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Measured Mile Labor Analysis

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Productivity, whether it is in manufacturing, white-collar work, professional sports, or construction, is one of the major components distinguishing success from failure. In construction, productivity has become even more important as budgets and time frames are tightened to the point of strangulation. As a result, the ability to measure productivity and to articulate deviations in productivity has become essential for the success of businesses involved in the construction industry. Presently, the most widely accepted evaluation of productivity deviations is the measured mile method. This paper provides a look at the history of labor productivity and the application and acceptance of the measured mile.

HISTORY

During the 1970s, petroleum and chemical companies (petro-chem) understood the importance of monitoring construction labor productivity on their major construction projects. As a result, petro-chem championed a system of monitoring construction progress against labor hours expended. In order to service petro-chem requirements, engineering procurement construction (EPC) companies of that time provided cost engineers and cost reporting systems for the project. The technique implemented to measure labor productivity was a standard workhour system. The basis for the system developed earlier in Alvin, TX, utilized time studies to develop base workhours for the installation of various commodities. These time studies resulted in standard labor units for installation of commodities such as reinforcing steel, concrete, structural steel, process piping, and electrical conduit and cable.

Petro-chem and EPC estimating departments expanded the standard labor units to include a multitude of labor functions such as equipment setting and alignment, welding, instrumentation and controls. The standard hours were based on the work being performed under certain conditions such as a 40-hour workweek, unobstructed access to the job site, moderate temperatures, etc. In order to quantify the standard workhours earned on a project at a given point in time, cost engineers would perform physical surveys and calculate the quantity of commodities installed. The quantity installed was then multiplied by the standard unit workhour factor for that commodity to develop the workhours earned. The earned workhours were then compared to the actual workhours expended installing the commodity. In most cases, the earned workhours were divided by the actual workhours, resulting in a productivity index. A productivity index of less than one, meaning that the actual workhours were greater than the progress earned workhours, indicated the project was experiencing lower than anticipated productivity. A productivity greater than one, where the progress earned workhours were greater than the actual workhours, indicated work was being performed better than anticipated.

The labor productivity was normally summarized in similar work activities much like today's specifications. For example, typically concrete installation activities such as formwork, placement of reinforcing steel, installation of embedded metals, placement of concrete, and stripping of forms would be summarized under a foundation activity. Table 1 provides a typical calculation.

In the example, the work being performed on the footing installation had a lower productivity compared to the wall and pier installation. Overall, the concrete work was being preformed at a slightly better efficiency (1.03) than the standard. Table 2 is an example of an in progress report on foundations.

Electrical activities such as hanging conduit, pulling wire, installing fixtures and devices, and terminations would be monitored as electrical activities. The standard unit rates used to monitor the progress were in fact usually identical to the unit rates used by the estimators, with the possible exception of an adjustment for local labor factors. The local labor multiplier is used to adjust for differences in labor conditions, work schedule and unique project complexity issues. By employing the standard workhour labor productivity method, EPCs were able to measure changes in labor productivity and exert management controls to mitigate losses. Further, a project was able to evaluate labor productivity on foundations compared to labor productivity on erecting steel or labor productivity on installing electrical components. All work activities were weighted in accordance with their standard workhour component.

During the period from 1970-1990, it was quite common to have 4-6 cost engineers providing monthly labor reports on projects \$100M-\$200M in value. However, economic pressures have forced EPCs, as well as others, to reduce field staffing, and in many cases, eliminate cost engineers who provide full time quantity surveys. In their place, other methods have been established for measuring labor productivity that are very similar to the original standard workhour method. As a starting point, let us examine how a typical contractor develops its lump sum price.

Most contractors use standard units similar to those identified by an estimating service such as Richardson or Means, or often

Table 1

Activity	Quantity Installed	Unit	Standard Unit Rate	Earned Standard Man hours	Actual Man hours	Productivity
Footings						
Set and Strip Forms	100.0	Sf	0.33	33.00	36.00	0.92
Reinforcing Steel	10.0	Cwt	1.95	19.50	24.00	0.81
Embedded Metal	-					
Pour Concrete	10.0	Cy	1.05	10.50	12.00	0.88
Subtotal Footing				**63.00**	**72.00**	**0.88**
Wall & Piers						
Set and Strip Forms	100.0	Sf	0.50	50.00	40.00	1.25
Reinforcing Steel	7.5	Cwt	2.15	16.13	14.00	1.15
Embedded Metal	1.0	Cwt	2.15	2.15	2.00	1.08
Pour Concrete	5.0	Cy	1.05	5.25	4.00	1.31
Subtotal Walls & Piers				73.53	60.00	**1.23**
Total Concrete				**136.53**	**132.00**	**1.03**

