Scholarly Paper

Measured-Mile Principles

William Ibbs, M.ASCE[1]

Abstract: Change is any addition, deletion, or revision to the general scope of a contract. It may cause an adjustment to the contract price or contract time of a design or construction project. Many disputes arise out of change, and successful resolution of those disputes requires that three elements be evaluated: liability, causation, and resultant injury (damages). One specific type of damage that is frequently alleged on changed projects is loss of labor productivity. One way to evaluate and quantify loss of labor productivity damages is through use of the measured-mile technique. Problems exist with the measured-mile approach, however, because the guidelines for developing and applying it are unclear. Based on a review and synthesis of project management literature and court and appeal board decisions, this paper presents guidelines for development and application of the measured-mile methodology. The intent is to help contractors, owners, consultants, and other parties step through a logical process for preparing and presenting a credible measured-mile analysis. **DOI: 10.1061/(ASCE)LA.1943-4170.0000087.**

CE Database subject headings: Construction management; Legal factors; Productivity; Contracts.

Author keywords: Change; Construction; Construction management; Legal issues; Loss of productivity; Measured mile; Productivity.

Introduction

Productivity is a measurement of output per unit of time [American Association of Cost Engineers (AACE) 2004] and is important because it is one of the three components of labor cost (along with the hourly rate and the work quantity). If productivity is impaired, project labor costs will increase. Because labor costs are usually a large proportion of total project costs, the overall total project costs will probably increase. Such an increase will probably jeopardize the owner's project business value and the contractor's profit.

One of the ways labor productivity may be impaired is through change, which is any addition, deletion, or revision to the general scope of a contract (Ibbs 1994). Because change may result in idled resources (e.g., waiting for new instructions), reassigned resources (with extra, unplanned transit time or learning curve losses), or other problems, a contractor may suffer a loss of labor productivity (LOP). Even though labor effort and schedule are related and somewhat interchangeable, the courts have held that LOP damages are different than and distinct from schedule delay damages.[1] This makes them a separate and important category of recoverable damages; cf., Clark Concrete.[2]

It is also a maxim of law that when claiming such damages a contractor must demonstrate what caused the change, why the owner is liable for the change, and that any claimed damages are reasonable.[3] There are different methods for estimating such LOP losses, including actual costs, total and modified total cost, project comparison studies, specialty industry studies, general industry studies, and the measured-mile approach (AACE 2004; Finke 1997). One of the ways that productivity damages can be estimated is through use of a measured mile.

Though seemingly simple in concept, there are actually a number of issues and nuances associated with measured-mile analysis. The AACE (2004) says the more common mistakes are (1) calculating lost productivity on a cost rather than a labor-hour basis; (2) applying calculated factors to all labor hours on the project rather than just those of the impacted period; (3) failing to account for typical learning curve effects and losses in the early stages of a project; (4) failing to deduct additional labor hours already paid for in change orders; and (5) failing to take into account other factors that impacted productivity but that are not recoverable under the contract's terms.

Thomas (2010b) categorizes the problems with measured-mile analysis as either analysis (or methodological) difficulties and process (or application) difficulties. Specific issues include selecting time periods that are not truly comparable; failing to verify cost, productivity, and progress data; using production rather than productivity data; and performing a cost-based analysis without understanding the project context and construction methods. To this should be added the general proposition that many project owners do not want to acknowledge LOP damages because they are by nature difficult to pinpoint and quantify, and often very substantial.

Objective and Research Methodology

The success rate for LOP claims is low because there is in general no rigorous methodology for quantifying damages and specifically no rigorous methodology for developing and applying the measured-mile concept (Thomas 2010a). Thus, there is a need for such guidelines. The purpose of this paper therefore is to present such.

The guidelines presented herein were developed by (1) reviewing the measured-mile basics; (2) summarizing key project management literature and court and board decisions on the subject; (3) identifying complications and contradictions in its use; and

[1]Professor of Construction Management, Dept. of Civil & Environmental Engineering, Univ. of California at Berkeley, Berkeley, CA 94720; and President, Ibbs Consulting Group, Inc., Oakland, CA 94618. E-mail: William.Ibbs@IbbsConsulting.com

Note. This manuscript was submitted on July 13, 2011; approved on September 2, 2011; published online on September 5, 2011. Discussion period open until October 1, 2012; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Legal Affairs and Dispute Resolution in Engineering and Construction***, Vol. 4, No. 2, May 1, 2012. ©ASCE, ISSN 1943-4162/2012/2-31–39/$25.00.

(4) synthesizing the literature and decisions. The result is a set of guidelines for general usage.

The intended audience of this paper is any contractor, consultant, or owner who needs to quantify LOP, either on a forward-looking or retrospective basis. Though it is written from the viewpoint of a contractor/plaintiff pursing a LOP claim against an owner/defendant, the points presented could apply to the reverse situation. They may also help in forward-pricing change proposals. This research and its guidelines are important because of the vast sums of money at stake in LOP disputes, probably exceeding $60 billion in the United States alone (Ibbs 1997). Improvement, whether by faster resolution or more accuracy of such disputes, will translate into cost savings for both the contractor and the owner parties.

Measured Mile: General Background

The preferred method for quantifying LOP damages is the use of actual costs, but when that is not possible, measured mile should be used (Calvey and Zollinger 2003, W.G. Yates, U.S. Industries). The goal in such an analysis is to compare the actual labor-hours spent and work output achieved during a period of time or for a category of work unimpacted by disruptions (the measured mile) with a period or category impacted by such. That arithmetic difference is then presumed to be the loss associated with the disruption and is used to calculate the LOP. The LOP is measured in terms of labor hours, which can then be multiplied by an hourly rate to derive the cost associated with LOP. Those lost labor hours can also be inserted into a project's as-built schedule to determine if the project duration was lengthened. If it was extended, the contractor may also be entitled to extended overhead costs. This approach has been accepted by U.S. federal and state courts (discussed in length below), as well as by overseas authorities such as the U.K.'s Society of Construction Law (2002).

