 26,500 equals a loss of productivity of approximately 10,070 total field craft labor hours arising from the changes and the contractor's bid error.

The claimant must apportion the total loss of productivity of 10,070 field hours between the contractor and the respondent, as follows: bid error of 2,500 hours; 2,500 hours of contractor caused impact ÷ 8,000 hours of total change = 31% to the contractor's account. Similarly, 5,500 hours of scope change hours ÷ 8,000 hours of total change = 69% to the respondent's account. The allocation would therefore be: 10,070 hours of lost production x 31% = 3,122 hours to the contractor's account and 10,070 hours of lost production x 69% = 6,948 hours to the respondent's account. The contractor would seek a recovery of 6,948 hours of loss of labor productivity caused by cumulative impact but would not claim the 3,122 hours of productivity impacts caused by its own bid errors that had to be remedied in an unplanned fashion in the midst of the project. This approach can also be used to address particularly sizable contractor installation errors that require the contractor to introduce significant, unplanned labor hours into the project during the course of construction to re-install or repair the installation deficiencies.

Application of Cumulative Impact Analyses on Projects with Very Limited Project Records

Sometimes on a limited number of construction projects, events occur that severely reduce the factual data that analysts may rely upon to perform an assessment of productivity. This condition may rise from the failure to contemporaneously maintain anything but the most rudimentary payroll records, or, in other cases, the loss of project records due to changes in the management staff or computer systems. With the inability to question members of the management team[25] or to review change files or other contemporaneous data, the analyst is severely hampered in the use of the methods provided in this chapter. Suggested steps will be provided that may assist the analyst in the use of the methods included herein, however, as an alternative, the contractor should evaluate and consider the use of the MCAA's labor inefficiency factors contained in the "How to Use the MCAA Labor Factors" chapter herein to estimate the adverse effects of cumulative impact.

For the purposes of this subsection, the following assumptions have been made:

- The management team, including the project managers and field superintendents, are not available for interview or offer very limited probative value;
- The superintendents' diaries and daily reports are not available or are not useful;

[25] On some projects, the entire field office management team is either terminated or terminates employment, making the process of fact finding even more difficult.

- Change order files do not provide for temporal tracking of the change order work;
- Basic payroll information is available

Given this difficult situation, the following steps are recommended:

A first step would be to consider retaining a competent loss of productivity expert who can advise, in very preliminary terms, on the prospects of recovery given the limited data. Whether through an attorney or a consultant, the contractor can catalogue the available project information to develop the best strategy for a reasonable recovery.

As the contractor's team engages in the collection of all pertinent support for the preparation of the request for equitable adjustment, subcontractors and vendors may be polled for information to support the timing of change. The owner, designer and, if one was utilized, construction manager may have key information (which probably will have to obtained through the discovery process) by which the timing and scope of changes can be ascertained. Other sources may be useful such as building inspection and permitting authorities, progress photographs maintained by the owner or architect, and even mapping services.

It is assumed for the purposes of the extreme condition of a dearth of contemporaneous records, that the change orders or change directive documents are available for review. A reasonable estimate of the labor hours involved in each of these changes can be derived from the pricing information by identifying or estimating the labor proportion of the change order and dividing that labor cost by an average hourly labor rate. If the description of the change work does not identify when the change work was performed, the signature dates may be used to estimate its timing. With this information, the change work can generally be determined to be of the early, average, or late variety.

This estimate of the change hours can then be compared to the number of labor hours in the bid. (Adjustments need to be made for any bid errors as discussed earlier in this chapter.) Dividing the change hours by the bid hours yields a very gross percent change value. For illustrative purposes and using the preceding formula, let us assume that this project's percent change is 10 percent. Depending on whether the project experienced early, median, or late change, the loss of productivity would be between 4 percent and 10 percent, which is useful information, as seen in Figures 4-A, 4-B, and 4-C.

Those same figures also yield another piece of useful information. Inspection of those figures reveals that all the projects in this database which had 10 percent change experienced a loss of productivity. This is demonstrated by noting that none of the data points in those three figures were associated with a productivity index above 1.0. This means that not only did the contractor have a productivity loss in the 4 percent to 10 percent range; it also means that there is a high probability that such a loss was incurred.

The discussion above has been focused on a project with virtually no extant records beyond basic payroll information. This discussion accentuates the need for the contractor to maintain contemporaneous change records that may include the initiating RFI, change proposals, photographs, related correspondence, diaries or notations citing when change work as performed and all associated contract modification documents. Generally, the more robust the recordkeeping, the more compelling will be the resulting request for equitable adjustment.

Summary and Conclusions

Virtually all projects, even the most comprehensively planned and designed and carefully scoped, have change. Change can adversely affect labor productivity, which in turn can substantially reduce or even eradicate a contractor's profit. Contractors deserve to be timely and fairly compensated for change. While many owners are willing to pay the direct costs of project change, often there is a resistance and reluctance to pay for the impact costs of change. This resistance and reluctance can arise from the contractor's lack of documentation and the lack of proper citation to industry-accepted means of impact quantification. This chapter has addressed this latter issue through the publication of a reliable method to estimate labor inefficiencies arising from cumulative impact.

Contract change often results in disputes over the quantitative impacts of the change, particularly the impacts on labor productivity. As previously stated, those impacts are discussed in this chapter and an approach to quantifying these impacts is presented. This approach, developed by one of the co-authors of this chapter, has been used to resolve numerous disputes and has been accepted in mediations, arbitrations and in trial courts.[26] That research clearly indicates there are strong correlations between the amount of change and the loss of productivity. The cited research indicates that the timing of change is a key factor as well. The concepts of cumulative impact and the timing influence of change have been accepted in international arbitrations as realities in the construction industry. The Ibbs Study also had been published in peer-reviewed scientific journals.[27]

Also, contractors should be aware that cumulative impacts may result in critical path schedule impacts. Labor inefficiency can cause growth in activity durations that may erode total float or impact the critical path. This chapter does not deal with project delay. Your attention is directed to the chapters entitled "Time Impact Analysis—Measuring Project Delay" and "How to Organize and Submit a Claim," which address potential project delay caused by productivity impacts.

As with all industry study applications, the results should provide for a *reasonable estimate of the damage*—not a precise computation. The contractor making a claim for cumulative impact should perform an investigation of the facts, provide a narrative explaining how the magnitude of change adversely affected the labor productivity[28] and should apply the Ibbs data and resulting curves in a proper

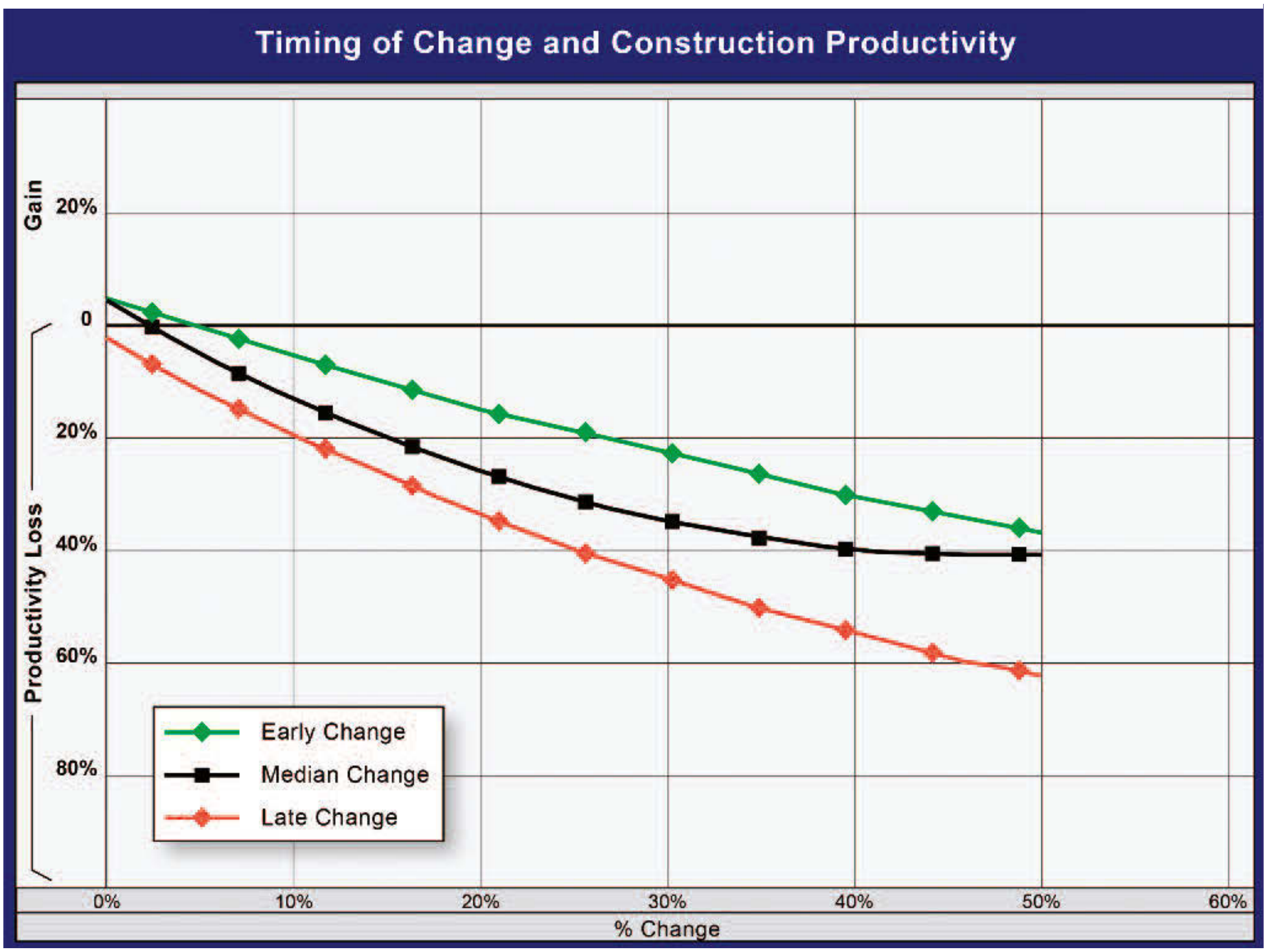
---

[26] As of the date of this publication, there have been no published decisions citing the study that is the subject of this chapter.