refer to contractor associations such as the National Electrical Contractors Association (NECA) or the Mechanical Contractors Association (MCA) for standard units, which are then adjusted based on the contractor's historical database. Just as EPCs, contractors perform rigorous takeoffs of design drawings to determine their quantities and multiply those quantities by the standard units. The resultant workhours are then multiplied by a dollar rate to include labor payroll, taxes, insurance, fringe benefits, and associated overhead and profit. In a similar manner, contractors use the quantity takeoff to obtain vendor quotes and unit prices for material needs and then mark them up for associated overhead and profit. The two are combined, and the overall price is submitted. If it is deemed that the bid is the lowest and best price, the contractor is awarded the contract. Following the award, the contractor submits to the architect a price breakdown of the project for the pay application. The contractor develops this breakdown by determining from the estimate the amount of labor and material dollars associated with work activities in a particular area of the project. In most cases, the breakdown of the project must be in sufficient detail to allow the architect and the contractor to agree on a physical percent complete based on a visual observation. The breakdown, in all cases, must be approved by the architect or owner's representative prior to the continuation of the project. It is often required that the value for labor and materials be separated in an agreed-upon breakdown. To develop this breakdown, the contractor refers to the estimate based on quantities and unit workhours. (See Table 3 for a sample estimate).

Once the project breakdown has been agreed upon, the architect and/or owner's representative review and approve, on a monthly basis, the progress complete achieved by the contractor. The more detailed information included in the project breakdown increases the accuracy of the observed percent complete. Using this method, the architect and owner's representative and the contractor are agreeing upon a labor percent complete of the project on a monthly basis. This percent complete is in fact based on the estimate weighting.

On a monthly basis, the contractor will have a labor report that provides workhour expenditures on the project. The workhour expenditures can be compared to the percent of labor progress earned. It is recommended that the noncontributing labor such as nonworking general foreman or supervisory staff be removed in order to enhance the labor productivity measurement. Table 4 is an example of the workhour comparison of percent progress versus actual workhours.

Another important element is to crosscheck the quantities used in the estimate/pay application breakdown against actual quantities in order to identify any significant variances from the estimate. Major variances should be adjusted before the calculation. Also check to determine that the estimated units are in fact proportional to normal standards. A high local adjustment factor or a low local adjustment factor will have a negligible effect on the overall productivity analysis. The above described productivity measurement techniques form the foundation for the present day productivity comparison analysis known as the measured mile.

MEASURED MILE ANALYSIS

The measured mile analysis employs the above productivity techniques to compare different periods of productivity within a project. This comparison is often used to explain and quantify the effect different conditions have on a labor force's ability to perform. The measured mile represents the labor force's ability to perform on the particular project at hand, versus a theoretical calculation. For example, if ABC Electrical contractor obtains a project away from its normal area, a measured mile analysis will identify the base efficiency at which ABC is able to employ a different labor force. Further, the measured mile can be used to determine

Table 2

	Budget				Progress					To Complete		
Activity	Quantity at Completion	Unit	Standard Unit Rate	Standard Manhours at Completion	Quantity Installed	Earned Standard Man hours	Actual Manhours	Productivity To Date	Percent Complete	Standard Man hours To Complete	Actual Man hours to Complete	Productivity To Complete
Footings												
Set and Strip Forms	100.0	Sf	0.33	33.00	100.0	33.00	36.00	0.92	100%			
Reinforcing Steel	10.0	Cwt	1.95	19.50	10.0	19.50	24.00	0.81	100%			
Embedded Metal	-			-	-							
Pour Concrete	10.0	Cy	1.05	10.50	10.0	10.50	12.00	0.88	100%			
Subtotal Footing				**63.0**		**63.00**	**72.00**	**0.88**	**100%**			
Wall & Piers												
Set and Strip Forms	100.0	Sf	0.50	50.00	50.0	25.00	20.00	1.25	50%	25.00	25.32	0.99
Reinforcing Steel	7.5	Cwt	2.15	16.13	5.0	10.75	8.00	1.34	67%	5.38	5.44	0.99
Embedded Metal	1.0	Cwt	2.15	2.15	-	-		0.00	0%	2.15	2.18	0.99
Pour Concrete	5.0	Cy	1.05	5.25	-	-		0.00	0%	5.25	5.32	0.99
Subtotal Walls & Piers				**73.53**		**35.75**	**28.00**	**1.28**	**49%**	**37.78**	**38.25**	**0.99**
Total Concrete				**136.53**		**98.75**	**100.00**	**0.99**	**72%**	**37.78**	**38.25**	**0.99**

the labor inefficiencies caused by a delay, disruption, or interference on a project. Previously, Zink published articles on the general methodology of the measured mile [3, 4, 5]. It was this now widely accepted hypothesis that if it can be determined that there is a period of unhindered or least hindered time on a project in which the labor expended reflects an efficient use of the labor force, then a ratio can be established between physical work accomplished and actual workhours expended. This time and associated percentage of work accomplished and related actual workhours provides a ratio of workhours to percent (workhours/percent) that becomes the measured mile.

