The measured mile: How to conduct the analysis

Robert J Gemmell and Professor Randolph Thomas

This article quantifies loss using the measured mile method.

INTRODUCTION

“The Quantification of Loss Caused by Disruption: How Applicable is the Measured Mile Method?” published in the December edition of this journal, examined the measured mile method to estimate loss caused by disruption to the progress of a construction project by providing an overview of the methodology, a literature and case law review and guidance on how a measured mile analysis should be conducted.

This article goes one step further. In this article the authors quantify loss using the measured mile method in 11 clear steps using the guidance in the previously published article. This article can be read as a standalone article. Some of the essential material from the previous article is restated – however, this has been kept to the minimum necessary in order to fully understand the 11 steps used here.

Due to the limitations of the measured mile method, suggested improvements to the method will need to be addressed in a later article.

IMPACT OF CHANGE

To demonstrate the impact that change has on the progress of construction projects, this article will review data collected and analysed by Ibbs and Leonard.

Ibbs and Leonard both conducted research on construction projects and identified a correlation between the number of project changes and the corresponding impact on labour productivity at the end of the projects.

Leonard analysed 57 construction projects on which there were 90 disputes and developed change versus productivity loss graphs. Ibbs analysed data from 170 public and private sector projects over a 12-year period, which ranged in value from US$2 million to US$14 billion.

Leonard’s work

Leonard’s work for electrical/mechanical contracts is represented graphically in Figure 1.

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Figure 1 shows three curves. The bottom curve represents projects which were affected just by variations. However, the middle and top curves represent projects which were also affected by other causes of loss of productivity, for example, change of sequence of work and late supply of information. Figure 1 illustrates the percentage of loss of productivity as a ratio of impacted labour-hours to actual original contract labour-hours on work not changed.

Ibbs\(^4\) points out that the Leonard work has not always been accepted as the projects that Leonard researched were already in dispute and therefore the loss of productivity may be “skewed to the ‘more disturbed’ end of the spectrum”. Leonard’s data set is also smaller in scope than Ibbs’ and the average project value of Leonard’s projects was about CAN$4 million. Further, Leonard did not define “other major causes” so it is not possible to understand the scope of these “other major causes”.

Ibbs’ data is represented in Figure 2.

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Figure 2 shows two curves. The bottom curve shows Ibbs’ data from his 2005 studies and the top curve shows Ibbs’ and Allen’s data from 1995. Like Figure 1, Figure 2 illustrates the percentage of lost productivity (vertical axis) compared to the percentage of change orders (horizontal axis).

Figure 2 again shows that, as the amount of change increases, the productivity of the contractor decreases and progress becomes less efficient. A review of both Ibbs’ and Leonard’s graphs leads to this same conclusion, as they show the same trend and become very similar for a higher number of changes. Ibbs points out that “at 40% change, Leonard predicts 29% productivity loss and Ibbs, 27%. At 50% change, Leonard predicts 30% and Ibbs, 34%.”

Therefore, on the basis of the Ibbs and Leonard data, it is reasonable to conclude that the results demonstrate that, the more the project changes, the higher the impact on productivity and the higher the productivity loss. This article will quantify such loss using the measured mile methodology.

Causes of disruption

The SCL Protocol states that “the most common causes of disruption are loss of job rhythm (caused by, for example, premature moves between activities, out of sequence working and repeated learning cycles), work area congestion caused by stacking of trades, increase in size of gangs and increase in length or number of shifts. But these are also symptoms of poor site management.”

However, the AACE\(^6\) goes further and identifies the following factors that cause and/or contribute to loss of productivity: absenteeism; acceleration (directed, or constructive); adverse, or unusually severe, weather; availability of skilled labour; variations, ripple impact, cumulative impact of multiple changes and rework; competition for labour; labour turnover; crowding of labour, or trade stacking; defective engineering, engineering recycle, or rework; dilution of supervision; excessive overtime; failure to coordinate trade contractors, subcontractors, or vendors; fatigue; labour relations and labour management factors; learning curve; material, tools and equipment shortages; over-manning; poor morale of labour; project management factors; out-of-sequence work; rework and errors; schedule compression; site, or work area access restrictions; site conditions; and untimely approvals or responses.

