APPENDIX – HYPOTHETICAL PROJECT WITH WORKED EXAMPLES

This section presents examples of how to apply loss-of-productivity computations to an impacted project. They are somewhat simplistic explanations that are designed to clarify the principles of estimating loss of labor productivity. Real-life situations are usually more complicated but should be approached by starting with the Key Principles and recommendations contained in this Standard.

A.1 The Berkeley Middle School Project

The Berkeley Middle School Project (the "Project") consisted of the construction of an $85,000,000 middle school that included classrooms, auditorium space, gymnasium, cafeteria and offices. The Project was new construction, based on a design-bid-build, lump sum bid delivery system.

The bid documents, which were prepared by the school district's design professionals, contained a

- Detailed scope of work,
- Set of comprehensive drawings and specifications, and
- Summary construction schedule that set forth a notice-to-proceed date and a final contract completion date.

The contract specified liquidated damages in the amount of $5,000 per day of inexcusable Project delay.

The Project documents divided the building into three areas:

- Area A, which included the gymnasium, cafeteria, and other support rooms;
- Area B, which contained classrooms and teachers' and administrators' offices; and
- Area C, which was composed mostly of classrooms.

The prime contract bidders solicited bids from qualified subcontractors, which included concrete, masonry, electrical, mechanical and sheet metal, plumbing, interior finishes, and other trades.

Note: For the purpose of this standard, corporate names used herein are fictitious, and any resemblance to actual corporations or companies is purely coincidental and unintentional.

The lowest-bidding prime contractor was Apex General Contractors (“Apex”). Apex executed a lump sum contract with the school district. In turn, Apex executed lump sum subcontracts with the various trade subcontractors. The district’s contract with Apex required Apex to produce BIM drawings, which were to be accepted by the district’s design professionals before fabrication of various systems could commence. Apex’s subcontract assigned the lead responsibility for the BIM process to the mechanical subcontractor.

We assume that Apex had the right to rely on the accuracy, completeness, and constructability of the contract documents that were provided to Apex by the school district prior to Apex submitting its lump sum bid on the Project.

A.2 Project Obstacles

We note some obstacles discovered and conditions experienced by Apex after execution of the contract and during the construction of the Project.

- On excavating for underground utilities that were to be installed under the slab on grade, Apex’s excavating subcontractor discovered unsuitable soils (i.e., a differing site condition) that required remediation before site and foundation work could continue.
- The bid set of documents contained latent defects such that the drawings were not spatially coordinated. Thus, the systems could not be installed in the spaces provided on the contract drawings.
- Certain items that were specified to be furnished and installed were no longer commercially available and had to be respecified and reprocured, delaying the construction process.
- Latent ambiguities and errors in the construction documents required hundreds of RFIs, were neither timely nor comprehensively responded to by the school district’s design professionals.

- After building dry-in, when the Project was about 35% complete, the school district changed certain room layouts, mechanical, electrical, and ductwork services, and finishes in the affected areas as changes in the base contract scope.

The lack of a coordinated and complete design, as well as the unanticipated frequency and duration of the clash detection and correction meetings caused substantial BIM overruns.

A.3 Project Assumptions

Assume for this example:

- Apex timely submitted requests for time extensions on behalf of Apex and its subcontractors that conformed to the requirements of the contract. In turn, the school district did not provide specific responses but only repeated, "There can be no delay; the school must open on time."
- In response to these repeated directives, Apex accelerated the work of the majority of the subcontractors to overcome the school district's delays, after having provided constructive acceleration notices to the district.
- Apex's subcontract form clearly stated that subcontractors could only recover time and cost impacts to the extent that Apex could recover such damages from the "owner"—in this example, the school district. Notwithstanding, Apex recommended to its affected subcontractors that they maintain production records to assist them in proving their delay and labor impact damages.
- At the conclusion of the construction process, Apex and its subcontractors delivered the school building on the original contract completion date, but only after extreme conditions of acceleration that included trade stacking, disruption of crew flow (start-stop-restart of activities), and unplanned crew size increases.
- An overtime work schedule was considered but was not implemented because of local labor market conditions and the potential of unpaid overtime premium and inefficiency costs.
- Apex did not waive its rights to recover time and productivity losses, as the change order and monthly payment application forms, which contained full accord and satisfaction language, were contemporaneously modified by Apex to allow exceptions, such as damages for productivity impact and delay.