The measured mile period is then compared to the impacted period, which in turn allows for a calculation of lost time associated with the impact. Further, if the owner is responsible for the delay or disruption, the contractor may be entitled to a claim for the added labor hours associated with the inefficiency. In some projects, the impact is very clear, such as in the case of acceleration. If the first 60% of the project were proceeding at a normal 40-hour workweek for 8 months and for 8 months a reasonably consistent level of productivity was achieved, then if for whatever reason the owner directed the contractor to accelerate the completion of the project by working 7-tens starting on the first day of the ninth month, the resultant loss of productivity becomes apparent. Figure 1 illustrates the measured mile comparison.

Labor productivity would be measured subsequent to the authorization of this acceleration and compared to the previous period. The contractor, however, has the burden of establishing a causal link between the impact caused by the owner and the contractor's increased time and cost. The measured mile approach has been found to be a reasonable approximation of those actual costs incurred.

The key advantage of a measured mile approach is that it relies on data agreed to by the architect and owner's representative on a contemporaneous basis during the actual contract performance. The labor productivity levels for both the measured mile and the impact periods are derived from project records, certified payroll, and pay applications.

Table 3

Activity	Quantity Installed	Unit	Estimate Unit Rate	Estimated Manhours	Labor Rate	Labor Dollar	Markup	Total Labor Dollars in Pay App (with markup)
			Contractor Estimate					
Footings								
Set and Strip Forms	100.0	Sf	0.33	33.00	$ 40.00	$ 1,320.00	$ 198.00	$ 1,518.00
Reinforcing Steel	10.0	Cwt	1.95	19.50	$ 40.00	$ 780.00	$ 117.00	$ 897.00
Embedded Metal	-						$ -	$ -
Pour Concrete	10.0	Cy	1.05	10.50	$ 40.00	$ 420.00	$ 63.00	$ 483.00
Subtotal Footing				**63.00**		**$ 2,520.00**	**$ 378.00**	**$ 2,898.00**
Wall & Piers								
Set and Strip Forms	100.0	Sf	0.50	50.00	$ 40.00	$ 2,000.00	$ 300.00	$ 2,300.00
Reinforcing Steel	7.5	Cwt	2.15	16.13	$ 40.00	$ 645.00	$ 96.75	$ 741.75
Embedded Metal	1.0	Cwt	2.15	2.15	$ 40.00	$ 86.00	$ 12.90	$ 98.90
Pour Concrete	5.0	Cy	1.05	5.25	$ 40.00	$ 210.00	$ 31.50	$ 241.50
Subtotal Walls & Pie				**73.53**		**$ 2,941.00**	**$ 441.15**	$ 3,382.15
Total Concrete				**136.53**	**$ -**	**$ 5,461.00**	**$ 819.15**	**$ 6,280.15**

Table 4

Activity	Pay Application: Total Labor Dollars in Pay Application (with Markup)	Percent Earned	Earned Labor Dollars	Weight Percent Earned	Progress: Actual Manhours	Actual Manhours Per Percent Complete	To Complete: Percent Remaining	To Complete Manhours
Footings								
Set and Strip Forms	$ 1,518.00	100%	$ 1,518.00		36.00			
Reinforcing Steel	$ 897.00	100%	$ 897.00		24.00			
Embedded Metal	$ -		$ -					
Pour Concrete	$ 483.00	100%	$ 483.00		12.00			
Subtotal Footing	**$ 2,898.00**		**$ 2,898.00**	**100%**	**72.00**			
Wall & Piers								
Set and Strip Forms	$ 2,300.00	50%	$ 1,150.00		20.00			
Reinforcing Steel	$ 741.75	67%	$ 496.97		8.00			
Embedded Metal	$ 98.90		$ -					
Pour Concrete	$ 241.50		$ -					
Subtotal Walls & Piers	**$ 3,382.15**		**$ 1,646.97**	**49%**	**28.00**			
Total Concrete	**$ 6,280.15**		**$ 4,544.97**	**72%**	**100.00**	**1.38**	**28%**	**38.18**

By employing the above crosschecks and adjustments, and having the parties work together on progress monitoring, the criticisms of using percent of labor as a measured mile are minimized. The labor percent complete is preferred over attempting to isolate a single commodity such as the installation of 1" conduit because there are many more construction activities associated with the success of the installation than just installing the conduit. It is important to note that it is widely recognized that the measured mile approach avoids the shortcomings of industrial studies or estimating guidelines because it is tied to the actual performance at the job site.