This approach relies upon the accuracy and completeness of contemporaneous project records and the skill, care, and impartiality of the analyst (Keane and Caletka 2008). The quality and availability of data will be important factors in determining the durations of the time periods (or work categories) studied. Good weekly labor-hour records, for instance, will lead to weekly labor productivity analyses. In some cases monthly pay applications, with monthly analyses based on dollars put-in-place, can be used. One example where this approach might be necessary is a general contractor's pursuit against an owner for a LOP claim on behalf of a subcontractor whose records are insufficient. It may also be the case that the project is so disrupted that even good record keeping is of no help:

> one of the ironic things about loss of productivity claims is that often the very factors that produce the loss of productivity can also serve to preclude the accurate and precise record-keeping that would constitute evidentiary certitude. (Shea 1989)

Measured-mile analysis is attractive to owners and triers-of-fact because it is based on actual project productivity. This avoids any problems created by a contractor bid bust and the necessity of making adjustments to the bid as is required in the modified total cost or earned value approaches. Measured mile analysis also takes into account the contractor's own inefficiencies.

Some contractors do not like it because it requires them to keep more detailed records than they customarily would. However, it does offer a benefit that an estimate-based earned-value calculation does not. Namely, the contractor may be able to recover more damages than what an earned-value approach would yield if he or she is actually more productive than expected in his original estimate. In addition, the measured-mile approach is more closely tied to the specific circumstances of the project at dispute than some of the other LOP estimating methods. That avoids the criticism often leveled at estimating guidelines and industry studies as being too generalized.

Project Management Literature Review

Zink (1986) introduced the concept of a measured mile. It is based on a project's actual labor hours, comparing productivity during an unhindered time to productivity during a hindered time. His original paper presented a pictorial representation of the concept along the lines shown in Fig. 1 of this paper.

The actual labor-hours curve in this figure shows the contractor's actual production at different points in time, from start to finish. The slope of that curve at any particular point in time is the contemporaneous productivity at that particular point in time. Often it is the case that there is a period of lower productivity at the start of the project while learning curve and other start-up effects are worked through. That is illustrated by the nonlinear portion of this curve, on the left-hand side of the figure. Then, the project hits its stride (the linear portion of the curve between the 40% and 60% complete points). Later, some event disrupts the project and creates lower productivity rates, as reflected in the higher, nonlinear curve on the right-hand side. The linear portion in the 40% to 60% range of this example would be extrapolated and used as the measured mile or unimpacted reference period. The difference between the two curves post 60% complete would be computed to estimate the LOP. In this case, that loss is the 670 cumulative labor hours.

As straightforward as the concept seems, years of application have revealed a number of nuances and intricacies. Wilson (1993), for example, was one of the first to illustrate how two different computational approaches applied to the same project—one being the productivity per cubic yard of excavated soil and the other being productivity per lineal foot of excavated soil—can yield substantially different results. The reason is because the cross-sectional

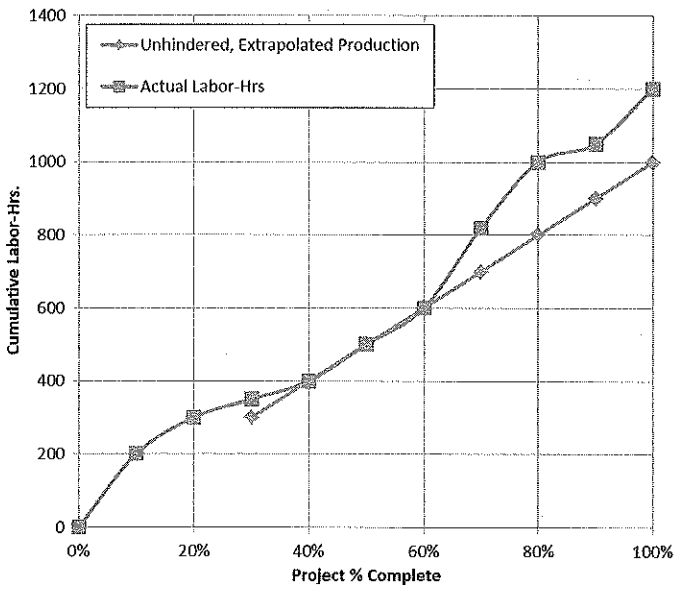

Fig. 1. The measured mile concept (adapted from Zink 1986)

area of the measured-mile section differs substantially from the allegedly impacted section.

A few years later, Finke (1998) reported that the impacted and unimpacted time periods could be concurrent if the underlying works are separate and distinct. This reinforces the point that LOP claims should be evaluated separately from schedule delay claims. He also noted that productivity can be defined as labor-hours per percentage point of completion or progress, labor hours per dollar of earned value, or labor hours per quantity installed.

Finke also made the important observation that measured mile analysis generally compares an average productivity rate for an unimpacted time period with an average productivity rate for an impacted time period. Moreover, such averages hide the fact that a contractor does not achieve a single, uniform rate of productivity throughout a time period. Thus, "once it is realized that you are dealing with a collection of productivity rates rather than a single average productivity rate, you open the door for a statistical analysis to determine whether there are meaningful differences."

This means that the laws of probability enter the discussion. There is a certain probability that the difference between $PR_{unimpacted}$ and $PR_{impacted}$ (PR is productivity rate) is simply a manifestation of the inherent variability of the contractor's productivity. That is, the differences may just be statistical noise and thus not qualify as a systemic owner-caused disruption. There must be a meaningful difference between $PR_{unimpacted}$ and $PR_{impacted}$ for owner liability to arise.

Thomas and Oloufa (1995) compared the productivity of various construction projects that had been disrupted by change. To standardize the data, they applied the ideas of conversion factors to obtain equivalent work types across the projects. The basis for these conversation factors was the earned value, using labor hours taken from standard estimating manuals. Thomas and Zavrski (1999) show that projects with more complex design have lower and more variable baseline productivity. That may be useful information when trying to compare an impacted project against an unimpacted project.

Thomas and Sanvido (2000) and Thomas (2010a) note some projects are disrupted throughout their entire duration, meaning no pure, unimpacted measured mile period exists. For such conditions, they propose using a baseline productivity method. In this approach, the best time periods are selected and used to estimate the LOP for other time periods, even if they are noncontinuous time periods and even if they have owner-caused disruption.

The approach has merit, although there are some insufficiencies, one being that according to Thomas the baseline period should be the time period constituting 10% of the entire project duration. There is no scientific evidence to support that 10% is an appropriate number. Abu-Hijleh and Ibbs (1993) have in fact shown that sometimes 20% is needed and other times 3% is sufficient. Holloway (2007) comes to the same conclusion. Thomas is also ambiguous and possibly mistaken when he says that the baseline subset is the "reporting periods that have the highest unit production or output." Unit production or unit output could refer to output per day, thus ignoring crew size and misrepresenting productivity, which would lead to computational errors.