A.4 Productivity Loss Calculations

Apex and its subcontractors prepared productivity loss calculations using various methods:

- Apex had no direct labor on the Project other than cleanup crews, and therefore Apex had no labor inefficiency claim. However, Apex had to add cleanup crews to service the substantially increased crews, and Apex prepared a *direct cost* claim for those added crews. Apex also added field office staff to deal with the impacts of the changed conditions, and prepared a *direct cost* claim for those unanticipated and added field office management staff.
- Sparks, the electrical subcontractor, contemporaneously maintained labor codes that allowed tracking of actual field labor charged to the various areas of the Project and identified by similar conduit size groups: ¾ to 1 ½ in. diameter, 2 to 4 in. diameter, and 6 in. diameter and greater. It used a *measured mile* approach.
- Flow Master, the mechanical and plumbing subcontractor, did not contemporaneously maintain any actual labor-hour breakdown and only charged actual labor-hours to two codes for the entire Project: HVAC Piping Field Labor and Plumbing Field Labor. Flow Master used a *productivity factors (industry-based experience) approach.*
- Air Services, the HVAC ductwork subcontractor, contemporaneously tracked its labor using an *earned value* labor tracking system that divided work activities by areas of the Project.
- Standard, the masonry subcontractor, did not track its labor in a detailed, contemporaneous manner. It used a *productivity factor (academic research) approach.*
- The added BIM labor-hours were claimed as added BIM hours for each affected change in scope (as a line item on the change order proposal), with the appropriate residual of the overrun being claimed on the basis of BIM time sheets that differentiated base contract versus added BIM labor-hours.

As a result of how the subcontractors maintained their field labor records, each subcontractor used a different loss of labor productivity quantification methodology. Further details are given in the next five subsections.

A.4.1 Measured Mile Method

Because Sparks maintained its actual labor-hour charges by Project area codes and by similar types of conduit, Sparks was able to prepare a *measured mile* loss-of-productivity computation. Sparks reviewed Project records that included

- RFIs;
- Changes log;
- Project schedule for activity durations, delays and acceleration, and sequencing and disruptions;
- Crew sizes; and
- Other relevant labor records.

By way of example, Sparks found the results shown in Table A-1 for its largest labor code, the installation of the ¾ to 1 ½ in. diameter conduit. Sparks then performed the same analysis for each of the conduit categories to demonstrate similar impacts.

Table A-1: Conduit Details for Berkeley Middle School.

	Area A	Area B	Area C
Actual lineal feet (LF) of conduit	50,000	60,000	40,000
Actual labor-hours (L-h) expended*	10,000	15,000	5,000
Actual productivity	5.0 LF/L-h.	4.0 LF/L-h	8.0 LF/L-h

* “Actual labor-hours” is defined as craft labor working with tools and does not include supervision labor not working with tools.

The measured mile area (Area C) demonstrated that Sparks could install ¾ to 1 ½ in. diameter conduit at a rate of 8 LF ft/h of craft labor, which is known as Sparks's measured mile productivity rate. During this analysis, Sparks evaluated the following:

- Were the types of conduits used in the comparisons reasonably similar?
- Were the crews, including the labor supervisors, of similar experience?
- Were the physical areas of the Project similar? That included an evaluation of ceiling heights, complexity of the conduit systems, spatial considerations, and other potential variables.
- Were the conditions complained about (trade stacking, disruption, etc.) not present? Or if present, were the conditions not as intense in the measured mile area (Area C) as in the impacted areas (Areas A and B)?