Productivity v production

To understand the example given in this article, it is necessary to understand the difference between productivity and production – they are not the same. Production measures output, for example, 26 structural steel members were installed on Day 18. Production is the rate of production/output, for example, on average from Day 2 to Day 11, 1.466 structural steel members were installed per hour.

A contractor may therefore achieve its target production but at a lower than anticipated productivity level but achieve that production level by working overtime or by using more resources. Therefore, although production may not be impacted, productivity may have been.

It is therefore not correct that if production is reduced by 25% there is a corresponding 25% reduction in productivity.

Productivity, on the other hand, is the amount of resources required to produce a unit of production. The most common definition of productivity is the unit rate, expressed as the man-hours per unit, ie man-hour/meter, man-hour/cubic meter, and so forth.

Methods of calculating loss of productivity

There are several methods of calculating loss of productivity which include: actual costs, total and modified total cost, project comparison studies, specialty industry studies, general industry studies and the measured mile, system dynamic modelling and earned value analysis.

Of these methods, the measured mile is considered to be the most robust and reliable method because, compared to other methods, it is based on contemporaneous project documentation and

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\(^5\) Delay and Disruption Protocol (Society of Construction Law 2002, March 2003 reprint) 32.

knowledge from the project and, importantly, it also calculates loss of productivity due to the actual effect of alleged impact which helps to eliminate disputes over the validity of cost estimates, or factors that may have impacted productivity due to no fault of the owner.

**THE MEASURED MILE METHOD**

The measured mile method is used to estimate loss of productivity due to an impact on the progress of a construction project.

**What is the measured mile method?**

The SCL Protocol states:

> 1.19.7 … The most appropriate way to establish disruption is to apply a technique known as the “measured mile”. This compares the productivity on an unimpacted part of the contract with that achieved on the impacted part. Such a comparison factors out issues concerning unrealistic schedules and inefficient working. The comparison can be made on the man-hours expended, or the units of work performed.

In *Clark Concrete Contractors Inc v General Services Administration*, the court said that a measured mile analysis compares work performed in one period not impacted by events causing loss of productivity with the same, or comparable work performed in another period that was impacted by productivity-affected events. The difference is the loss associated with the disruption and used to calculate loss of productivity. The loss of productivity is calculated in labour-hours which in turn are multiplied by the labour rate to obtain the cost of the loss of productivity.

Schwartzkopf and McNamara say that:

> The most widely accepted method of calculating lost labor productivity is known throughout the industry as the “measured mile” calculation. This calculation compares identical activities on impacted and non-impacted sections of the project in order to ascertain the loss of productivity resulting from the impact…

**Current practice**

Unfortunately, there are no procedures to define how to conduct a measured mile analysis. There are many decision points in an analysis, and the analyst is left to their own devices to select procedures that will work. Sometimes procedures are chosen to achieve a desired outcome.

A comprehensive review of judicial cases has been conducted to determine the most frequent reasons why the measured mile technique was rejected by a judicial body. The most common reasons were:

- Work during the unimpacted (baseline) period and the impacted period is not comparable.
- The analysis makes use of cumulative data.
- There is no cause–effect analysis.
- Characterising an unconventional analysis as being a measured mile analysis when it isn’t.
- Using unconventional methodologies to calculate losses.

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7 AACE International Recommended Practice, n 6.
9 *Delay and Disruption Protocol*, n 5, 32.
10 *Clark Concrete Contractors Inc v General Services Administration* 99-1 BCA 30280 (1999), GSBCA No 14340.
How the measured mile analysis should be conducted

A measured mile analysis is performed under the following headings: 13

- Step 1: Define the performance measure;
- Step 2: Reconcile the data;
- Step 3: Decide on the scope of analysis;
- Step 4: Partition into periods;
- Step 5: Plot performance (productivity) curve;
- Step 6: Determine unimpacted and impacted periods;
- Step 7: Calculate the datum from which damages are measured;
- Step 8: Validate percentage of production;
- Step 9: Calculate inefficient work hours;
- Step 10: Cause–effect analysis; and
- Step 11: Validate the analysis.