[27] "Evaluating the Cumulative Impact of Changes on Labor Productivity – an Evolving Discussion," Dr. W. Ibbs and G. McEniry, *Cost Engineering*, Vol. 50/No. 12, December 2008, Association for the Advancement of Cost Engineering International; and Ibbs, William (2005). "Quantitative Impacts of Project Change: Timing Issues," *Journal of Construction Engineering and Management*, ASCE, 131(11), November, 1219-1223.

[28] Construction productivity cases often mention the need to establish the "cause-and-effect nexus," however the nature of cumulative impact renders it virtually impossible to tie individual changes to specific effects in terms of labor productivity impacts. However, that does not relieve the contractor from evaluating its estimating, labor performance and documentary records to demonstrate that the impacts were not self-inflicted and to offer a narrative that describes the contractor's plan and how that plan was disrupted by the influences of multiple changes on the project.

Figure 14: Sample Inefficiency Chart for Readers' Use[29]



manner. The finding in *S. Leo Harmonay, Inc.* (cited at page 123 herein) represents sound reasoning in this regard:

> ... courts have often recognized that the extent of harm suffered as a result of delay, such as the loss of efficiency claim at issue, may be difficult to prove. Thus, courts have recognized that a plaintiff may recover even where it is apparent that the quantum of damage is unavoidably uncertain, beset by complexity, or difficult to ascertain, if the damage is caused by the wrong.

Every project and every dispute should be evaluated with the facts of the situation in mind. Applying the approach presented herein without careful regard to the actual circumstances that took place on the project could lead to errors in the quantification of the impacts that a project has incurred. However, if the contractor making claim for

[29] This chart is provided for the contractor's use in plotting Percent Change and the resulting Percent Productivity. If desired, this chart may be copied and inserted into the contractor's request for equitable adjustment to demonstrate the plotting of the data.

cumulative impact prepares a comprehensive narrative report that describes the contractor's reasonable plan for the work, how that plan was disrupted and impacted by unanticipated change, and how the contractor estimated its loss of labor productivity by properly applying the methodology provided in this chapter, the contractor may improve its opportunity to amicably and equitably resolve its productivity loss claim.

The contractor should consider including in the submission of its cumulative impact change request the following items:

Review of all pertinent documents, such as the contract, executed change order forms, and monthly payment applications, by the contractor's executive management and/or construction counsel to ascertain waiver risks, if any, for recovering cumulative impact;

Modified total cost calculation showing the unallocated loss of labor productivity;

Narrative of the contractor's reasonable plan to construct the project within the labor hours contained in its original, or revised, labor estimate and a contrasting description of what events took place to change that reasonable plan—including comparative crew curve graphics, as-planned and as-built schedule analyses, photographs of impacting conditions, pertinent daily reports and correspondence, and other contemporaneous and relevant proofs of the impacting conditions;

Description of all adjustments that have been made in the computation of the contractor's loss of labor productivity including: estimate errors, contractor's field rework, and total change hours;

Change timing chart showing the actual or estimated start and finish dates of the changes to the original contract scope of work;

Application of the cumulative impact methodologies provided in this chapter utilizing the appropriate curves and calculations;

Proof of damages as recorded in job cost reports or other accounting documentation and a summary of damages that are sought as the contractor's recovery in its request for equitable adjustment or claim document.

By properly applying the methodologies described herein and by preparing a comprehensive narrative of the cause-and-effect nexus, a mechanical contractor may enhance its opportunities to recover cumulative impact damages.

Prepared by Professor William Ibbs, PhD, University of California, Berkeley and Paul L. Stynchcomb, CCM, PSP, CFCC of Vero Construction Consultants Corp. with peer review performed by: Michael R. Cables, Executive Vice President of Kinetics Systems, Inc.; Norman Escover, COO of Kinetics; Richard Freeman, Vice President of Stromberg Metal Works; Charles F. Mitchell, General Counsel of The Kirlin Group; and the members of MCAA's Education Committee.

How to Estimate the Impacts of Overtime on Labor Productivity

Introduction

The cost impact of unplanned extended overtime work[1] may exceed the increased costs of the premium pay associated with an overtime work schedule. This impact comes in the form of reduced worker productivity as compared with the productivity of work performed on a straight-time basis. A mechanical contractor confronting significant periods of unplanned extended overtime work must consider the reduced productivity associated with working an overtime schedule.

A number of published studies attempt to quantify the decrease in labor productivity associated with working extended overtime in the construction industry. This chapter will discuss the most frequently cited studies that have been used to quantify overtime labor inefficiency in the construction industry. The chapter also will set forth some general guidelines for a mechanical contractor's consideration in assessing the labor inefficiency impact of unplanned extended overtime. The principles set forth in this chapter can provide meaningful guidance in estimating the loss of labor productivity arising from overtime in the forward pricing of change orders as well as in a retrospective application.

Previous MCAA publications on overtime inefficiency included histograms that depicted loss of labor productivity data based on various overtime schedules. The histograms published in MCAA's Bulletin Nos. 18-A and 20 were based on the 1947 U.S. Department of Labor Bulletin No. 917, a study of prolonged overtime worked in the manufacturing sector. As several courts and commentators have recognized, the 1947 Bulletin No. 917 has limited application in the construction industry.[2] As a result, MCAA Bulletin Nos. 18-A and 20 have now been superseded by this version. This current publication is based on more recent stud-

[1] We are unaware of any data showing the difference in impact, if any, between "planned" and "unplanned" overtime. Generally, planned overtime has been included in the base contract estimate and was accounted for in the baseline CPM schedule. Unplanned overtime, which is the subject of this chapter, occurs when no overtime, or only very limited overtime for equipment setting or start-up tasks, was contemplated under the terms of the base contract and is implemented during the course of construction.

[2] See, e.g. *Appeal of J.A. Jones Constr. Co.*, 00-2 BCA ¶ 31000, ENGBCA Nos. 6386, 6387, 6390; 2000 WL 1044011 (Eng. BCA 2000) ("The study itself states that it was based upon prolonged overtime schedules in manufacturing plants and that it may not be applicable to construction projects.")

ies that provide a basis of estimating labor inefficiencies utilizing data provided by construction contractors or from quantitative data actually measured on construction projects.

Background

Often mechanical contractors are directed by an owner or general contractor to accelerate the work for a variety of reasons. Acceleration can be achieved by adding crews, adding shifts, and/or working longer hours over and above 40 hours a week for the primary crew. This latter form of acceleration is known as “overtime,” and the direct costs of this process (i.e., the overtime payroll premium costs) are reasonably easy to compute. However, the indirect effects of working an overtime schedule can be more difficult to quantify. The primary indirect effect of working an overtime schedule is the loss of labor productivity by the workers performing the overtime work. The added cost in terms of the loss of labor productivity may, as noted above, exceed the direct payroll costs of supporting an overtime work schedule. The subject of this chapter is the added inefficiency costs of working overtime. While the MCAA has not prepared an empirical study within this chapter, the better-known overtime inefficiency studies have been revisited herein and compared, thus allowing the contractor to consider several sources of data in one set of tables.

Overtime inefficiency is the most generally accepted category of labor inefficiency within the construction industry. That is true because virtually everyone who has worked extended hours—executives, managers, technical and support personal, as well as the field labor forces—have personally felt the reduced productivity effects of overtime schedules. These effects can include fatigue, increased absenteeism, increased incidence of accidents, reduced morale, and a more negative work attitude.