Note that the measured mile can be prepared using time frames rather than physical areas on a project. Also, a key concept in the measured mile analysis is determining whether the work operations are "reasonably similar" or "measurably dissimilar" as to the effects being claimed. Inherent dissimilarities must be accounted for in the measured mile analysis.

Because Sparks maintained its labor records to allow for a measured mile method, Sparks did not need to address its project estimate, because the measured mile method does not rely on the claimant's estimate. As stated, the measured mile method is the preferred method of labor loss-of-productivity computation when detailed records are kept contemporaneously and there is an uninterrupted or minimally interrupted period of production.

From the previous discussion, Sparks's loss of craft labor productivity claim was formulated as in Table A-2, in the computation of Sparks's "should have spent" labor-hours.

Table A-2: Conduit and Labor-Hour Details for Berkeley Middle School.

	Area A	Area B	Area C
Actual LF of conduit	50,000	60,000	40,000
"Should have spent" labor-hours*	6,250	7,500	
Actual labor-hours spent	10,000	15,000	5,000
Less "Should have spent" labor-hours	6,250	7,500	

Claimed lost labor-hours	3,750	7,500	

* “Should have spent” labor-hours is at the proven production rate of 8 ft of similarly sized conduit per labor-hour, expended per the measured mile analysis.

From the total loss of labor productivity labor-hours Sparks multiplied the hours by the labor rate (including burden, overhead, and profit) to calculate its claimed amount. Since the measured mile method is based on actual production rates, the claimant’s estimate does not enter into the analysis. However, it may be used as backup support for the production achieved in Area C as opposed to the other areas.

A.4.2 Productivity Factors Method: Industry Study

Because Flow Master, the mechanical and plumbing subcontractor, did not maintain particularized actual labor charges and only charged to two gross labor codes (mechanical piping and plumbing piping), Flow Master chose to use an *industry productivity factors study* method. Flow Master chose the labor inefficiency factors published by the Mechanical Contractors Association of America (MCAA factors).

Flow Master first prepared a modified total “cost” (actually, labor-hour) calculation to demonstrate its total field craft labor loss (Table A-3).

Table A-3: Labor-Hours for MCAA Calculation for Berkeley Middle School.

Total actual labor-hours expended (by labor code)	55,000
Original estimated labor-hours	–30,000
Approved change hours	–3,000
Estimate error	–2,500
Corrections owing to contractor field mistakes	–1,500
Unallocated labor-hour loss	18,000

There are two basic ways to apply the MCAA factors: prospectively and retrospectively. Both start with review of the 16 inefficiency factors listed in the MCAA's publication.

The *prospective* method involves choosing the appropriate MCAA factors and applying them against the estimated hours, with the concept that had the claimant known the types and intensity of inefficiencies that would be experienced on a project, it would have "factored" its estimated hours accordingly.

For example, assume that Flow Master interviewed its field staff and area foremen and selected three MCAA factors:

- "Reassignment of manpower," also known as disruption, with an "average" impact of 10%;
- "Stacking of trades," with an "average" impact of 20%; and
- "Crew size inefficiency," with a "minor" impact of 10%.

This would yield a total estimated impact of 40% if all three factors were added together. Note that there might be situations where the analyst might decide, based on professional judgement, to use a somewhat lower number.

Flow Master would then take its original estimated hours and multiply this total by 40%. Flow Master's estimated labor-hours might be increased to account for any estimating error.

The original estimated hours of 30,000 hours times the 40% estimated loss results in a loss-of-productivity claim of 12,000 field craft labor-hours. The subcontractor actually lost 18,000 field craft labor-hours, so the claimant is not claiming 6,000 field craft labor-hours as an "unallocated" and unclaimed loss of labor productivity. This difference can be attributed to the subcontractor's own productivity issues or backcharges it plans to recover from other parties.