CASE STUDY PROJECT

A case study of the erection of a four storey steel frame building has been used to illustrate the procedure for conducting the measured mile. The superstructure consisted of bolted connections and 406 pieces of steel.

The work was performed by a crew of four ironworkers and was monitored for 22 working days. The work was plagued by fabrication errors.

The daily productivity of the erection crew, expressed as work hours (wh) per piece (beams, columns, major pieces), is shown in Figure 3. The construction performance was consistent for the first 11 work days and the workforce was able to accommodate any disruption until Day 12. Thereafter, performance deteriorated.

Step 1: Define the performance measure

In order to compare construction labour performance in the unimpacted period with that in the impacted period(s), it is necessary to establish a definition of performance. Performance requires inputs and outputs. The performance measure used in this article is the “unit rate” for example: daily, weekly or monthly work hours per unit of work.

The most common definition of performance is:

\[
\text{Productivity (the unit rate)} = \frac{\text{Work hours}}{\text{Quantities (commodity items)}}
\]

If the unit rate is calculated pursuant to the above formula, a lower unit rate value will mean a higher productivity than a higher unit rate. This is because fewer resources are required per unit of work and hence a lower cost per unit.

It is recommended that labour performance if at all possible should not be based on cost. The reason is that cost is affected by factors unrelated to productivity, for example, labour rates may be impacted by labour availability, increase over time due to inflation, crew sizes and labour functions changing.

The units of work in the unit rate should be commodity items, for example m² of partition wall, or m³ of concrete, or linear metres of pipe. 14 However, contractors often do not track work completed on a commodity item basis. In this case the analyst will have to use an alternative to using commodity items in the calculation of productivity.


14 Thomas and Barnard, n 13, 16.
An alternative to using a commodity item, could be to use m² of area completed, for example wall or floor area completed. However, an analyst must exercise caution when using area completed as area completed may comprise several commodity items and lessen the accuracy and increase the subjectiveness of the calculation.

The calculation of loss of productivity and the corresponding loss is an estimate and is therefore not exact. It is therefore essential that the most accurate estimate available is conducted. The unit rate is the most accurate measure of performance. A percentage of work complete per workhour will be less accurate and could be unreliable.

A productivity analysis may be carried out, not only on labour, but also in relation to plant and equipment. Plant and equipment have output ratings. However, the output of a fleet may vary due to variances and changes in the makeup of the fleet. The performance measure of plant and equipment should therefore be a function of fleet capacity, and not time related.

**Step 2: Reconcile the data**

It is necessary to ensure that the data being used is correct and reliable. The analyst should appreciate that it is not uncommon for a contractor to inadvertently record data incorrectly. For example, the contractor’s administration department may book several months of labour resources all together in the final two weeks of the two months. This may be because the recording of labour hours is not done on a regular basis, for example, recorded each day or week. This may result in the appearance of low labour resources for the first six weeks then a very high level of resources for the remainder of the period for which labour hours are being recorded. An examination of timesheets may reveal that the labour resources were in fact consistent throughout the period being recorded.

In judicial proceedings, incorrectly recorded data must be identified and corrected and it will be necessary to explain any adjustments made.

On occasions a main contractor may decide to engage a subcontractor to carry out work that it planned and intended to perform. Again, it may be necessary to make adjustments to the account to reflect this change from the intended program and any inadvertent over-reporting of production.

A method to detect errors in a contractor’s data recording system is to plot the quantities of work installed in a reporting period using the contractor’s original data set. This will make it easier for the analyst to detect unusually high or low production.

Without making corrections to account for any mistakes and/or adjustments in the contractor’s accounts it will be unknown whether any or all subsequent productivity calculations are flawed. Making the correct adjustments, if required, will require the analyst to make good judgment.

Contractors may do strange and unexplained things with their records. These issues must be identified, and the analyst must explain how the issues were handled. If not, it may appear that the analyst manipulated the contractor’s data to achieve a desired outcome. If this corrective action is not undertaken, the analysis may not be correct.

**Step 3: Decide on the scope of analysis**

It will be necessary for the analyst to decide on how many and which tasks will be combined. This will depend on which tasks have been impacted. On occasions it is only necessary to analyse one task, or several tasks individually. However, a much more difficult situation is where multiple tasks are required to be analysed at once. Thomas points out that one “primary cause of rejection of a measured mile analysis is that too many tasks are grouped together or the grouping was done improperly”.