While many prime contractors and owners may be willing to pay the mechanical contractor’s direct cost of overtime if the acceleration was not caused by the mechanical contractor’s delay, the mechanical contractor is much more likely to be denied its inefficiency costs for the overtime schedule. It is essential for the mechanical contractor to establish a range of inefficiencies that may arise as a result of embarking on an overtime work schedule such that payment for the direct costs as well as the inefficiency costs can be reimbursed. This chapter seeks to provide the mechanical contractor with estimated inefficiency rates for various overtime schedules seen most frequently on construction projects. The percent inefficiency values offered herein are reasonable estimates of the inefficiency impacts that can be sustained by mechanical crews working various overtime schedules. The inefficiency percentages are to be applied to *all hours* worked by a crew performing on an overtime schedule and not just the overtime hours.[3]

The construction industry generally uses three terms to describe different overtime scenarios: shutdown or turnaround projects, spot overtime, and extended overtime. Shutdown or turnaround projects are those in which a system or plant is completely shut down for the project duration, and due to the production value of the system or plant,

[3] The well-accepted axiom is that the inefficiency effects of overtime affect the worker while he or she works the straight-time schedule as well as the overtime schedule.

the construction schedule is highly compressed (often working 24/7 with multiple shifts) in order to minimize the duration of the shutdown. These working conditions are clearly understood during the bid/proposal process, and the contractor should include the associated inefficiencies in the mechanical contractor's bid or proposal.[4]

Spot overtime is short in duration (from as little as one day to a week) and is generally not planned in advance—it is usually caused by a delay or other unanticipated event that requires the mechanical contractor to make up quantities or finish work that was not completed during the preceding week.[5] Spot overtime is also normally worked by only a few crews at a time—those responsible for the specific work scope in question. The impact of working periodic and infrequent spot overtime is normally considered negligible in terms of inefficiency effects. As a result, spot overtime is not normally calculated in industry studies that attempt to quantify the lost labor productivity due to unplanned extended overtime.

Unplanned extended overtime is a condition wherein the entire project, or a significant portion of the project (e.g., all mechanical crews), work an overtime schedule for an extended period of time, sometimes without a planned return to a normal 40-hour week. 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. Thus, when utilizing any of the data provided herein, it is important to know the work schedule of the crews working overtime. If using a study that shows a progressively increasing loss of productivity over time, should a crew cease overtime and return to a straight time schedule, the crew's inefficiency upon resuming overtime work must be reset to normal production for the first measured period. Mechanical contractors should ensure that their bid or negotiated proposals clearly state that the base price for the work does not include any overtime, if in fact, no overtime was estimated. If overtime was estimated and its scope exceeds infrequent and limited spot overtime, an inefficiency factor should be included in the price for the work using a prospective estimate of inefficiency described in this chapter.

As previously noted, this chapter does not offer an empirical study based on new overtime loss of productivity data. Rather, this chapter reviews, analyzes, and summarizes four existing studies that have gained recognition in the construction marketplace and have been utilized to prove claims for overtime inefficiency. These studies are:

1) The November 1980 Business Roundtable publication entitled *Schedule Overtime Effects on Construction Projects* (hereinafter referred to as "BRT");

[4] Similarly, on a non-overtime-based project estimate, the mechanical contractor should qualify in its bidding documents if the bid excludes overtime work.

[5] The delay or event causing the mechanical contractor to engage in spot overtime may not arise from the fault or negligence of the mechanical contractor. For instance, the mechanical crews may be required to work spot overtime installing sleeves in slab pours because the concrete contractor was delayed and was required to accelerate, thus requiring the sleeving crew to work alongside on an overtime basis.

2) The 1989 study published by the National Electrical Contractors Association (NECA) entitled *Overtime and Productivity in Electrical Construction* (hereinafter referred to as "NECA");

3) The 1997 study published by Dr. H. Randolph Thomas of Penn State University, et al, entitled *Schedule Overtime and Labor Productivity: Quantitative Analysis*, published in the June 1997 *Journal of Engineering and Construction Management*, which was based on data included in a 1994 Report to the Construction Industry Institute entitled *Effects of Scheduled Overtime on Labor Productivity: A Quantitative Analysis* (hereinafter referred to as "Thomas"); and

4) The July 1979 United States Army Corps of Engineers publication *Modification Impact Analysis Guide*, Publication No. EP 415-1-3 (hereinafter referred to as "the Corps").

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.[6] Each has its strengths and weaknesses, including criticisms ranging from the use of limited data sources to the withdrawal of reports from publication.[7] 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.

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. These studies and the resulting curves are not offered as precise or exact forecasts of impacts. Rather, they are reasonable guidelines to be used to estimate a loss of labor productivity caused by overtime. The courts and boards of contract appeals have clearly set forth the principle that a contractor does not have to prove its loss of labor productivity with mathematical precision, but can offer a reasonable estimate of its damages.[8] These studies offer just that—a source from which to prepare a reasonable estimate of inefficiency damages arising from unplanned extended overtime.

[6] See, e.g., *Ace Constructors v. United States*, 70 Fed.Cl. 253, 281-283 (Cl.Ct. 2006), aff'd, 499 F.3d 1357 (Fed.Cir. 2007)(contractor entitled to recover lost productivity due to overtime based on BRT); *Appeal of Harbison & Mahony*, 68-1 BCA ¶ 6880, ENGBCA Nos. 2819, 2820, 1968 WL 436 (Eng. BCA 1968)(allowing claim for overtime inefficiency based on NECA); *Appeal of States Roofing Co*, 10-1 BCA ¶ 34356, ASBCA No. 54860, 2010 WL 292732 (ASBCA 2010)(Thomas study recognized); *Appeal of Sante Fe Engineers, Inc.*, 86-3 BCA P 19092, ASBCA No. 29362, ASBCA No. 28058, 1986 WL 20062 (ASBCA 1986), *aff'd*, 818 F.2d 856 (Fed.Cir. 1986)(allowing inefficiency claim using the Corps study).

[7] See, e.g., *Hensel Phelps Const. Co. v. General Services Admin*, 01 BCA ¶ 31249, GSBCA No. 14744, GSBCA No. 14877, 2001 WL 43961 (General Services BCA 2001)("the Modification Impact Evaluation Guide of the Corps of Engineers is not recognized by GSA and, indeed, no longer used by the Corps.") While the Corps has removed its *Modification Impact Evaluation Guide* EP 415-1-3 from publication, it has not repudiated any of the data contained in that publication.

[8] See, e.g., B.Bramble, et al, *Construction Delay Claims*, §5.07, p. 5-53(3d ed. 2000) ("Where the damages are directly attributable to the breach, they are often recoverable even though they are uncertain in amount. 'Thus, courts have recognized that a plaintiff may recover even where it is apparent that the quantum of damage is unavoidably uncertain…or difficult to ascertain.' The courts have recognized that ascertainment of damages, especially lost productivity, is not an exact science. When the responsibility for damages is proven, it is not essential that the amount of damages be 'ascertainable with absolute exactness or mathematical precision.'" (and cases cited therein).

In some cases a measured mile analysis can be performed that will compute, by use of the contractor's project payroll and field records of installed material, a comprehensive loss of labor productivity comparing actual impacted and non-impacted production on the jobsite. When a measured mile analysis can be performed, such an analysis usually subsumes all types of inefficiency categories on a project. Therefore, if a measured mile labor productivity study is utilized, there is no need for a separate inefficiency analysis for overtime loss of productivity using industry studies.

Discussion of the Four Studies

Business Round Table (BRT)

The BRT is a study of a Proctor & Gamble construction project that experienced overtime during the course of the work. The BRT has been frequently cited as a reasonable guideline to predict loss of labor productivity. While the BRT is sometimes criticized because it is based on only one project, its critics have not undermined its underlying data. A positive facet of this study is that its data were based upon payroll records of the workers compared to actual units of material installed on the project by those workers. This study provided overtime loss of productivity data over a 12-week period at various overtime intensity levels and demonstrated that, in general, inefficiency increases as the overtime schedule extends in duration.

National Electrical Contractors Association (NECA)

NECA provides the user with various overtime models measured over a 16-week period. The underlying data for NECA was gathered by surveying electrical contractors who were members of the association.[9] The survey data was compiled and presented as tables and graphs showing expected overtime productivity losses as "Low," "Average," and "High" for each one-week period. These categories allow the user to factor the weekly inefficiency by gradients defining more precise levels of impacts. For instance, if the contractor had been given substantial notice of the implementation of overtime to allow some pre-planning to lessen the effects of the overtime, the contractor could select a "Low" or "Average" impact. Alternatively, if the overtime schedule imposed upon the contractor created havoc on the project site, or if there was stiff competition for overtime on nearby projects, the contractor could select a "High" impact category. Like BRT, NECA demonstrates decreasing labor productivity as the overtime schedule extends in duration.

Dr. H. Randolph Thomas, P.E. (Thomas)[10]

Thomas compared various overtime inefficiency data with those independently derived from studies prepared under his supervision. Interestingly, Thomas opined that: "…it is concluded that the BRT curve is a reasonable esti-

[9] It is a generally accepted axiom in the construction industry that inefficiency impacts sustained by the mechanical trades are similar in nature to the inefficiency impacts sustained by the electrical trades given reasonably comparative adverse conditions.

[10] Dr. H. Randolph Thomas, P.E. is a professor of civil engineering at Penn State University, author or co-author of a series of well recognized published papers on labor inefficiency, and frequent expert witness on the subjects of labor productivity and construction management.

mate of the minimum loss of productivity. For projects experiencing worsening degrees of distress and disruption, the loss of productivity will probably be greater."[11] Thomas tracked labor inefficiency caused by overtime in the mechanical and electrical trades. In order to attempt to accurately isolate the effects of overtime on labor productivity, Thomas removed projects where overtime occurred at the outset of the work, projects that suffered from adverse labor action, and projects on which there were an "inordinate" number of changes in scope or other conditions that would exacerbate the inefficiencies arising strictly from overtime.