Note that using this method (the prospective method), the subcontractor assumes that every estimated hour would have been subjected to a 40% loss of labor productivity, in every area and during each time period of a project. While this may not be inaccurate or unreasonable, it may be subject to criticism from the respondent.

A more particularized method of applying the MCAA Factors is the *retrospective* method, applied to adjusted actual labor-hours and used in conjunction with a temporal or spatial analysis. The subcontractor did not contemporaneously track actual labor-hours by discrete activities, review of the subcontractor’s labor records, and employee name and time of labor charge on the payroll reports (reviewing the actual dates in the schedule). Nevertheless, it may be possible to estimate the number of actual hours charged to each project area. Thus, it is often possible to prepare a temporal (on this Project example) and retrospective MCAA factors approach as a more particularized methodology, as shown in Table A-4.

Table A-4: MCAA Factors for Berkeley Middle School.

	Area A	Area B	Area C
Actual labor-hours	18,000	26,000	11,000
Downward adjustments	–2,500	–4,000	–500
Adjusted actual labor-hours	15,500	22,000	10,500
MCAA factors			
Reassignment of manpower	10%	10%	10%
Stacking of trades	20%	20%	10%
Crew size inefficiency	10%	10%	0%
Total percent impact	40%	40%	20%

Note that by using a more particularized method, the MCAA factors can be varied by intensity, based on the project record and witness interviews. Particularization by time frame (temporal approach) or by project area (spatial approach) when applying any factored methodology enables a more specific, and usually a more accurate, and usually, a more accurate, estimate of labor productivity impacts.

The MCAA factors temporal approach, usually applied in the retrospective method because the actual labor-hours used come from the claimant’s payroll reports by weeks, months, or sometimes quarters, is not dependent on the claimant having tracked its actual labor by defined activities. Planned and actual labor can be defined by discretely bounded activity codes.

"Discretely bounded" means activity charge codes with defined physical boundaries that can be identified on a construction drawing and which can have planned labor-hours assigned to each such activity code.

Using the temporal approach, the claimant prepares a chart with time periods on the *X* axis and the actual labor-hours by period as well as the MCAA factor categories along the *Y* axis. This temporal approach can be combined with the spatial approach.

By using this more particularized method, the MCAA factors can be applied in a much more specific fashion. As with the spatial approach shown, the claimant can assign differing MCAA factors, and factor intensities, over time as adverse events actually affected the claimant's labor productivity. This method requires considerably more analysis but can result in a more equitable recovery of the claimant's loss of labor productivity. Moreover, a particularized MCAA factors analysis may be integrated into the claimant's cause-and-effect narrative that ties the causal events on a project and the lost hours together. That connection does not need to be ironclad, just reasonably persuasive.

When using the retrospective MCAA factor approach, the total inefficiency percentage cannot simply be multiplied by the adjusted actual labor-hours, because the actual hours already contain the inefficient hours (Table A-5). Thus, the equation must solve for the efficient hours:

Adjusted Actual Labor-hours ÷ 1.*n* = Efficient Labor-hours

where *n* is the MCAA factor percentage; and

Total Labor-hours – Efficient Labor-hours = Inefficient Labor-hours.

Table A-5: MCAA Calculated Inefficient Labor-Hours for Berkeley Middle School.

	Area A	Area B	Area C
Adjusted actual labor-hours	15,500	22,000	10,500
Total percentage impact	40%	40%	20%
Productive labor-hours	11,071	15,714	8,750

Inefficient labor-hours	4,429	6,286	1,750

The total lost labor productivity hours are thus 4,429 + 6,286 + 1,750 = 12,465 L-h. × payroll hourly rate + burden, overhead, and profit.

The factors' selection and the intensity levels applied should be cogently explained in the claimant's written narrative or expert report.