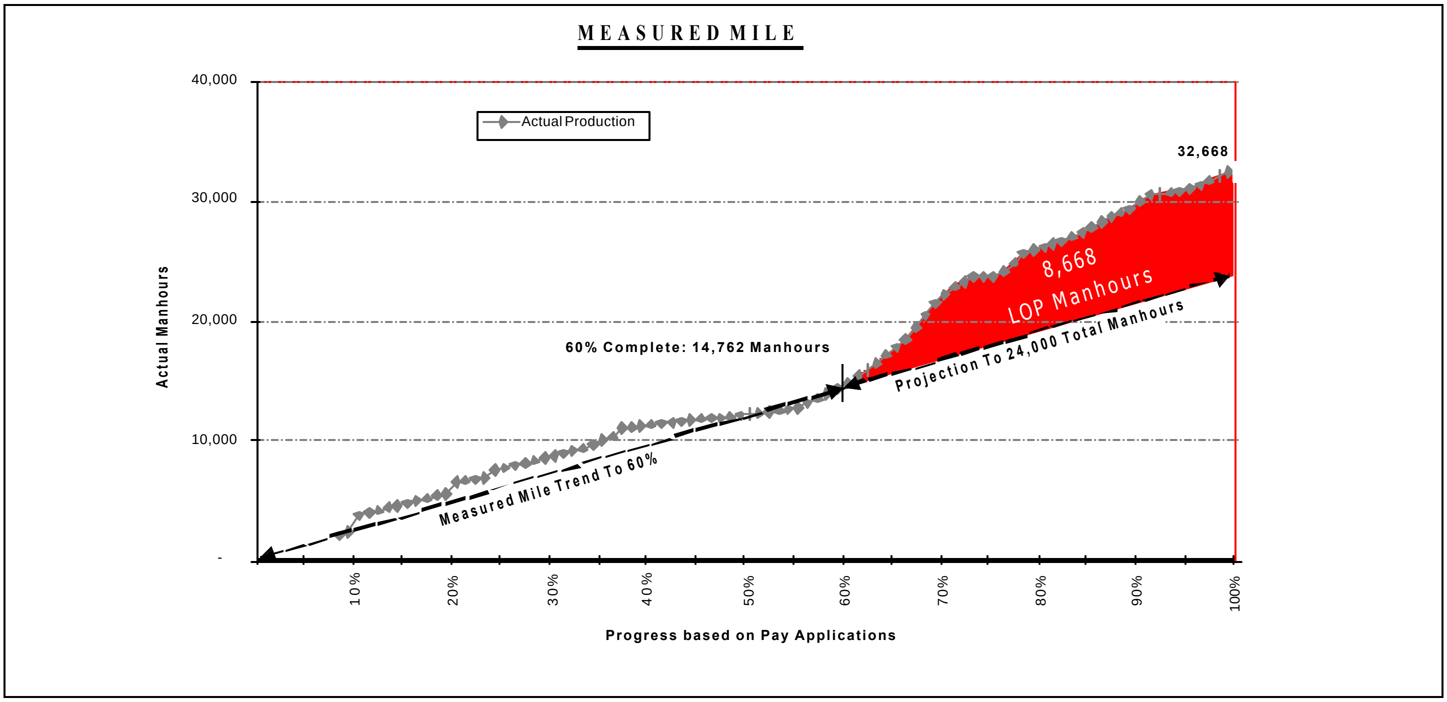

Figure 1

SUPPORT OF THE APPLICATION

One of the more common criticisms of a measured mile analysis is that some practitioners allege that a measured mile can only be performed on same or identical work activities. An example of one such position is that one can only measure productivity of exactly the same type of work, such as installing one-inch branch conduit on the third floor of the building, and this cannot be compared to the labor productivity of two-inch feeder conduit on the fourth floor of the building. However, in a recent government contract case from September 2001, the US Department of Veterans Affairs Board of Contract Appeals ruled that a contractor could use the measured mile method of calculating labor productivity, even though it was impossible to compare identical impacted and less impacted work activities [2].