Thomas' comparative curve utilized in the aforementioned study was based on data collected on the project site by site personnel.

The U.S. Army Corps of Engineers ("the Corps")

The United States Army Corps of Engineers ("the Corps") study included an overtime loss of productivity graph showing predicted losses of labor productivity for various work schedules over a four-week period. Similar to the other reports cited herein, the Corps showed declining productivity as the overtime schedule was extended. The Corps' overtime inefficiency graph was widely used to calculate impact and inefficiency claims until the Corps formally withdrew this publication several years ago for unspecified reasons. It is noteworthy that *Publication EP 415-1-3*, which contained the Corps' overtime study, has never been repudiated by the Army Corps of Engineers, but was withdrawn without any criticism of the underlying data used in the overtime inefficiency graph. Thus, the Corps study and curve are included herein to compare its findings with those of other overtime charts.

Presentation of Data

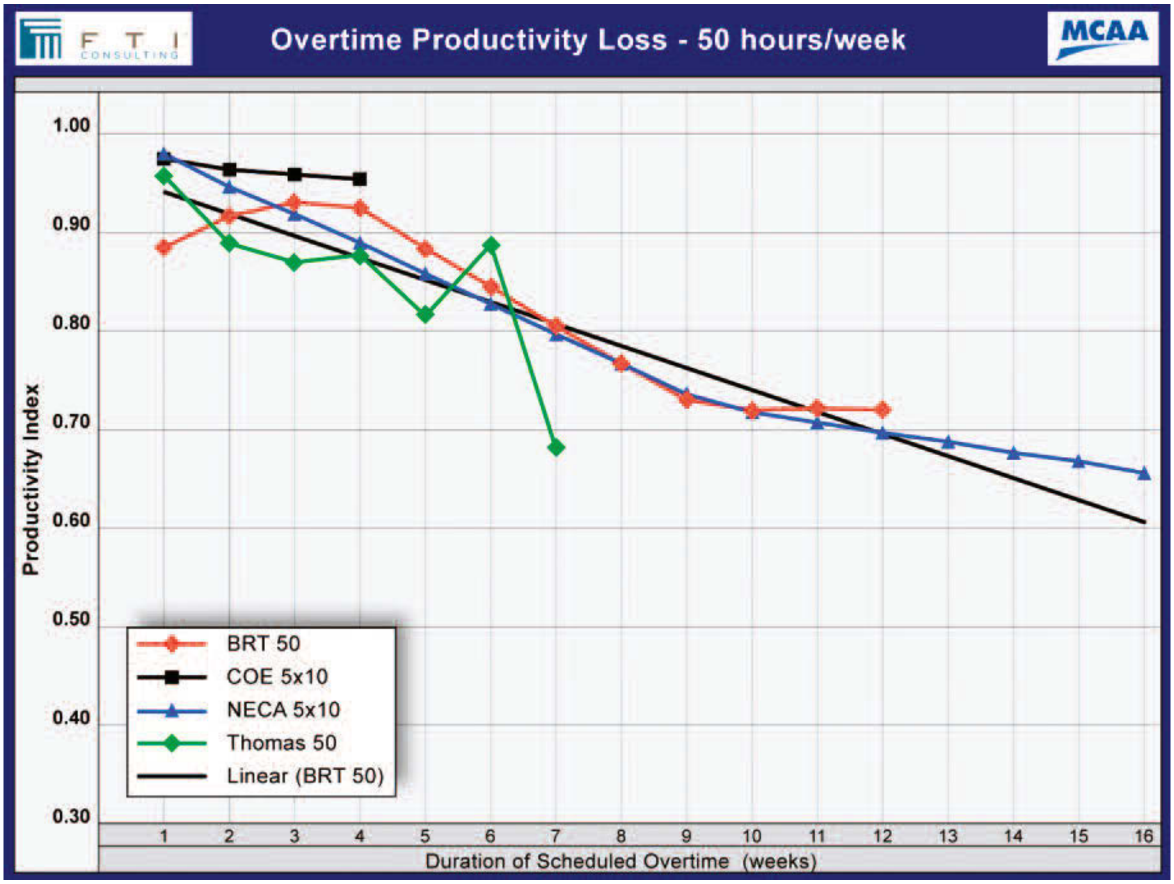
The following charts present the loss of productivity as determined by the four referenced studies. The loss of productivity is presented in terms of a Productivity Index, or PI, such that

$$PI = \frac{\text{Planned Activity}}{\text{Actual Activity}}$$

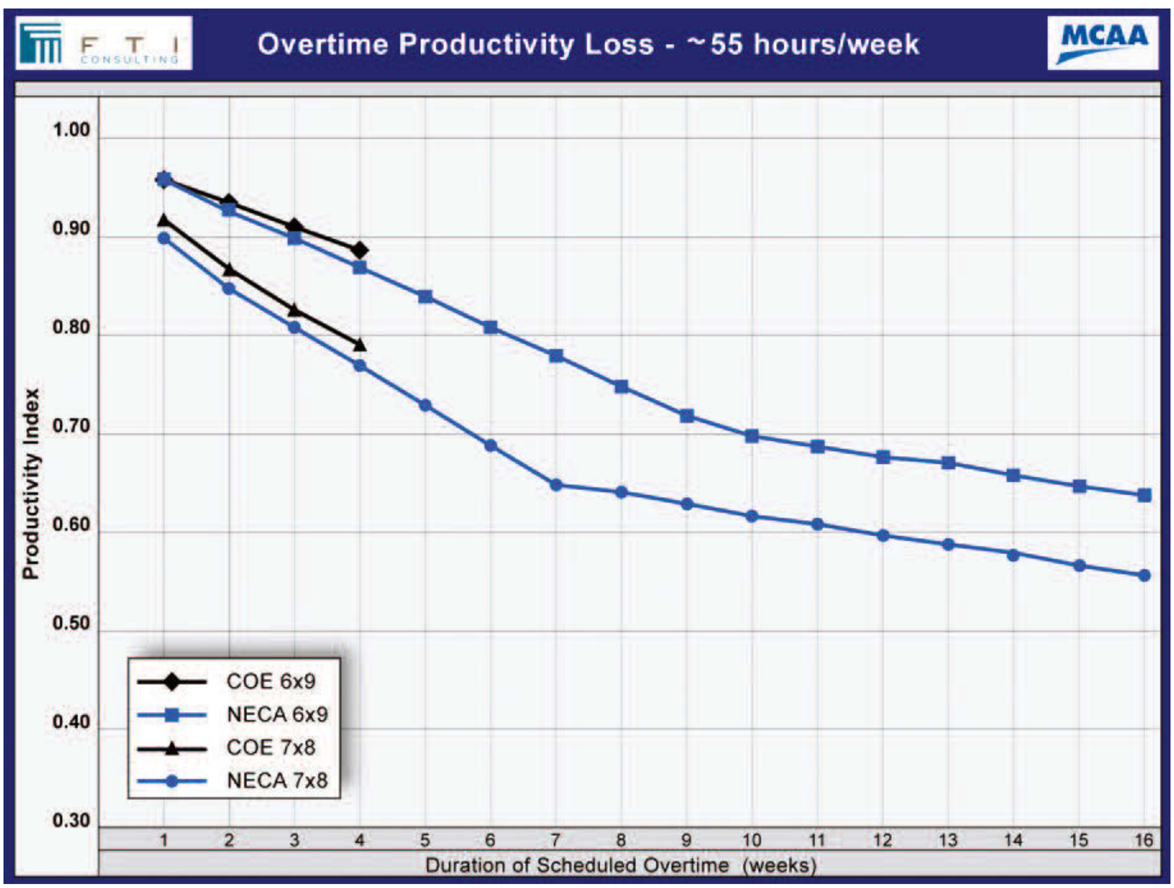
where Productivity is in terms of work hours expended per unit of work installed. In this case, a PI of 1.0 indicates that the actual productivity was equal to the planned productivity; a PI > 1.0 indicates that the actual productivity exceeded (was better than) the planned productivity; and a PI < 1.0 indicates that the actual productivity was less than (worse than) the planned productivity.

In all cases, the PI during a normal 40-hour work week is assumed to be 1.0. The PI during a given overtime schedule is then indicated on the chart over a number of weeks of consecutive overtime. If a chart indicates a PI of 0.90 for a given week, that shows a 10% loss of productivity for that week (1.00 – 0.90 = 0.10, and 0.10 ÷ 1.00 = 10%).