**Step 4: Partition into periods**

It is often necessary for the analyst to partition the overall project into several parts and conduct a separate analysis for each part. For example, the analysis of a building may be partitioned into the following different phases: foundations, superstructure, and services and finishes.

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Thomas and Barnard, n 13, 25. 

(2016) 32 BCL 6 11
A separate measured mile analysis may be required for each phase.

**Step 5: Plot performance (productivity) curve**

It is now possible to plot a graph of the unit labour productivity or performance of each phase of the work. These productivity curves are important analysis tools, because they may show the unimpacted and the impacted periods in which there were disruptions and labour inefficiencies. Figure 3 is an example of productivity plots.

This curve identifies the impacted and unimpacted periods.

**FIGURE 3  Daily productivity of steel erection activity**

![Graph showing daily productivity of steel erection activity](image)

Vertical axis = productivity (wh/piece)

Horizontal axis = Work day

Figure 3 shows the daily productivity of a structural steel erection crew, expressed as work hours (wh) per piece (beams, columns, major pieces).

Figure 4 is a production graph for the erection of the same crew. The figure shows the output in pieces erected for the crew for each work day. Using Figure 4, a common argument that would be made is that Days 2 to 11 were unimpacted and the last 11 days were impacted. But Figure 4 tells a different story about the disruptions on the steel frame building because high and low production work days are scattered throughout all 22 work days. Actually, Days 2 to 11 were disrupted by equipment breakdowns, fabrication errors, and adverse weather. Figure 4 is a more accurate reflection of how the activity was disrupted.
Step 6: Determine unimpacted and impacted periods

The graphs in Step 5 are used to identify the impacted and unimpacted periods. The periods are determined uniquely for each project and phase of each project. A detailed knowledge of the history of the project is important.

The reason for identifying and defining unimpacted periods is that these timeframes are used to calculate the baseline from which loss of productivity is estimated. The unimpacted periods should be based on the high levels of production – production being output, i.e., the number of units installed per period of time, for example, 7.8 pieces of steel were installed on Day 17.

Then transitioning from an unimpacted to an impacted period or vice-versa, this period should correlate with an event that explains the transition.

Figure 3 shows a situation where the alleged unimpacted period occurs during Days 2 to 11. The alleged impacted period occurs during Days 12 to 22.

Step 6a: Impacted period

The measured mile method compares actual labour performance during an impacted period with the actual labour performance in the unimpacted period. Both these periods therefore need to be identified.

The analyst, having to identify the impacted periods, should prepare graph(s) of productivity to identify the periods of disruption. A graph of the labour productivity for each phase of the project should be plotted which will show both the unimpacted and impacted periods.

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17 Thomas and Barnard, n 13, 31.
If there are no productivity records, it may be possible to estimate the percent complete of a project to estimate the quantities in the unimpacted parts of the analysis. The percent complete approach is generally much less reliable because it is based on an estimate, or a guess.\textsuperscript{18}

However, to plot the productivity graph, if possible, the quantity of work per labour-hours as a measure of productivity should be used, or, if this is not possible, work per percent project complete.\textsuperscript{19}

**Step 6b: Unimpacted period/measured mile**

*Continuous period of time*

The unimpacted/measured mile period is “a continuous period of time when labour productivity is unimpacted”.\textsuperscript{20} Even though there may be inefficiencies for which the contractor is responsible in the continuous unimpacted period, ideally, this period should be free from all client-caused impacts.

**Selection of similar work to impacted period**

It will be necessary to identify an unimpacted period that is the same as or similar to the impacted disrupted period.\textsuperscript{21} It is important when comparing labour productivity that the tasks being compared are substantially similar.\textsuperscript{22} It is also necessary to ensure that workers in the unimpacted period have comparable skill levels to the workers in the impacted period, the work carried out should represent an attainable level of productivity; and the work was carried out in an environment similar to the work carried out in the impacted period.