Finally, the best time period (i.e., the baseline period) and the time period being impacted and reviewed may both have LOP that is the owner's responsibility. To compute the LOP as the difference between the baseline and impacted periods would therefore be to compare one time period with modest owner-caused problems with another time period that had significant owner-caused problems. This would lead to an underestimate of the true LOP and penalize the contractor. A better approach would be to select the baseline period, make adjustments for that period's productivity, and then compare this adjusted baseline to that of other project periods. This is something the courts have allowed, as discussed in a subsequent section.

Gulezian and Samelian (2003) note that plotting the to-date productivity in a cumulative fashion may smooth the data and more clearly reveal systematic abnormalities. They also apply statistical control chart theory to the measured mile concept. In this approach, a center line is computed for the average of all the productivity data points during the course of a project. Then upper and lower control limits are plotted as three standard deviations from that average rate. Values falling within these control limits are said to fall within a normal range of variation. Those falling outside the control limits are said to be attributable to some systematic event, not a chance event. Those events would be events where productivity was meaningfully disturbed; events within the three-sigma range would not qualify as LOP events. Gulezian presents no evidence, though, to validate the use of three standard deviations other than historical usage.

Eden (2005) notes that the measured mile approach does not easily allow disaggregation between different categories of disruption and delay, and triers-of-fact often want to assess disruptions and delays individually because of liability provisions in the project contract. Shea (1989) notes that cases with measured mile analysis are usually too complicated to parse in detail: "Commenting on the practicality of proving damages the board [in Robert McMullen & Sons, Inc.] stated that to attempt to deal with each individual issue and to segregate delays and loss of efficiency would be a wasteful exercise. It was impractical if not impossible to distinguish with any degree of accuracy the contract work from extra work."

Braimah (2010) notes that one key to developing a credible measured-mile analysis is good underlying project documentation. A critical first step is developing a flexible and usable work breakdown structure (WBS). As project change arises, it is important to create separate WBS accounts in a timely way and update progress and labor-hour expenditures frequently.

Presnell (2003) and Serag (2010) describe the measured-mile process in very general terms as (1) defining the work activity or cost, (2) account for the work performed, (3) log accurate labor hours used to perform the work, (4) log accurate quantities of work completed for the period, and (5) briefly define any condition or event that prevented optimum production. These guidelines also refer to production (output) rather than productivity (output per unit of time), which is incorrect. Loulakis and Santiago (1999) suggested choosing a measured mile according to (1) the work performed during the unimpacted period should be substantially similar in type, nature, and complexity to the affected work, and (2) the skill and composition of the workers should be comparable.

Ibbs and Liu (2005, 2011) have developed and tested a statistical K-clustering method for separating productivity data into impacted versus nonimpacted categories. Applying this method to an actual claim, Williams (2011) found that it yielded results that were closer to the actual project losses than other methods. The method also demonstrated that a hard and fast 10% rule is arbitrary.

Dieterle and Gaines (2011) offer some practical points about measured-mile use, including the fact that shifting the measured-mile period forward or backward in time may have substantial impacts on the claimed LOP amount. This allows the analyst to perform a sensitivity analysis and assess the confidence in the analysis. They also encourage step-by-step explanations of the LOP analysis with transparent use of data.

Case Law and Board Decision Literature Review

There have been many project disputes involving the measured mile concept that have resulted in published court or board decisions. Federal decisions that are instructive and have been favorable for plaintiffs using measured miles include:

- Bell BCI Co., where compensation was granted to the general contractor based on use of a measured mile using units of work complete and earned valued on a weekly basis. Bell's practice for many years had been to track productivity rates by requiring the foremen to record each week the amount of units installed on a project, allowing analysis of the actual time to install units against its estimates. A subcontractor on this project was also granted compensation after using a quantity/labor-hour-based measured-mile approach: "Stromberg installed the changed duct work on the third floor at a rate of 6.26 lb per hour, compared to the 11.23 lb per hour it experienced early in the project."
- Natkin & Co. In this case Natkin suffered LOP because the owner failed to furnish design drawings and permanent equipment in a timely manner, and the owner and general contractor abandoned the CPM schedule. At the same time, they forced Natkin to accelerate its piping work. Natkin began tracking productivity for the affected piping systems shortly afterward.
- DANAC, Inc. The court awarded the contractor LOP damages for out-of-sequence work. It also put the burden to disprove LOP back on the defendant after the government repeatedly asserted that DANAC's analysis was flawed.[4]
- P.J. Dick. Electrical design deficiencies occurred throughout the entire installation of electrical branch circuits. This led to uneven workflow, constructive acceleration, and reduced labor productivity. The court allowed the contractor to compute a LOP using a measured mile based on similar work (feeder circuit) even though that work was done by a different crew. The board found that there was "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 of the loss of productivity."
- Alstom Power. Alstom's expert used a measured mile to validate a rebid of the project. Verifying that estimate allowed Alstom to successfully prosecute a modified total cost claim.
- Lamb Engineering & Construction Co. Here, the Board of Appeals allowed use of a corrected measured mile, incorporating a large number of corrections in scraper cycle time to reflect site conditions. Those corrections were substantiated with extensive documentation.
- Bay West. Board allows use of measured mile that was adjusted for learning curve and other factors. Such adjustments were made by the analyst after careful review of daily diaries and interviews with the dredge leverman.

Luria Bothers & Co. is an instructive case because it supports the use of measured-mile productivity rates that are then adjusted by experts to account for slight differences with the impacted period. However, those adjustments must be substantiated with reasoning, not just observation and experience:

> It is a rare case where loss of productivity can be proven by books and records; almost always it has to be proven by the opinions of expert witnesses. However the mere expression of an estimate as to the amount of productivity loss by an expert witness with nothing to support it will not establish the fundamental fact of resultant injury nor provide a sufficient basis for making a reasonably correct approximation of damages...we cannot ignore the fact that the percentages testified to were merely estimates based on [the contractor's witness] observation and experience. Furthermore, his estimates are much higher than those testified to in other cases in which the conditions are not materially different from those present here. Taking these things into consideration and in view of the fact that no comparative data, no standards, and no corroboration support his testimony, we are constrained to reduce his estimates based on the record as a whole and the court's knowledge and experience in such cases...