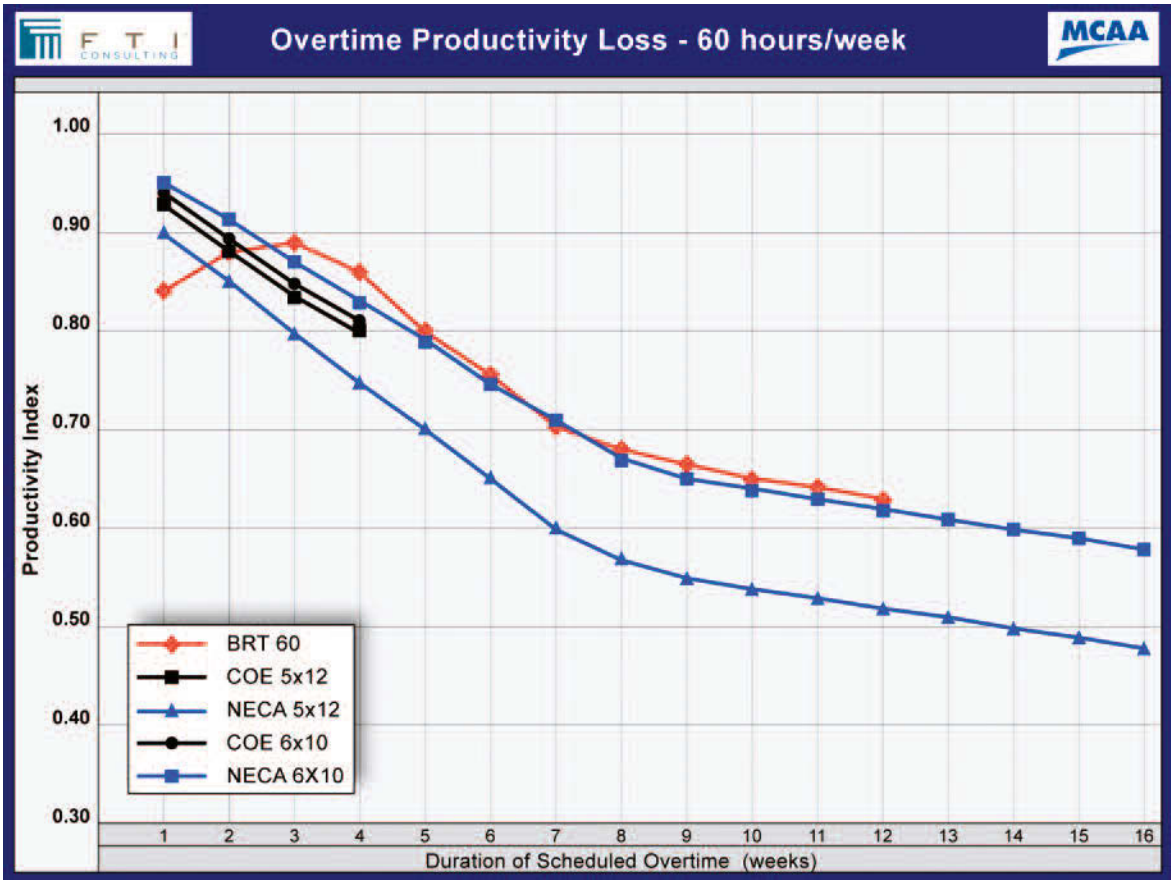
[11] Thomas, et al, "Scheduled Overtime and Labor Productivity: Quantitative Analysis" *Journal of Construction Engineering and Management*, June 1997.



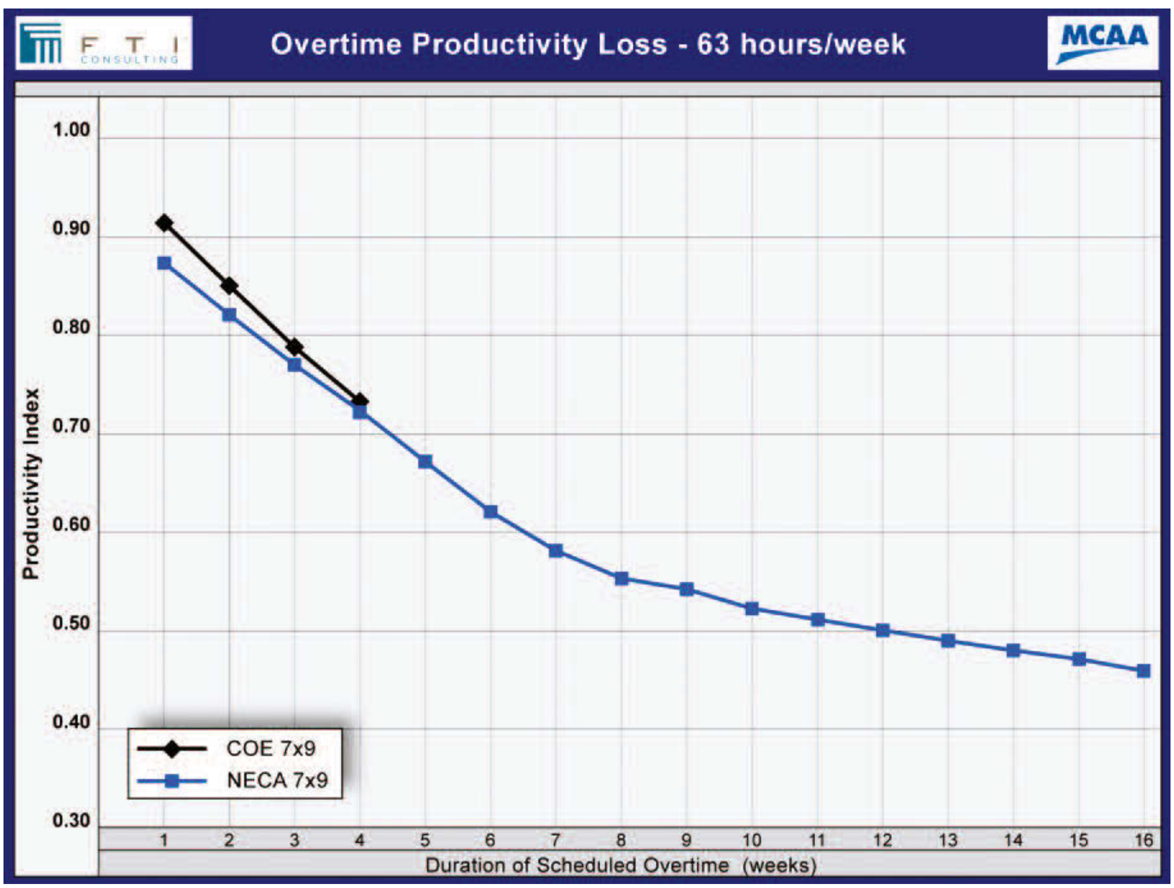
FTI CONSULTING
Overtime Productivity Loss - 50 hours/week
MCAA
Productivity Index
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
BRT 50
COE 5x10
NECA 5x10
Thomas 50
Linear (BRT 50)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Duration of Scheduled Overtime (weeks)



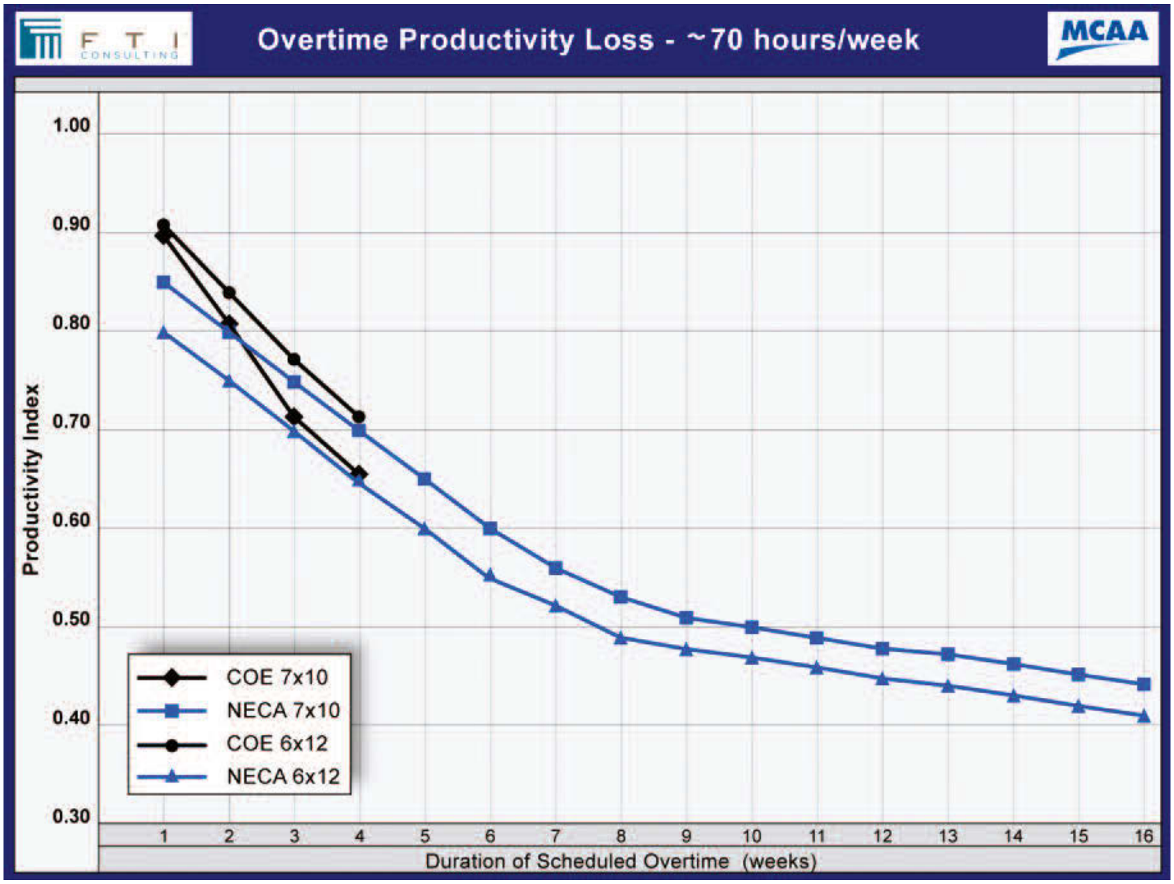
FTI CONSULTING
Overtime Productivity Loss - ~55 hours/week
MCAA
Productivity Index
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
COE 6x9
NECA 6x9
COE 7x8
NECA 7x8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Duration of Scheduled Overtime (weeks)