A.4.3 Earned Value Method

Air Services, the HVAC duct work subcontractor, maintained an *earned value* labor tracking system during the course of construction. Air Services divided the Project into the three discrete areas (A, B, and C), and then further into duct mains and duct branches. Thus, the earned value chart contained six field erection activities.

This variation of earned value compares the contractor's labor estimate and/or its labor plan to actual hours charged to discrete elements of the work. Like other modified total cost (labor-hour) methods, the earned value's dependence on the labor estimate or plan requires the claimant to review, and if necessary adjust, the estimate. This variation of earned value relies on an independent evaluation of progress, expressed as a percent complete:

Earned hours = percent complete × estimated/planned hours.

A periodic (usually weekly or monthly) comparison of the earned to actual hours provides the variance, either ahead or behind planned labor-hours (Table A-6).

Table A-6: Labor-Hour Variance for Berkeley Middle School.

	Area A	Area B	Area C
Planned labor-hours	12,000	16,000	8,000
Percent complete	50%	40%	25%
Earned labor-hours	6,000	6,400	2,000
Actual labor-hours	8,500	9,200	1,950

Variance	–2,500	–2,800	50

One facet of an earned value analysis is to validate the claimant's estimate. For example, if Area C was completed basically "on plan," with Areas A and B falling measurably behind in labor-hours and the productivity impacts identified by the claimant occurred principally in Areas A and B, the claimant could postulate that, but for the productivity impacts being described, the claimant could have achieved its estimated production rates.

Another use of the earned value method is to represent an earnings ratio of hours expended and percent complete progress earned (as independently assessed by field inspections and not as a result of a calculation). Using the earned value method in this manner is benefited by a much more detailed breakdown of activities, as opposed to the very summary level depicted in the previous example.

To use earned value to offer "hours to earn a percent compete" in addition to developing a reasonably detailed labor plan breakdown, the claimant must measure how many actual labor-hours were charged to each activity code by period (usually weekly or monthly) and then compare that to the percent complete value recorded for the reporting period.

Once a timeline table has been prepared showing hours charged by activity code (activity codes should encompass project areas and discrete work operations) and the percent earned by reporting period is reported, the claimant should assess the "earned value" ratio of hours expended versus progress gained (in terms of percent complete) to determine whether the analysis reveals a pattern of productivity difficulty (loss). This productivity over time is then typically used as a substitute productivity for a measured mile method of analysis.

In this case, Air Services' claim for loss-of-productivity hours, based on the status of work represented in Figure A-6 is 2,500 h for Area A and 2,800 h for Area B, totaling 5,300 h. Those 5,300 labor-hours would then be multiplied by the payroll hourly rate, burden, overhead and profit. Note that this claim would represent only the loss up to this point in the Project. The claimant would update its claim at completion to capture all its losses.

The issues identified as productivity impacts such as those inefficiency categories described by the MCAA factors table can be overlaid onto the earned value production chart to demonstrate the presence or absence of a correlation between the perceived impact categories and the time frames or areas in which hours required to earn a percent complete is measurably higher than in the perceived non- or less-impacted areas or time frames. The cause-and-effect connection should be made between identifiable inefficient events and conditions and the resulting effort to earn a percent complete.

Because the percent complete estimates per reporting period are a central element in this sort of analysis, the claimant must use consistent methodologies to measure progress. For instance, the claimant may mark the physical extents of the work activities onto a contract drawing and then "color in" or mark physical progress by reporting period. In that manner, the claimant can visualize what is earned in a percent complete evaluation of particular activities of work. The contractor's payment application forms may also be used for such analyses.

A.4.4 Productivity Factors Method: The Ibbs Academic Study

Standard Masonry ("Standard") was the masonry subcontractor to Apex. The vast majority of the interior and exterior walls were of concrete masonry unit construction. While construction was ongoing, the school district made substantial changes to the wall layouts.