Other cases in which contractors successfully used a measured-mile approach include Batteast Construction, where the analyst developed his LOP by working with the foreman actually coping with the disrupted work. James Corporation is an example of a state court permitting use of the measured-mile concept. In this case labor billings as percentage of the contract's total labor value were deemed to be a sufficient measure of completion.[5]

Most denials of measured-mile analysis are rooted in the application details, not the methodology itself. One common reason for rejection is the faulty rationale by which the reference period is selected, such as choosing an unimpacted period that is not comparable to the impacted period. A noteworthy example is P.W. Construction, Inc., in which the court sharply criticized the expert:

> 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... [PWCI's expert] deleted both the welding work and the trenching work from the pre-disruption rate and left both kinds of work in the post-disruption period... The two periods thus have not made a correct comparison... Indeed, the Government submitted unrebutted evidence that adding the welding costs back into the ideal period yields an ideal rate of 0.171 hours per linear foot, a rate very close to the impaired rate.

Another reason for denial is that analysts sometimes make adjustments to the measured-mile period to make it better fit the unimpacted period. The adjustment may not be credible or the adjustment may be credible but not fully explained in a clear and transparent manner. Such was the case in Clark Concrete Contractors. Here, a subcontractor's work was disrupted by the addition of some extra concrete work and, the court believed, the government's failure to respond to RFIs in a timely manner and the government engineer's lack of experience. The analyst in Clark Concrete also defined and used two types of impacted periods: severely and moderately, which the court accepted. Using multiple categories of impacted period makes it easier for a trier-of-fact to accept a LOP claim.

Unfortunately, Clark Concrete expert's use of an adjusted unimpacted period productivity rate was denied because the expert making the adjustment did not sufficiently corroborate his proposed adjustment. Shields, Inc. had the same problem.[6] Similarly the Board in Bay Construction Co. denied a contractor claim because his expert failed to separate trades between the comparison periods.

In Southern Comfort Builders Inc., the contractor's expert claimed that it was impossible to identify a measured mile because the construction period was too short. He also asserted that the whole period was subject to lost productivity because of the owner's late change orders and the acceleration and out-of-sequence work that resulted from those change orders. In an attempt to overcome these problems, he developed a measured mile using productivity rates achieved by another contractor on the same

project and then applied those rates to the disputed portion of the project.

The court did not accept this analysis:

> Based on the information presented, this court cannot adopt [contractor's] measured mile analysis or modified total cost analysis to support SCBI's calculation of damages for loss of productivity... Plaintiff's expert attempted three different methodologies without explicitly signing on to any one of those definitively, and his analysis on each of the methodologies presented at trial was flawed. SCBI's measured mile calculation is deficient in that it does not adequately represent a comparison between SCBI's unimpacted work with SCBI's impacted work. Instead, SCBI's calculation compares SCBI's work with the work performed by another contractor, Merritt. Although the two companies conducted similar work, even SCBI's own expert...indicated that, under a measured mile analysis, comparing two separate companies is fundamentally flawed. Also, since SCBI did not provide a basis of its work unimpacted by government actions, the court cannot properly conclude what SCBI's unimpacted work would have been. Another flaw in SCBI's measured mile analysis is that in its calculations, plaintiff's final average labor costs under the measured mile analysis is [sic] greater than the total cost calculations. This presents a fundamental problem because, [as plaintiff's expert] admitted, a total cost analysis represents the maximum amount a contractor could possibly receive. It, therefore, is unreasonable for SCBI's measured mile calculations to be higher than its total cost calculation, perhaps a result of comparing SCBI's costs with Merritt's costs.

The court was also critical of SCBI because many of the disruptions encountered by SCBI could have been identified by SCBI had SCBI drafted the coordination drawings required by the contract. SBCI also failed to attend the prebid site visit, which may have contributed to the court's skepticism of its claim.

Despite the fact that this court was not comfortable accepting use of a measured mile from an adjacent contractor in Southern Comfort, Shea (1989), Jones (2001), and Society of Construction Law (2002) state that it is possible to use productivity from a similar project or series of similar projects. Schwartzkopf and McNamara (2001) cite Robert McMullan & Sons, Inc. and Ginsburg (1985) cites Maryland Sanitary Manufacturing as corroboration that similar projects can be used as a measured mile on a disrupted project.[7]

The tipping point in Southern Builders might have been that the contractor's expert applied the measured-mile productivity rate from the other contractor's project to SBCI's entire project duration. Merritt (2008) goes so far as to describe this as an example of a measured mile being identified for reasons of convenience rather than from a rigorous, impartial basis. Another problem was that the court saw this as a total cost claim, which defeats the whole point of preparing a measured-mile analysis in the first place.

Calvey and Zollinger (2003) stress the importance of an impartial qualified expert in quantifying LOP claims. Lack of such impartiality has been cited in several cases, including Daewoo Engineering. In that case, the court rejected the experts' opinions, noting they made a presumption of efficiency with regard to the impacted period, which were neither substantiated nor justified:

> We assume that a finder of fact faced with the measured mile method of estimating damages would want to have confidence in the expert's ability and objectivity. A court would be particularly concerned to know how the experts picked periods of productive and non-productive construction for comparison. We did not have such a level of confidence in the plaintiff's experts. Cross examination showed their choices of productive and non-productive periods to be arbitrary at best. More likely they were chosen to achieve a pre-determined result.

J.A. Jones Construction is another example of a misapplied measured mile. The plaintiff's expert used a one-of-a-kind measured-mile approach and testified that a contractor suffered LOP as the result of the cumulative impact of numerous change orders. The Board rejected his analysis for several reasons. First, the expert appears to have derived his 28% inefficient factor by a very subjective and convoluted route that was not explained clearly to the Board. His analysis was also weakened by a failure to eliminate other noncompensable factors that could have contributed to LOP.

Another major problem was that the expert did not attempt to perform a cause-and-effect analysis, even failing so much as to show the timing of when the purported disruptions occurred and their consequences. (The lack of trying to demonstrate a cause-and-effect undercut a LOP analysis in Sunshine Construction & Engineering too.) Other problems included the fact that craft labor hours were coded to various cost accounts and in some cases materially overstated and not corrected by the contractor's expert. As one example, the analyst included all the labor hours of a flagger in the LOP calculation even though that flagger was providing traffic control service to the entire project, which had undisturbed parts.