**Use of productivity graphs**

To identify the unimpacted period, productivity graph(s) for the entire project period which were prepared to identify the impacted period(s) should be used, and the quantities of work installed during the unimpacted period (and impacted period) should be recorded.\textsuperscript{23}

**Adjustments/corrections**

The analyst should consider and adjust productivity calculations as necessary to account for discrepancies between the impacted and unimpacted management and supervision, work hours, project program, site logistics, weather conditions, and trades to carry out the work.\textsuperscript{24} These factors can change over time, ie from the unimpacted to the impacted period. The analyst should therefore also note and take into account that the work environment of a project changes as the project progresses and early phases can be very different from the later phases. The environment will change with more congestion, changes, subcontractors etc.\textsuperscript{25}

**Identification of workers**

Workers with a similar level of skill and knowledge as those in the impacted period should be identified. The same or similar labour pool is therefore desirable. For example if one crew is composed of five journeymen and five apprentices, it may not be comparable to a crew of two journeymen and eight apprentices even though the crew size of both is ten craftsmen.

\textsuperscript{18} Thomas and Barnard, n 13.


\textsuperscript{20} Thomas and Barnard, n 13.


\textsuperscript{22} Thomas and Barnard, n 13, 18.

\textsuperscript{23} Thomas and Barnard, n 13.

\textsuperscript{24} Zink, n 16, 19-21; AACE International Recommended Practice, n 6; Thomas, n 21; Appeal of Bay Construction VABC No 5594, 02-1 BCA WL 442118 (2002).

\textsuperscript{25} Thomas, n 21.
Separation of labour trades

If possible, the analyst should separate the loss of productivity by labour trade. This will provide a more accurate picture of which labour resources have and have not been impacted.

Owner-collected data

The analyst should use owner-collected data if it is available as it will be more difficult for the owner to rebut the contractor’s evidence if it is taken from owner-collected sources. Inevitably, however, much of the data will have to come from the contractor’s own records.

The unimpacted period, the measured mile period, and unhindered productivity

The analyst should ensure that the unimpacted period used contains contractor unhindered productivity.

To do this, the analyst should identify and adjust as necessary for contractor-caused hindrances and will need to explain the adjustments.

However, the analyst may need to use conversion factors to allow for differences that may exist between impacted and unimpacted periods.

Other sources: If measured mile productivity actual project data is not available

If it is not possible to calculate a measured mile using actual project data, it may be possible to use other sources of information, for example, to supplement the analysis using published industry estimating guides, productivity data from different projects constructed by the same contractor or by similar contractors, and/or cost as a percentage of completed work and/or earned value rates.

Step 7: Calculate the datum from which damages are measured

This step uses the productivity data for the unimpacted periods to calculate the baseline, ie the measured mile. The baseline is calculated differently depending on whether the baseline is continuous (measured mile) or intermittent (baseline productivity). The measured mile is based on a continuous baseline and is the basis of this article.

If the unimpacted period occurs at the beginning of the project, and/or the beginning of an activity, the analyst needs to calculate the cumulative productivity (wh/unit) at the end of the unimpacted period.

Step 8: Validate percentage of production

It is important that the performance during the unimpacted period is based on a reasonable amount of production. In this case study, the percentage of production during Days 1 to 11 was 44%. This pattern of production is typical of most construction projects.

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26 Appeal of Bay West, ASBCA No 54166, April 25, 2007.
28 Lamb Engineering & Construction Eng, EBCA No C-9304172; Department of Energy Board of Appeals 97-2 BCA (CCH) P29,207; 1997 EBCA LEXIS 7 (July 28, 1997); Luria Brothers v United States 369 F2d 701 (Ct Cl 1966); Southern Comfort Builders Inc v United States, No 00-542C (July 29, 2005).
29 Luria Brothers v United States 369 F 2d 701 (Ct Cl 1966).
31 AACE International Recommended Practice, n 6.
33 Bell BCI v United States 72 Fed Cl 164, 168 (2006); AACE International Recommended Practice, n 6.
Step 9: Calculate inefficient work hours

The following are the variables:

\[ i = \text{work day} \]
\[ xi = \text{work hours} \]
\[ qi = \text{total quantity} \]
\[ yi = \text{should have} \ (qi \times \text{baseline productivity}) \]
\[ xi - yi = \text{inefficient work hours} \]

The impacted days in the erection of the steel frame building are 1, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 22. The first reporting period is therefore Day 1. Nothing was installed so \( qi \) is nil. However, nothing should have been installed on Day 1. Therefore \( yi \) is also nil. There were 30 work hours charged in Day 1. The inefficient work hours are therefore 30 hours, ie \( xi \) (30 hours) less \( yi \) (nil hours).