In some cases, the district issued change orders to Apex for Standard's work, and in other cases Standard's scope changes were not converted to change orders and remained as pending changes in scope as the Project neared completion. Although the material costs for added concrete masonry units were not substantial, the labor to remove partially completed walls and to reconstruct and relocate walls consistent with the district's changes was extensive. Moreover, these design changes were issued during the midpoint of the construction period when Standard's crews were on site, attempting to build the base contract scope of work. Thus, the district's changes occurred during Standard's peak crew periods—and after it had planned its work and laid out the partitions based on the original contract drawings. Because these changes pervaded the building, Standard could not find a less impacted area or time from which a measured mile analysis could be performed.

As the Project neared completion, Standard performed a review of its planned (usually bid) and its actual labor.

- Standard determined that its original bid estimate contained a potential labor error of approximately 1,500 labor-hours but was otherwise reasonable and sound. Its original estimate contained 70,000 hours of field craft labor, net of nonworking supervision, to erect the masonry walls on the Project.
- By the completion of Standard’s work, it had expended 135,000 field craft labor-hours.
- Of Standard’s total field craft labor-hour overrun, only 11,000 hours had been compensated in executed change orders.
- Standard had approximately 15,000 hours in scope changes submitted to Apex, which had in turn submitted that amount to the school district for processing.
- Neither Apex nor Standard had signed any change order or payment forms that waived rights for labor impacts.

Table A-7 shows Standard’s labor assessment in the form of a modified total labor-hour computation.

Table A-7: Unallocated Labor-Hour Loss for Berkeley Middle School.

Total labor-hours	135,000
Estimated labor-hours	–70,000
Executed change order labor-hours	–11,000
Scope change labor-hours	–15,000
Bid adjustment	–1,500
Rework to Standard’s account	–2,000
Unallocated labor-hour loss	35,500

Based on Standard’s original estimated labor-hours and the hours in executed and pending scope changes, Standard believed that it had been adversely affected by the cumulative impact of the substantial labor-intensive changes to its base contract scope, which occurred mostly in the midterm of Standard’s schedule. Standard referenced the published materials and studies on the subject of cumulative impact and prepared its analysis in accordance with a published *productivity factor* approach (Ibbs 2005).

As mentioned, the majority of the impacts (change order and scope change work) occurred during the midpoint of the Project, making this a “median” analysis, as described in the Ibbs reference. Then, Standard prepared an analysis to determine the actual contract labor-hours (ACLH) (Table A-8).

Table A-8: Actual Contract Labor-Hours for Berkeley Middle School.

Total actual labor-hours	135,000
Less adjustment to Standard’s account	–3,500
Less change order/scope change labor-hours	–26,000
Actual Contract Labor-Hours	105,500

Standard then computed the change as

26,000 change labor-hours / 105,500 ACLH = 0.25

Thus, Standard had sustained a 25% change impact on the Project. Standard then reviewed the statistical regression curves provided in the cumulative impact reference materials and selected the curve that resulted from impacts that principally occurred during the midpoint of the projects under study, or the “median” curve, shown in Figure A-1.