His approach also was suspect because a single impacted day determined whether entire months of data were categorized as impacted or unimpacted. It appeared the contractor's expert had not reviewed all the pertinent documents or else chose to ignore them because some internal documents placed blame for cost overruns on the contractor. Those documents recounted high turnover of supervisory personnel, a bid bust, and unreasonable overly aggressive productivity estimates. Those same internal postmortem documents noted that the productivity rates were better on this disputed project than those on a similar but less complex project performed a short distance away. Finally, the decision also suggests that the Board was swayed by the credentials and experience of the government's expert relative to those of the Contractor's expert.

E.C. Ernst, Inc. is a case noteworthy for using dissimilar work types to compute LOP. Ernst's expert computed that there were roughly 100,000 labor hours lost on a three-year project. To allocate number of lost labor hours per year, he decided that the major cause for delay was the extraordinary number of drawing revisions developed by the defendant. This led to a calculation of the percentage of drawing revisions that were submitted in each of the three years. From this, he prorated the lost labor hours to a particular year and assigned that year's labor cost to those labor hours.

The court dismissed this approach because

> Ernst's hypothetical allocation of unpaid journeyman hours on the basis of the number of drawing revisions received per year is invalid. Not all drawing revisions required work by Ernst, and all revisions requiring work would not cause an equal amount of work. Thus, a calculation based on an artificial method of allocation is not a proper substitute for a calculation based on historical expenditure [on] labor.

Recommended Measured-Mile Practices

The preferred method for computing LOP damages on a disrupted project is the actual costs methodology. However, this approach is often not available for various reasons, one being that contractors

sometimes do not realize they are in a substantially changed circumstance until it is too late. They may be too late because they literally do not recognize the changed condition or because they cannot react quickly enough to set up new cost accounts to capture the quantity, timing, and productivity of the change work.

In lieu of actual costs, the measured mile technique is preferred. However, the cases and decisions summarized above indicate that there problems with this approach. To help ameliorate the situation, the following guidelines are recommended for conducting a measured mile analysis. Some of the key, specific references cited in this paper are cited in the parentheses behind a guideline when that reference is used as the basis for the particular guideline.

1. Selection of the measured mile analyst.
   a. Use impartial, experienced, knowledgeable experts (Luria Brothers; Daewoo; J.A. Jones; Calvey and Zollinger 2003).
   b. Someone who understands both construction cost accounting and construction work methods (J.A. Jones).
   c. Review the entire project record. Interview the project personnel, including field personnel. Review pertinent documentation, obtain clear understanding of the issues in dispute (Batteast; J.A. Jones; Keane and Caletka 2008).
2. Selection of the impacted period.
   a. Graphically plot daily, weekly, monthly productivity over time to identify periods of disruption (Zink 1986; Finke 1998; Thomas 2000; Ibbs 2005).
   b. Consider use of statistical methods to select impacted and unimpacted periods objectively (Finke 1998; Ibbs 2005, 2011).
   c. Compute productivity, not production data (Zink 1986; Ibbs 2005; Thomas 2010b).
   d. At the minimum, make an effort to demonstrate cause and effect between the change(s) and the consequence(s) (J.A. Jones).
      (1) Ideally, prove what the causes of LOP were. If unable to prove, demonstrate and explain to a reasonable degree.
      (2) Investigate the timing of the purported disruptions and their alleged consequences.
   e. Make adjustments for noncompensable changes and contractor-caused problems in the impacted period (J.A. Jones).
   f. Consider developing categories of "impact severity" rather than one general category (Clark Concrete).
3. Selection of the measured-mile period.
   a. Select a reference period for a narrow spectrum of similar work.
      (1) Select a period that as similar to the disrupted period as available (Zink 1986; AACE 2004; Loulakis 1999; Presnell 2003; Serag 2010; Ibbs 2005, 2011; Thomas 2010b; Ernst).
      (2) Use quantity of work per labor-hour as a measure of productivity if possible; if not, resort to quantity of work per percent project complete or quantity of work per dollar spent (Bell BCI; P.J. Dick; P.W. Construction; James Corp., AACE 2004).
      (3) Consider the physical character and amount of the work (Zink 1986; AACE 2004; E.C. Ernst).
      (4) Consider the means and methods, e.g., weather conditions, work hours, project schedule, site logistics, management and supervision, trades, used to perform the work (Zink 1986; AACE 2004; Thomas 2010b; Bay Construction).
      (5) Consider the administrative and managerial aspects governing the work; e.g., supervisory ratios, number of and time spent processing shop drawings, RFIs, and change orders (AACE 2004; Ibbs 1997).
      (6) Select workers with reasonably similar skill, knowledge, and effort. The same labor pool is desirable (P.J. Dick Construction; Loulakis 1999).
      (7) Separate the loss of productivity by labor trade if possible (Bay West).
      (8) Use owner-collected data if available (Dieterle and Gaines 2011).
   b. Confirm that the reference period has unhindered productivity. Both for the contractor and any subcontractors or suppliers.
      (1) Make adjustments if there are contractor-caused hindrances to adjust the reference period (Lamb Engineering; Luria Brothers; Southern Comfort).
      (2) Be prepared to explain those adjustments with solid reasoning, not just assertions (Luria Brothers).
      (3) Conversion factors, perhaps derived from authoritative estimating sources, may be needed to compensate for differences between unimpacted and impacted work (Thomas and Oloufa 1995).
   c. If no measured-mile productivity data available on disputed project, use other information sources.
      (1) Published industry estimating guides (AACE 2004).
      (2) Other projects built by this contractor or by similar contractors (Robert McMullan & Sons; Maryland Sanitary; Southern Comfort; Shea 1989; Jones 2001).
      (3) Dollar per percent complete, earned value rates (Bell BCI; James Corp.; AACE 2004).
      (4) Baseline Productivity analysis (Thomas 2010a).
         (a) Make adjustments as necessary to baseline reference period to develop true unimpacted baseline productivity rate (Bay West; Luria Brothers).
4. Calculate the loss of productivity.
   a. Test the integrity of the underlying productivity, change, progress, etc. data (Dieterle and Gaines 2011).
   b. Apply LOP factors to just the time period and labor trade disrupted (AACE 2004).
   c. Adjust for learning curve productivity factors in the early stages of a project (Bay West; AACE 2004).
   d. Adjust for additional labor-hours already paid for in change orders (AACE 2004).
   e. Exclude any loss which is not recoverable under the contract's terms, including contractor's own problems (AACE 2004).
   f. Look for several different ways to compute a measured mile from the instant project (Wilson 1993).
      (1) Report the results using those different ways and bracket them into a high–low range.
   g. Consider other reference sources.
      (1) Other projects by this contractor, other projects by other contractors (Society of Construction Law 2002).
      (2) Other decisions by this court or board (Luria Brothers).
   h. Be conservative.
      (1) Apply the LOP factor to just the crews and the time period involved (J.A. Jones).
   i. Check the mathematics: do not present results that strain credibility, such as a measured-mile analysis that claims more damages than a total cost claim (Southern Comfort).
5. Present the analysis clearly.
   a. Explain the cause and effect (J.A. Jones; Southern Comfort; Sunshine Construction).