The contractor in this case was P.J. Dick Inc. (PJD), who was awarded a contract by the VA to construct a clinical addition to a medical center in Ann Arbor, MI. PJD subcontracted the electrical work to Kent Electrical Services (KES), on a time and material basis. PJD alleged that the VA's electrical design was incomplete and in error, and these problems resulted in delays and inefficiencies. The VA refused to grant a time extension and ordered Dick to accelerate. Dick's subcontractor, Kent, was forced to add crews and perform the work in an accelerated, disruptive manner. Dick paid Kent for all the increased labor required and then pursued a claim against the VA. Dick's expert, Mr. Apprill, used a measured mile analysis. Mr. Apprill determined that all installation of branch circuits had been affected by design problems or acceleration. He examined other electrical work performed and determined that the installation of feeder circuits was sufficiently similar to branch circuit installation. Both branch and feeder circuits use the same basic materials of conduit and wire and were installed by union electricians. However, feeder circuits were long continuous vertical runs of large size conduit and did not involve any device installation. Mr. Apprill compared the branch circuit work against productivity achieved on the installation of feeder circuits prior to the acceleration.

The VA's expert expressed a general objection to the measured mile methodology on the basis that feeder circuit work is not the same as branch work. The expert argued that the measured mile methodology requires good and bad period productivity performance of one crew performing the same work and that since the feeder and circuit work involved different crews, Dick's measured mile analysis was fatally flawed. The VA Board of Contract Appeals disagreed. "We find no basis to conclude that either the productivity of the same crew or 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 Contractors, Inc., 99-1 BCA 30,280* [1]:

> (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 inefficiency 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.
>
> On balance, we find that Mr. Apprill's approach to quantification of the VA-caused productivity loss is reasonable and valid. We recognize that feeder circuit work generally involves installation of larger sized electrical conduit and wire in longer, straighter conduit runs. However, KES' labor for feeder circuit installation was drawn from the same labor pools used for branch circuit work, and

> the skills, knowledge, and effort involved in feeder circuit work are reasonably similar enough to branch circuit work to permit a valid comparison. The work was performed in the working conditions planned and budgeted by KES. Consequently, we find PJD's measured mile analysis to be a reasonable approximation of the effect of the VA-caused inefficiencies under the Clark Concrete Contractors standard."

In addition to providing the above clarification that the work need not be identical, the board goes on in a quantum discussion to describe the merits of the measured mile analysis.

> We, as most other courts and boards, recognize that quantifying the loss of labor productivity is difficult and that the determination of the dollar amount of damages for labor inefficiency with exactitude is essentially impossible. In recognizing this fact, we expect that measurement of the amount of inefficiency would usually be supported by expert testimony. The use of a "measured mile" analysis developed by a qualified expert is recognized as the most reliable, though not exact, methodology to quantify labor inefficiency. Clark Concrete Contractors, Inc. GSBCA No. 14340, 99-1 BCA 30,280; W.G. Yates & Sons Construction Company, ASBCA No. 48,398, 01-2 BCA 31,428; *U.S. Industries, Inc. v. Blake Construction Co.*, 671 F.2d. 539 (D.C. Cir. 1982); *Luria Bothers & Co. v. United States*, 369 F2d. 701 (Ct. Cl. 1966).

In the Clark Concrete Contractors case the General Service Board of Contract Appeals upheld Clark's use of a measured mile analysis to quantify labor productivity decreases as a result of the government's design changes. Clark Concrete Contractors, Inc., was contracted to build an FBI field office in Washington DC. As a result of the Oklahoma City bombing, federal building designs were changed in order to make the structures more blast proof. As a result of the late design changes, Clark's labor costs were impacted. Clark used a measured mile analysis comparing the unaffected work prior to the design changes and the affected work after. Clark made adjustments to the measured mile due to the floor elevation and type of construction. The government characterized the Clark measured mile as a total cost method of pricing a claim. The board ruled that the measured mile analysis was the preferred method and a reasonable method to calculate lost labor and efficiencies. The board did selectively agree or disagree with some of Clark's measured mile adjustments.

The courts generally recognize the validity of loss of efficiency claims based on the measured mile analysis. While there are many methods of computing such damages, the use of a measured mile analysis, properly developed by a qualified expert, is the most reliable.

The success or failure of a construction project often rides on the shoulders of labor productivity. Therefore it is incumbent upon the industry to educate and understand the basis for measurement and monitoring of labor productivity. If a project's planning and budget allow for the assignment of cost engineers and quantity surveys, the project has an extremely high probability of success. Also, should occurrences, problems, and/or events be introduced into a project, it is critical for management to recognize the importance and return on investment of employing onsite monitoring of the labor productivity. The measured mile technique provides the avenue for loss of productivity mitigation and labor impact analysis.

REFERENCES

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