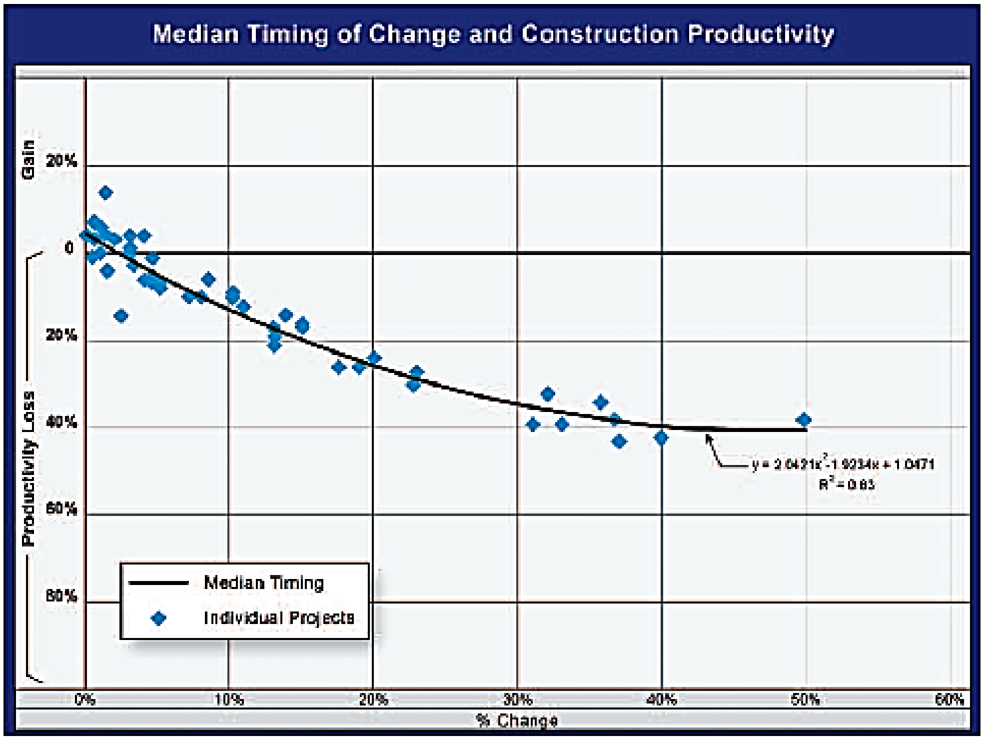

Figure A-1: Productivity loss for median timing curve.

Source: Ibbs (2005).

From this curve, Standard found the 24% change value on the *X* axis of the graph and correlated that value to the “Productivity Loss” percentages shown on the *Y* axis. Standard found the correlated value to be approximately a 30% loss of labor productivity from the effects of cumulative impact.

It then multiplied the 30% loss of labor productivity by the ACLH of 105,500. The result was a request for equitable adjustment of 31,650 field craft hours of lost productivity occasioned by the substantial labor-intensive changes required by the school district.

In this example, the modified total labor-hour analysis revealed that Standard actually lost 35,500 field craft labor-hours, so 3,850 h were unidentified and thus unclaimed in Standard’s loss of labor productivity request for equitable adjustment.

A.4.5 Cause-and-Effect Nexus

Apex agreed to preserve its subcontractors' rights to submit requests for equitable adjustments at the conclusion of the Project. Apex agreed, with the subcontractors' input, to prepare an omnibus claim narrative that would explain each component of the request. The subcontractors agreed to pay reasonable portions of this report preparation effort.

In this example, there were four methodologies employed by subcontractors:

- Measured mile empirical study,
- MCAA factors as an industry factors study,
- Earned value method, and
- Recovery using the Ibbs study method.

However, although different damages models were prepared, a narrative setting forth the cause-and-effect nexus should be prepared for most loss-of-productivity claims. To the fullest extent possible, specific causal factors should be linked to a specific damage, or damages. This narrative, or expert report, should do the following

- Describe the claimant's original plan to accomplish the work under contract in an efficient manner.
- Outline the events that occurred that altered the claimants' trajectory.
- Identify, if possible, the causes.
- Connect the unanticipated, adverse conditions to the effects (the damages).

In most cases, mathematical models are not, by themselves, sufficient to perfect a loss of labor productivity claim or a request for equitable adjustment.

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ADDITIONAL READING

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[1] This guide has been officially rescinded without explanation by the USACE but is still used by some parties in practice.

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Includes insufficient design, financial issues, insufficient coordination, inability to understand scope of work, improper inspection or study of the contract during the bidding stage, ineffective planning and scheduling, delay in making the required submissions, wrongful payment, labor satisfaction, excessive inspection, rework, noise and pollution control, resource levelling, constructability of design, and labor motivation.

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