b. Use more than broad, unsubstantiated statements such as based on "my experience" (Luria Brothers).
c. Focus on key points, not minutia (J.A. Jones; Clark Concrete; Southern Comfort).
d. Include photographs, other graphic aids, correspondence, job diaries, etc.
e. Corroborate with other methods such as modified total cost, industry guidelines.
f. Rehearse before presenting. Anticipate questions and prepare answers (Dieterle and Gaines 2011).
g. Tell the truth (Merritt 2008; Loulakis 2003).

Discussion

The previous section presented a set of guidelines for developing the measured-mile approach in LOP claims. Applying these proposed guidelines requires a variety of implementation steps, which is the subject of this section.

One of the keys to being able to apply the measured-mile approach properly is to have the right productivity data, both impacted and unimpacted. Ideally the contractor will have developed and maintained a detailed WBS with a sufficient number of cost accounts so that the processes are already in place to capture the data. What constitutes a sufficient number of cost accounts depends on many factors, including the type of work, project size and duration, the contractor's familiarity with that type of work, the labor proportion of the work, future estimating needs, owner requirements, and the risk-sharing nature of the project as expressed by the contract terms.

Teicholz (1987, 1974) observes, however, that many contractors fail to keep good, detailed cost control systems, in part because they believe it is too expensive to collect and put the data into the system. In such cases, the contractor who has an insufficient cost control system must recognize early that he may be installing disputed work and must therefore react quickly to define new cost accounts so he can begin capturing the productivity data. Further complicating this is that many contractors and owners initially deceive themselves into believing that a changed condition really is not a serious matter, only to realize much later that the problem is significantly worse than they thought and that impact productivity data needs to be collected (Ibbs 1994). By that time much or all of the disputed work has been completed and it is too late to capture the productivity of that changed work and in sufficient detail to be accurate.

Even if the contractor does recognize in a timely manner the need to start tracking this information, there can be other difficulties. One such difficulty involves setting up new cost accounts. This is not easy because new codes must be developed and the personnel must be trained to use those codes. On large projects, it can take a considerable amount of time to communicate these changes. Another problem is that it can be difficult to separate contract work from changed work. As an example, estimating the amount of time to add 1 in. of extra shotcrete to a tunnel lining when the base contract calls for 4 in. is a judgmental call. If the field engineers or foreman are not properly trained, the data may be collected inconsistently because they are using their individual judgments without any overarching guidance. That inconsistency can in turn jeopardize the quality of the measured-mile analysis.

Once the information is collected, it must be analyzed fairly. Though that almost seems unnecessary to note, several of the cases cited above underscore the importance of objectivity and candidness. Loulakis (2003) writes, "the baseline for demonstrating what the contractor could have done needs to be unimpeachable." In other words, the baseline used for demonstrating losses does not need to be perfect, but it should be credible if not irrefutable. The cases reviewed earlier in this paper demonstrate that most of the problems associated with measured-mile analyses are application problems, in particular problems with the measured-mile analysis being a fair and balanced estimate of the project's problems. The contractor and his expert should presume that the owner's team is familiar with the measured-mile approach and will be looking for ways to discredit the contractor's analysis. A single instance of skewing the analysis and trying to hide chicanery can discredit the contractor's entire claim. Better to present information that is not entirely favorable than to try to sneak a skewed analysis through the owner's review.

The benefit of using these guidelines is that labor productivity losses will be more accurately and consistently quantified, which will make disputes easier and less expensive to resolve. A collateral benefit of using them is that more detailed productivity information may be collected, which will help to better plan and estimate future projects. They may also help evaluate employee performance.

Conclusions

The measured-mile methodology is one of the preferred methods for quantifying loss of productivity claims. The technique computes the difference between the actual productivity on an unimpacted portion of a project to an impacted portion of the project, and treats the difference as the LOP associated with that impact. Responsibility for the costs of this impact are then assigned to the party responsible, as determined from the cause of the impact and the liability, as determined by a reading of the contract or interpretation of industry custom and practice.

The measured-mile technique has been the subject of many court and appeal board decisions. Those decisions and applications in professional practice have shown that there are nuances to the methodology and those nuances undermine the results of its consistency and reliability. The purposes of this paper are to review those decisions to identify specific methodological and application issues and to develop and present a series of guidelines that can be used by contractors, owners, and other interested parties to develop and apply measured miles for quantifying the loss of labor productivity on disputed projects. They may also help in forward-pricing change proposals. The intent is to help reduce the uncertainty and inconsistency in LOP requests and claims, and make construction more cost effective.

From this review, it is clear that impartial and unbiased selection and application of the measured-mile methodology is the most important determinant in its success. Preference is given to computing a measured mile on a labor-hour basis, not a cost basis, and presenting a conservative analysis, which includes taking into account other factors that impacted productivity but which are not recoverable under the contract's terms. Also important is the selection of the type of work or time period used as a reference. Though the reference work does not need to be identical to the impacted work, the analyst must show a good faith effort when trying to find the mile, and if similar work is used, a good explanation of that similarity is essential. Finally, consider use of a measured mile from similar projects, if available.

List of Cases

Alstom Power, Inc. v. RMF Industrial Contracting, Inc., 2006 U.S. Dist. LEXIS 8019 (March 2, 2006).