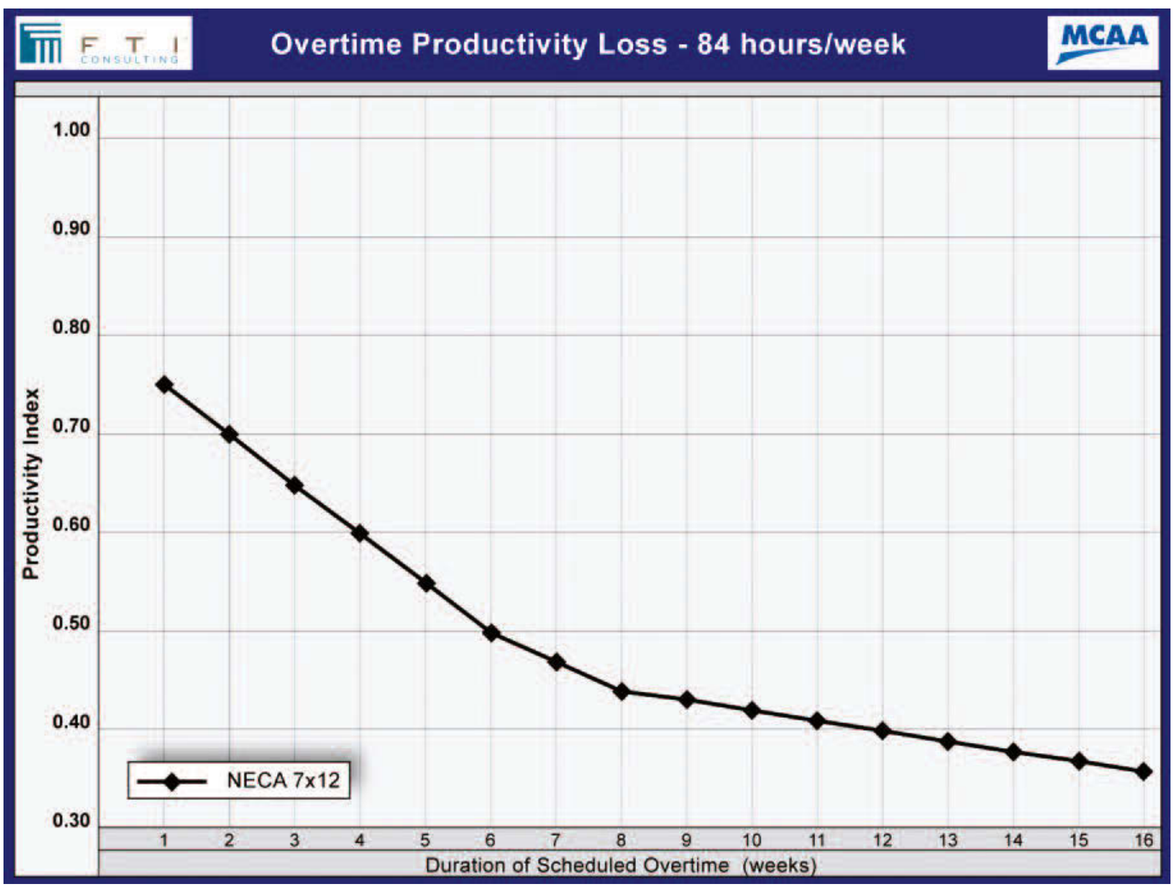


F T I CONSULTING
Overtime Productivity Loss - 60 hours/week
MCAA
Productivity Index
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
BRT 60
COE 5x12
NECA 5x12
COE 6x10
NECA 6X10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Duration of Scheduled Overtime (weeks)



F T I CONSULTING
Overtime Productivity Loss - 63 hours/week
MCAA
Productivity Index
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
COE 7x9
NECA 7x9
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Duration of Scheduled Overtime (weeks)


F T I CONSULTING
Overtime Productivity Loss - ~70 hours/week
MCAA
Productivity Index
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
COE 7x10
NECA 7x10
COE 6x12
NECA 6x12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Duration of Scheduled Overtime (weeks)


F T I CONSULTING
Overtime Productivity Loss - 84 hours/week
MCAA
Productivity Index
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
NECA 7x12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Duration of Scheduled Overtime (weeks)

Overtime

Application

As noted above, the curves were generally within the same relative order of magnitude. Using the average of the four studies, the table of PI at the bottom of this page was developed.

The Prospective Application

When the period(s) of extended overtime have been determined, the mechanical contractor can find the chart for the applicable work schedule and determine a reasonable range of productivity loss by reading the PI for the given week of consecutive extended overtime and subtracting it from the "normal" value of 1.0. For instance, a PI of 0.60 equates to a inefficiency estimate of 40% (1.00 – 0.60 = .40 x 100% = 40%). In a *prospective*, or forward-priced analysis, the resulting percentage of productivity loss is multiplied against the estimated number of hours to be worked during that week to identify the estimated impact of working extended overtime. In a *retrospective* analysis (i.e., an analysis prepared after the fact using actual labor hours), the formula for computing a conservative inefficiency estimate is discussed in a following subsection.

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 result-

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

ing 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.

When inefficiency factors are applied to estimated hours in a forward priced or prospective analysis, the user multiplies the factor percentage against the estimated hours for the overtime and for the straight time worked by the overtime crews. For instance, if a contractor expects to work a 50-hour work week with 25 mechanics for five weeks, the computation appears in the forward pricing table below.

Based on a forward priced, or prospective, estimate of overtime inefficiency, the contractor would request compensation for 552 labor hours of lost labor productivity.

The Retrospective Application

Retrospective analyses are performed after the overtime hours have been spent. For a retrospective example, let us assume that a contractor was directed to put its mechanical crews on overtime during construction of a processing plant. The contractor's planned working hours were a 40-hour week, and in an effort to maintain schedule the contractor placed the mechanical crews on a five-day 10-hour shift over an 11-week period. In calculating the retrospective (performed after the fact) loss due to unplanned extended overtime, the contractor should apply the formula and procedures described below.

Most inefficiency tables, such as the MCAA's labor inefficiency factors, were prepared with the anticipation that these factors would be applied to forward-priced change order requests.[12] Thus, the percent inefficiency factor would be utilized as a multiplier against the estimated hours to provide the forecast loss of productivity. However, when using tables and factors in a retrospective manner (i.e., applying these factor percentages to actual payroll hours), an adjustment must be

[12] As a conservative approach, it has been assumed that the NECA overtime tables, as well as other published tables designed for use as forward-pricing guides, require the use of the retrospective formula when applying such factors to actual labor hours.

FORWARD PRICING TABLE

Week Ending	Act Hrs Worked	# Mechanics working over 40 hrs	Total Hours Subject to Loss Productivity	Loss (pct) from 5/10 Table	Inefficient Hours
6-Feb-10	50	25	1,250	5%	63
13-Feb-10	50	25	1,250	7%	88
20-Feb-10	50	25	1,250	8%	100
27-Feb-10	50	25	1,250	9%	113
6-Mar-10	50	25	1,250	15%	188
TOTAL					552

made in order to eliminate overstating the inefficient hours. The use of the retrospective formula adjusts for the fact that the inefficient hours are already embedded within the actual labor hours used in the retrospective computation. Multiplying the inefficiency factor against the actual hours that also include the inefficient hours results in an overstatement of the estimated inefficiency.

1) Identify the individual craft persons who worked unplanned extended overtime.

The contractor's payroll records should identify those individual craft labor who worked at least 50 hours a week during the period of unplanned overtime. It should not be assumed that every worker recorded on the daily craft report actually worked overtime during a given week. Note that the number of workers working over 40 hours declines with each successive week, indicating that some members of the crew did not work 50 hours. The result of such a calculation is shown in the table below.

Note that when the crew moved back to the normal 40-hour week, the "OT week clock" started over at Week 1 on March 27, 2010, and no hours were subject to any lost efficiency in the preceding two weeks. This was due to the fact that the crew was able to recover during the normal work weeks ending March 13 and 20. Thus, when overtime work resumed for the week ending March 27, 2010, the "Week 1" percentages were utilized.

2) Apply the applicable percentage tables above for the applicable overtime period (in this case 5/10s) to the craft hours subject to lost productivity due to unplanned extended overtime using the *retrospective* formula.

In this retrospective example using actual payroll data, the result is as shown in the table at the top of the following page.

In this example, the contractor lost 748 craft hours due to working unplanned extended overtime caused by the attendant

OT Week	Week Ending	Hrs Worked	Mechanics Working Over 40 hrs	Total Hrs Subject to Lost Productivity
Week 1	6-Feb-10	50	25	1,250
Week 2	13-Feb-10	50	24	1,200
Week 3	20-Feb-10	50	22	1,100
Week 4	27-Feb-10	50	22	1,100
Week 5	6-Mar-10	50	21	1,050
No OT	13-Mar-10	40	0	0
No OT	20-Mar-10	40	0	0
Week 1	27-Mar-10	50	25	1,250
Week 2	3-Apr-10	50	23	1,150
Week 3	10-Apr-10	50	23	1,150
Week 4	17-Apr-10	50	20	1,000

RETROSPECTIVE PRICING TABLE

Week Ending	Act Hrs Worked	# Mechanics working over 40 hrs	Total Hours Subject to Loss of Productivity	Loss (pct) from 5/10 Table	Inefficient Hours
6-Feb-10	50	25	1,250	5%	59
13-Feb-10	50	24	1,200	7%	78
20-Feb-10	50	22	1,100	8%	81
27-Feb-10	50	22	1,100	9%	91
6-Mar-10	50	21	1,050	15%	137
13-Mar-10	40	0	0	0%	0
20-Mar-10	40	0	0	0%	0
27-Mar-10	50	25	1,250	5%	59
3-Apr-10	50	23	1,150	7%	75
10-Apr-10	50	23	1,150	8%	85
17-Apr-10	50	20	1,000	9%	83
TOTAL					748

overtime inefficiency over an 11-week period using a retrospective analysis approach. In order to produce a conservative inefficiency estimate, it is recommended that when actual labor payroll hours are used, as would be the case in a retrospective analysis, the retrospective formula should be utilized, as described below.

The retrospective formula appears as: actual labor hours - (actual labor hours ÷ (1 + the percent inefficiency factor)), or as an example from the table above: 1,250 – (1,250 ÷ 1.05) = the inefficient hours, or 1,250 - 1,191 [the *efficient* hours] = 59 inefficient hours in a retrospective analysis. This formula solves for the efficient hours [1,191] in the equation and then allows the user to subtract the efficient hours from the total, yielding the inefficient hours [59].

Preparation of the Request for Equitable Adjustment

It is not unusual for a general contractor or owner to request that a mechanical contractor provide a prospective cost proposal to accelerate a construction project. However, such requests are often limited to the added payroll costs attendant to the overtime schedule. When a mechanical contractor is asked to submit a proposal to engage in overtime on a prospective basis, the attendant estimated labor inefficiencies must be added to the direct payroll costs of the overtime schedule.

Thus, in cases where a mechanical contractor is asked to forward price an overtime change order request, both the direct payroll and the inefficiencies should be included. The content of this chapter provides the guidelines for forward pricing an overtime-inefficiency change order request. In cases where the extent of the overtime is unknown, the mechanical contractor, at a minimum, should include an express reservations clause in the change order proposal.

For example:

> This change order proposal represents the direct additional payroll costs arising from the requested overtime schedule. No overtime inefficiencies are included in this proposal. Amalgamated Mechanical Contractors expressly reserves its rights to request compensation for labor efficiencies attendant to the requested overtime schedule. A revision to this change order proposal containing the costs for overtime labor inefficiencies will be forwarded for processing as soon as these costs can be computed. We estimate that the labor inefficiencies arising from this overtime schedule will not be less than ____ %.[13]

There may be occasions when the general contractor or owner denies the opportunity to supplement a change order request based on future events. Such prohibitions also may be a part of the contract or printed on the change order forms themselves as "full accord and satisfaction" clauses. If the mechanical contractor is prohibited from submitting supplemental change order requests, such as for labor inefficiencies arising from an overtime schedule, then forward pricing of the overtime inefficiencies may be the only option.

For example:

> The overtime pricing contained herein includes the added payroll costs for the overtime schedule provided by your office. Furthermore, this change order proposal contains a loss of labor productivity estimate based on the overtime schedule that we have received from your firm. The proposed overtime schedule provided by your office is the basis of our estimate for direct and inefficiency costs associated with this change order request. Amalgamated Mechanical Contractors expressly reserves the right to submit a separate change order proposal in the event the overtime schedule changes in any manner from that upon which we have relied in the pricing of this proposed change order.

It is recommended that the forward-priced (prospective) overtime change order request be treated, to the fullest extent possible, in the same manner as a "sticks and bricks" change would be priced. In a "sticks and bricks" change order request, the contractor takes off pipe, fittings, and appurtenances based on a scope of added work provided by the general contractor or owner. The labor is derived there from and the final pricing is added to the change order proposal.

In like fashion to the fullest extent possible, overtime change order requests should be based on a fixed scope. A fixed scope means that the general contractor or owner will provide the mechanical contractor with the number of days of overtime and the number of hours per day that are to be worked in order to form a basis for the forward-priced change order. Once the fixed scope is known, then the mechanical contractor can estimate the added payroll costs and the expected loss of labor productivity using the tables included herein. The tables refer only to estimated overtime inefficiency and do not include inefficiencies arising from other categories of impacts, such as unanticipated trade stacking, reassignment of manpower ("disruption"), lack of site access, or other inefficiency factors. Refer to the chapter titled "How to Use the MCAA Labor Fac-

[13] The estimated inefficiency percent can be derived from the data and tables contained in this chapter.

tors" for a more complete listing of potential inefficiency factors to consider when preparing a change order request or a claim.

In summary, it is essential that the mechanical contractor define, in its proposal, what costs are and are not included in its overtime change order request. Obviously, if the general contractor or owner direct an overtime acceleration effort without a requirement for a prospective change order proposal, and with only the requirement to provide the proof of overtime payroll costs for reimbursement, the mechanical contractor must make it clear that in addition to the actual payroll costs, a request for reimbursement of its overtime inefficiency costs will be submitted for payment.

Conclusions

A sustained and unplanned overtime schedule can result in a substantial loss of labor productivity. The mechanical contractor may be entitled to recover the associated costs, in addition to the direct overtime premium payroll costs. The current available data on inefficiency resulting from unplanned extended overtime, when properly utilized, provide the mechanical contractor with a reasonable basis to estimate such losses in either the prospective or forward pricing of an original estimate or a scope change, or in a retrospective application. The inefficiency factor will vary depending on the amount of overtime to be performed, the number of mechanics required, and the duration of the unplanned extended overtime. Additionally, other inefficiency factors may occur simultaneously, such as stacking of trades, reassignment of manpower, or site access restrictions. Such additional impacts can be separately estimated using the MCAA inefficiency factors described in this manual.[14]

Crew considerations also can affect overtime inefficiency levels. Such considerations include whether or not to place the entire crew on overtime even if only a definable portion of the work requires acceleration (i.e., the critical path activities), whether or not rest intervals can be interspersed into the overtime schedule to allow for one or more weeks of straight time work, or whether certain activities that would be subject to overtime acceleration can be scheduled for a second-shift crew. These sorts of considerations are made on a project-specific basis and can affect the amount of inefficiency sustained by a mechanical contractor resulting from performing the work on an overtime schedule.

Mechanical contractors should not accelerate to mitigate schedule slippage that was not caused by the mechanical contractor's fault or negligence on a *voluntary* basis. If a mechanical contractor is directed by a general contractor or owner to accelerate the work by commencing an extended overtime work schedule in order to overcome delays not caused by the mechanical contractor, a specific notice is necessary. While most construction contracts contain provisions that require the mechanical contractor to follow the

[14] The "Overtime" component (Item No. 15) listed on the MCAA inefficiency factors table in the chapter on "Factors Affecting Labor Productivity" herein was designed to give general guidance in forward-pricing overtime inefficiency. It is recommended that the more specific estimates of impacts contained in this chapter be applied to overtime inefficiency analyses due simply to the increased level of specificity offered by the studies and tables contained in this chapter.

direction of a general contractor or owner to accelerate the work,[15] such direction and the ensuing acceleration must be accompanied by clear and timely notice that includes a statement that the mechanical contractor is proceeding under protest and that a claim will be filed for reimbursement of all costs as soon as those costs can be computed. If a mechanical contractor is placed in a position of *constructively accelerating*[16] a project to overcome delay that has not been caused by the acts or omissions of the mechanical contractor, the review of these conditions by the contractor's upper management and counsel is highly advisable.

A schedule time impact analysis may be an essential factor in demonstrating that the mechanical contractor is not critically delaying a project. This is important in properly deflecting responsibility for the costs of acceleration in that the party controlling the critical path in a delayed schedule is usually the party that is found responsible for the costs to mitigate the delay. One primary means of delay mitigation is overtime. If the mechanical contractor is being charged with the acceleration costs, or the payment for the direct and indirect costs of acceleration are being withheld on the basis that the mechanical contractor was the responsible party, the contractor can employ a schedule time impact analysis to identify the party causing the critical path delay.

A schedule analysis also may be helpful in demonstrating, to the extent that the mechanical contractor's activities are not controlling the critical path of the current project schedule, that overtime demanded by a general contractor or owner will have no mitigating effect on the forecast end date of the project. It is an accepted axiom of construction Critical Path Method (CPM) scheduling that reducing the duration (i.e., by way of overtime acceleration) of a path of logic that does not control the critical path has no effect whatsoever on the end date of the overall project. Put another way, the end date of a CPM schedule can only be foreshortened by accelerating work on the controlling critical path. If the mechanical contractor can demonstrate that its work is not on, or even near, the controlling critical path, accelerating those non-critical activities will have no mitigating effects on a project that is behind schedule and will represent potentially substantial economic waste.