Appeal of Batteast Construction Co., Inc., ASBCA Nos. 35,818 & 36,609, 92–1 BCA ¶ 24,697 (Dec 31, 1981).
Appeal of Bay Construction Co., VABCA No. 5594, 02–1 BCA WL 442118 (2002).
Appeal of Bay West, ASBCA No. 54166, April 25, 2007. Board allows use of Measured Mile but it must be adjusted for learning curve & conditions accurately indicated in contract documents.
Bell BCI Co. v. United States, 72 Fed. CL. 164, 168 (2006).
Clark Concrete Contractors, Inc. v. General Services Administration, GSBCA No. 14340, 99–1 BCA ¶ 30,280.
Daewoo Engineering and Construction Ltd v. U.S., 73 FedCl 547(2006).
Danac, Inc., ASBCA 33394, 97–2 BCA ¶ 29184.
E.C. Ernst, Inc. v. Koppers Company, Inc., U.S. Court of Appeals, 626 F.2d 324, 327 (3d Cir. 1980). 476 F. Supp. 729 (W.D. Pa. 1979).
James Corporation v. North Allegheny School District, No. 1268 C.D. 2007.
J.A. Jones Construction Company v. Corps of Engineers., BCA, ENG BCA Nos. 6348, 6386–6391. 00–2 B.C.A. (CCH) ¶ 31,000 (July 7, 2000).
Lamb Engineering & Construction Co., Eng., BCA No. C-9304172, 97–2 BCA ¶ 29,207.
Luria Bothers & Co. v. United States, 369 F2d. 701 (Ct. Cl. 1966).
Maryland Sanitary Manufacturing Corp. v. United States, 199 Ct. Cl. 100 (1951).
Natkin & Co. v. George A. Fuller Co., 347 F. Supp. 17 (W.D. Mo. 1972), reconsidered, 626 F.2d 324 (8th Cir. 1980).
P.J. Dick Inc. v. Principi, 324 F.3d 1364, 1370 (Fed. Cir. 2003).
P.W. Construction, Inc. v. U.S., 53 Fed. Appx. 555 (Fed. Cir. 2002).
Robert McMullan & Sons, Inc., ASBCA No. 191229, 76–2 BCA ¶ 12,072, at 57,947, 962.
Safeco Insurance Co. of America v. County of San Bernardino, U.S. Court of Appeals for the Ninth Circuit, No. 07–55832 (October 1, 2009).
S. Leo Harmonay, Inc. v. Binks Mfg. Co., 597 F. Supp. 1014 (S.D.N.Y., 1984).
Southern Comfort Builders, Inc. v. United States, No. 00–542C (July 29, 2005).
Sunshine Construction & Engineering, Inc., v. United States, No. 02–250C (March 4, 2005).
U.S. Industries, Inc. v. Blake Construction Co., 671 F.2d. 539 (D.C. Cir. 1982).
United States for Use and Benefit of Shields Inc. v. Citizens and Southern National bank of Atlanta, 367 473 4th cir (1966).
Warwick Construction, Inc., GSBCA Nos. 5070 et al., 82–2 BCA 16,091 at 79,854.
W.G. Yates & Sons Construction Company, ASBCA No. 48,398, 01–2 BCA ¶17 31,428.
Wunderlich Contracting Co. v. United States, 351 F.2d 956 (Ct. Cl. 1965).

Endnotes

[1]S.L. Harmonay, Inc.: Subcontractor Harmonay was able to recover LOP because his general contractor, Binks, accelerated the project and forced Harmonay to double crew size and move to a three-shift per day operation. "On the other hand, courts have often recognized that the extent of harm suffered as a result of delay, such as the loss of efficiency claim in issue, may be difficult to prove."

[2]Clark Concrete Contractors, Inc.: "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 man-hours necessary to produce a given unit of work. As is self-evident, if productivity declines, the number of man-hours of labor to produce a given task will increase...."

[3]In Warwick the court noted "It has always been the law that in order to prove entitlement to an adjustment under the contract or for its breach, a contractor must establish the fundamental facts of liability, causation and damage." And in Wunderlich, "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 his computation, even though the result is only approximate... Yet this leniency as to the actual mechanics of computation does not relieve the contractor of his essential burden of establishing the fundamental facts of liability, causation, and resultant injury."And in Safeco the federal appeals court ruled that the expert's measured mile was acceptably even though it may have inaccurately treated some low productivity days: "Because damages need not be proved with mathematical precision, nitpicking regarding the calculation is seldom successful grounds for appeal."

[4]"Fourth, while respondent speculates that appellant's quantum evidence is unreliable, suspect, and most likely done after-the-fact, ...respondent has failed to direct our attention to any specific entries in those exhibits that are inaccurate."

[5]The court wrote, "This approach compares the cost of completing work not subject to delay or acceleration with costs of completing work during a period of impact, the difference representing the measure of damages. Atlas Cas. Surety Co. *v.* The George Hyman Constr. Co., No. 93-CV-4570, 1998 U.S. Dist. Lexis 22627 (E.D. Pa. May 15, 1998). The work compared need not be exactly the same, as the ascertainment of damages for labor inefficiency is not susceptible to absolute exactness. Clark Concrete Contractors, Inc. *v.* Gen. Servs. Admin., 99–1 Bd. Contract Appeals, ¶ 30280, 1999 WL 143977 (Gen. Servs. Bd. Contract Appeals 1999). When a contractor alleges a loss of productivity, the measured mile approach is the preferred method of computing damages. Atlas Cas. Surety Co.; cf. Angelo Iafrate Constr. Co., Inc. *v.* Pa. Tpk. Comm'n, 2006 Pa. Bd. Cl. Lexis 4 (Dkt. No. 3654, Pa. Bd. Cl. 2006) (experts agreed measured mile analysis is ideal method to determine loss of productivity.)" One of the persuasive factors in the contractor's favor was that the school district presented no counterexpert to rebut the measured mile analysis.

[6]"...it appears that a not insubstantial part of the extra cost for which the plaintiff sought reimbursement [in the impacted periods] could be attributed to factors for which [the contractor] was not responsible, As the evidence does not provide any reasonable basis for allocating the additional cost among these contributing factors, we conclude that the entire claim should have been rejected...this court has heretofore recognized and applied the principle that if there are actionable and nonactionable factors, the court, in the absence of a showing of some reasonable basis in the evidence, will not attempt to apportion the damages." Shields Inc.