The mechanical contractor should clearly note in its bid or change order proposal whether or not overtime has been included in its lump-sum pricing, and if so, to what extent it was included. If a contractor includes extended periods of overtime in a lump-sum bid or change proposal, the attendant loss of labor productivity should be

---

[15] A subcontractor's refusal to comply with an acceleration directive provided by a general contractor or owner, in the presence of contractual authority to issue such a directive, may result in a termination for default. Before a direct, contractually proper acceleration order from a general contractor or owner is disregarded, the mechanical contractor should consult with construction counsel to evaluate the various courses of action.

[16] *Constructive acceleration* is a condition wherein a contractor is directed to accelerate to mitigate a delay not caused by the contractor at no additional cost. In anticipation of a claim to recover the costs of the constructive acceleration, the contractor takes express exception to the acceleration directive, provides notice of a claim, and then executes the acceleration as directed. The submission of the claim for added costs occurs as soon as the contractor can compute the added costs either while the acceleration is taking place, or after the acceleration has concluded. The steps that should be taken to perfect a constructive acceleration claim are best set forth by the contractor's counsel.

evaluated and if deemed appropriate, the costs should be included in the lump-sum price for the work. At a minimum, the contractor's right to claim for such cost impacts should be preserved.

Preservation of the contractor's right to be reimbursed for its overtime inefficiency costs, on projects where the other party refuses to pay for such overtime inefficiency costs, is of paramount importance. As described in greater detail in the chapter on "Time Impact Analysis—Measuring Project Delay," many general contractors and owners are including broad waiver language on change order forms and on the monthly payment applications. The contractor should take great care to limit this waiver language to matters that it deems have been settled and take express exception to each unsettled item, such as a pending inefficiency claim.

Overtime inefficiency costs for extended periods of unanticipated overtime may exceed the payroll costs of overtime premium. The mechanical contractor should employ every reasonable management tool including issuing proper and timely notice, keeping comprehensive records, performing schedule analyses, taking exception to broad waiver language, and timely submittal of change order requests to help ensure that the contractor's right to recover all of its overtime costs are preserved and that payment will be forthcoming.

Prepared by Paul L. Stynchcomb, CCM, PSP, CFCC of Vero Construction Consultants Corp., Dr. Mike Pappas, P.E., PhD of Pappas Consulting, Inc. and Jarad Kriz, CCM, LEED® AP (BD+C), PSP of FTI Consulting with peer review performed by: Robert Beck, President of John W. Danforth Company; Michael R. Cables, Executive Vice President of Kinetics Systems Inc.; James Durant, President and CEO of Trautman & Shreve; Richard Freeman, Vice President of Stromberg Metal Works; Matthew Hahr, Senior Vice President of Kirlin Mid-Atlantic, LLC; Michael Loulakis, Esq., President/CEO of Capital Project Strategies; Michael Mack, Executive Vice President of John J. Kirlin, Inc.; and Adam Snavely, President and CEO of The Poole & Kent Corporation.

Shift Work and its Effects on Productivity

The following paragraphs list factors that may affect productivity when work is done on a shift work basis. Most apply to "extra" shifts, although you should note that paragraph B and C also affect costs on a regular shift. All factors may not apply to a particular job.

Factors Affecting Shift Work Productivity

1. Additional Needs—Night versus Day. Since the extra shift will be performing at night, natural lighting will not be available and good quality artificial lighting may have to be provided. Even if the work is done inside a building, additional lighting in yards, storage areas, etc. would be required. It would also be expected that the temperature and weather conditions at night would be more severe than during the daytime period and additional heating would, therefore, be needed.

2. Since both shifts will be working on the same installation, there will be a certain inefficiency in the transition from one shift to the other. The new shift must go through a learning period to become familiar with the work done by the previous shift.

3. Since both shifts use the same tools and equipment, they will not be at the same place and in the same condition as a man leaves them when he completes his shift. Extra time will be spent reorganizing tools and equipment.

4. Night work will result in work force fatigue to a greater extent than daytime work.

5. Supervision will be diluted, since the normal supervisory employees of the company must be spread out over several shifts. Supervisory problems also include transferring information between shifts as to work completed, ordering of materials, deliveries, field orders, etc.

6. Additional welders may have to be qualified for second shift operations, resulting in increased manhours for testing, together with the cost of qualification tests.

7. The men required for ancillary services, such as laborers and operating engineers, whose time is normally distributed over a broader base of total pipefitter manpower, will add disproportionally to the smaller work forces normally used on additional shifts.

8. When only one trade is working shifts, they probably will not be "pushed" to complete certain work, as they may be during the regular shift.
9. If the shift works 7 1/2 hours in lieu of 8 hours, the percentage of work hours spent in starting, stopping, and coffee breaks becomes a greater proportion of the work shift.
10. The social aspects of the tradesmen may have to be considered, such as the disruptions on family life by working nighttime hours, and the effects on a man of having to change his schedule, such as sleeping during regular daytime hours.

The following is an index of additional factors which should be considered as direct costs when pricing bids for shift work operations.

Additional Factors

Coordination Costs

1. **Overtime Supervisory Personnel.** It may be necessary to overlap supervisory personnel by 1–2 hours per shift.
2. **Engineering Costs.** Additional engineering costs may be required for all shifts, at least in the initial stages of the project.
3. **Project Support and Communication.** A jobsite business office containing business machines, such as faxes, computers, etc., may be necessary due to the need for intense coordination, communication and information disbursement among shifts. The lack of available personnel in the home office after regular shift hours may require supervisory personnel from all shifts to meet on a regular basis for coordinating, planning and establishing relationships among shifts.

Labor Costs

1. **Hiring for Shift Work.** If it is necessary to hire additional personnel to man the shift, be aware that the productivity of "new hires" may not be the same as for the established crew. This may also depend on the employment levels and labor availability within your local jurisdiction.

2. **Shift Premium Differential.** Shift premium differential should be a part of the labor contract.

3. **Absenteeism.** Absenteeism can run as high as 30 percent during summer vacation months, particularly on Fridays and Sundays, and when holidays occur during shift schedules.

4. **Bodily Adjustment Period.** An adjustment period can be from 30 to 60 days, with a productivity loss of 15 percent to 25 percent during this time.

5. **Accident Rate.** An accident rate increase of up to 15 percent may be experienced, which would mean additional workers' compensation costs.

6. **Efficiency Loss.** From 10:00 p.m. to midnight, there is up to a 25 percent loss of efficiency.

7. **Alcohol.** Often there is an increased consumption of alcohol before coming to work by shift workers.

8. **Attitudes.** Lack of productivity and quality workmanship can transfer from one shift to the next.

Job Costs

1. **Safety.** Safety requires more emphasis due to potential increase in the accident rate.

2. **Heat.** Heat in colder climates may be required to a greater extent on second and third shifts.

3. **Lighting.** Particularly when work is being performed outdoors, i.e., installation of rooftop units, additional lighting may be required.

4. **Rental of Equipment.** All shifts must have adequate tools and equipment available.

5. **Delivery Charges.** If they are required, delivery costs can be costly outside of regular hours.

6. **Material Availability.** A crucial scheduling consideration, depending on schedules and productivity, may be the requirement for accompanying shifts in the fabrication shop.

7. **Tool Availability.** Time required in searching for and/or replacing tools can be staggering. Most companies provide a set of tools for each work shift.

Additional Resources

When shift work is not the norm of the company, all of the items described above may apply. However, the company may also require additional resources to accommodate the shift project and other projects in progress could suffer drastically—a real hidden cost. Some of the added resources that should be considered for sporadic shift work:

1. Additional engineers for the other shifts and overlap with daytime engineers.

2. Additional project managers for other shifts for continuity and resolution of problems which surface on late shifts.

3. Additional supervisory personnel, foremen, etc.

Conclusions

After the contractor considers these items, he should then determine the effects on overall productivity and the cost of shift work based upon overall productivity. He may also want to consider that during the short-term, such as one through four weeks, the productivity of shift work will be different than during the long-term, such as three months or more.

In situations of a controlled environment, such as a fabrication shop, there may be some advantages (or perhaps less disadvantages) to shift work other than for those outlined above. These factors include using a plant twice, thus cutting the fixed overhead cost; fewer interruptions on the work force; and less supervisory problems. The latter is true since fabrication work tends to be production-type work and information is normally passed directly to the tradesman by fabrication drawings or fabrication tickets.

In some regions of the country, such as summertime in the Southwest, weather and temperature conditions may be such that it would be an advantage to work shifts. If so, this should be considered by the contractor.

If the contractor is in the position of being able to make a decision as to whether to use shift work or overtime, he should determine a total productivity factor for shift work and compare this with the productivity factor for overtime work, as described in other Management Methods Bulletins. (See “Factors Affecting Labor Productivity” on page 99 and “How to Estimate the Impacts of Overtime on Labor Productivity” on page 185.) This information should be used in making the final decision.

Notes

Notes

Publication #M3

Mechanical Contractors Association of America, Inc.
1385 Piccard Drive, Rockville, MD 20850-4340
301-869-5800 ■ fax 301-990-9690 ■ www.mcaa.org