[7]The Maryland court also points out that to use a measured mile method it is necessary to demonstrate: (a) that there actually exists a representative period that can be used as a baseline and that that period is itself actually undisrupted; (b) that there actually exists a single period that has been consistently disrupted by the event being analyzed; and (c) that the relative lack of productivity in the disrupted period is solely attributable to the event being analyzed, and not to other events. This last criterion is rather restrictive and would seem to preclude expert adjustments, though as seen elsewhere in this paper other courts have permitted such adjustments.

References

American Association of Cost Engineers (AACE). (2004). *Estimating lost labor productivity in construction claims, AACE RP24R-3*, Morgantown, WV.
Abu-Hijleh, S. F., and Ibbs, C. W. (1993). "Systematic automated management exception reporting (SAMER)." *J. Constr. Eng. Manage.*, 119(1), March, 87–104.
Braimah, H. (2010). "A conceptual model for effective maintenance of productivity records: A tool for facilitating the analysis of disruption claims." *The Construction, Building and Real Estate Conference for the Royal Institution of Chartered Surveyors*, Royal Institution of Chartered Surveyors, London.
Calvey, T. T., and Zollinger, W. R., III. (2003). "Measured mile analysis." *AACE International Transactions. EST.03.1 to EST.03.6*, American Association of Cost Engineers, Morgantown, WV.
Dieterle, R. A., and Gaines, T. A. (2011). "Practical issues in loss of efficiency claims." *Cost Eng.*, 53(2), 29–34.

Eden, C., Williams, T., and Ackermann, F. (2005). "Analysing project cost overruns: Comparing the 'measured mile' analysis and system dynamics modelling." *Int. J. Proj. Manage.*, 23(2), 135–139.

Finke, M. R. (1997). "Claims for construction productivity losses." *Public Contract Law J.*, 26(3), 311–338.

Finke, M. R. (1998). "Statistical evaluations of measured mile productivity claims." *Cost Eng.*, 40(12), 28–30.

Ginsburg, G. J., and Bannon, B. A. (1985). "Loss of efficiency." *Construction Briefings*, Federal Publications Inc., Washington, DC, December, 1–16.

Gulezian, R., and Samelian, F., (2003). "Baseline determination in construction labor productivity-loss claims." *J. Manage. Eng.*, 19(4), 160–165.

Holloway, J. S. (2007). "The measured mile revisited—what you should know." *The E-Mail Construction Reporter*, February 20.

Ibbs, C. W., Wong, C., Kwak, Y. (1994). *Project change management*, CII Special Publication, Austin, TX, November, 43-1.

Ibbs, C. W. (1997). "Quantitative impacts of project change: Size issues." *J. Constr. Eng. Manage.*, 123(3), 308–331.

Ibbs, W., and Liu, M. (2005). "Improved measured mile analysis technique." *J. Constr. Eng. Manage.*, 131(12), 1249–1256.

Ibbs, W., and Liu, M. (2011). "An improved methodology for selecting similar working days for measured mile analysis." *Int. J. Proj. Manage.*, 29(6), 773–780.

Jones, R. M. (2001). "Lost productivity: Claims for the cumulative impact of multiple change orders." *Public Contract Law J.*, 31(1), 1–46.

Keane, P. J., and Caletka, A. F. (2008). *Delay analysis in construction contracts*, Wiley-Blackwell, New York.

Loulakis, M. C., and Santiago, S. J. (1999). "Getting the most out of your 'measured mile' approach." *Civ. Eng.*, 69(11), 69.

Loulakis, M. C., Gaba, C., and Rodrigues, J. (2003). "The measured mile approach." *Civ. Eng.*, 73(11), 96.

Merritt, D. (2008). "Quantifying disruption—the measured mile." Civil Engineering Surveyor, Institution of Civil Engineering Surveyors, April, 28–32.

Presnell, T. W. (2003). "'Measured mile' process." *Cost Eng.*, 45(11), 14–20.

Schwartzkopf, W., and McNamara, J. J. (2001). *Calculating construction damages*, 2nd Ed., Aspen Law and Business, New York.

Serag, E. (2010). "Change orders and productivity loss quantification using verifiable site data." Ph.D. dissertation, Univ. of Central Florida, Orlando, FL.

Shea, T. E. (1989). "Proving productivity losses in government contracts." *Public Contract Law J.*, 18(2), 414–431.

Society of Construction Law. (2002). "Delay and disruption protocol." Society of Construction Law, Oxford, UK, October.

Teicholz, P. (1987). "Cost control systems: Needs and directions." *Proc., ASCE Specialty Conference on Project Controls: Needs and Solutions*, W. Ibbs and D. Ashley, eds., ASCE, Reston, VA.

Teicholz, P. (1974). "Requirements of construction company cost system." *J. Constr. Div.*, 100(C03), 255–263.

Thomas, H. R. (2010a). "Quantification of losses of labor efficiencies: Innovations in and improvements to the measured mile." *J. Leg. Aff. Dispute Resolut. Eng. Constr.*, 2(2), 106–112.

Thomas, H. R. (2010b). "Why are loss of labor efficiency damages so difficult to recover?" *J. Leg. Aff. Dispute Resolut. Eng. Constr.*, 2(4), 190–193.

Thomas, H. R., and Oloufa, A. A. (1995). "Labor productivity, disruptions, and the ripple effect." *Cost Eng.*, 37(12), 49–54.

Thomas, H. R., and Sanvido, V. E. (2000). "Quantification of losses caused by labor inefficiencies: Where is the elusive measured mile?" *Constr. L & Bus.*, 1(3), 1–14.

Thomas, H. R., and Zavrski, I. (1999). "Construction baseline productivity: Theory and practice." *J. Constr. Eng. Manage.*, 125(5), 295–303.

Williams, G. H., Jr. (2011). "Use of a production function to estimate the impact of work fragmentation on labor productivity." *PICMET Proc., Portland International Center for Management of Engineering and Technology, Portland, OR*, Project Management Institute, New York.

Wilson, R. L. (1993). "Use and abuse of the measured mile." *J. Construct. Account. Taxation*, Winter.

Zink, D. A. (1986). "The measured mile: Proving construction inefficiency costs." *Cost Eng.*, 28(4), 19–21.