It is necessary to calculate loss of efficiency hours for each day. An example of that calculation is for Day 17 as follows:
- There were 48 work hours on Day 17;
- 7.8 pieces were installed (see production data);
- Had the work been carried out at the productivity rate achieved during the undisrupted period (ie 1.346 work hours per piece), 7.8 pieces would have been installed in 10.5 work hours; and
- There were therefore 37.5 inefficient work hours (ie 48 work hours actually undertaken less 10.5 work hours it should have taken) on Day 17.

If this analysis is conducted for the remaining impacted days, 348.10 inefficient work hours are calculated as set out in Table 1:

### TABLE 1 Calculation of inefficient work hours

<table>
<thead>
<tr>
<th>Work day ( (i) )</th>
<th>&gt;Work hours ( (xi) )</th>
<th>Total Qty ( (qi) )</th>
<th>Should have ( (yi) )</th>
<th>Inefficient Work hours ( (xi - yi) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.00</td>
<td>0.00</td>
<td>0.00</td>
<td>30.00</td>
</tr>
<tr>
<td>12</td>
<td>32.00</td>
<td>0.00</td>
<td>0.00</td>
<td>32.00</td>
</tr>
<tr>
<td>13</td>
<td>45.50</td>
<td>0.00</td>
<td>0.00</td>
<td>45.50</td>
</tr>
<tr>
<td>14</td>
<td>38.00</td>
<td>0.00</td>
<td>0.00</td>
<td>38.00</td>
</tr>
<tr>
<td>15</td>
<td>48.00</td>
<td>6.30</td>
<td>8.40</td>
<td>39.60</td>
</tr>
<tr>
<td>16</td>
<td>48.00</td>
<td>37.05</td>
<td>49.60</td>
<td>0.00</td>
</tr>
<tr>
<td>17</td>
<td>48.00</td>
<td>7.80</td>
<td>10.50</td>
<td>37.50</td>
</tr>
<tr>
<td>18</td>
<td>48.00</td>
<td>26.05</td>
<td>34.90</td>
<td>13.10</td>
</tr>
<tr>
<td>19</td>
<td>48.00</td>
<td>7.30</td>
<td>9.80</td>
<td>38.20</td>
</tr>
<tr>
<td>20</td>
<td>9.00</td>
<td>0.00</td>
<td>0.00</td>
<td>9.00</td>
</tr>
<tr>
<td>21</td>
<td>48.00</td>
<td>0.00</td>
<td>0.00</td>
<td>48.00</td>
</tr>
<tr>
<td>22</td>
<td>40.00</td>
<td>17.00</td>
<td>22.80</td>
<td>17.20</td>
</tr>
</tbody>
</table>

**Total:** 348.10
Data testing
The data used to calculate productivity must be tested. The accuracy of the data being used is critical to a reliable analysis. The analyst must therefore ensure that the data reported is correct, and if it is not, it should be corrected.

Productivity factors
Loss of productivity factors should be applied to just the disrupted labour. It may be necessary to combine tasks rather than just analysing each task individually. However, a primary reason for the measured mile analysis being rejected is that too many tasks are combined or that the combination is inappropriate.

Adjustments to be made
It is necessary to make adjustments to calculations, for example, to take account of the learning period in the early phases of the work, any labour-hours included in variations, and any loss not recoverable under the contract and/or the contractor’s own inefficiencies.

Actual costs v unit rate
Actual costs on their own should not be used to calculate labour productivity. This is because costs can be affected by several factors, for example, labour costs may not be recorded in the correct cost code, labour rates change, crew sizes fluctuate and crew functions may also change. The unit rate can be described as “commodity items”, for example, m² of a partition wall, cubic metres of concrete and linear metre of pipe. The unit rate being contrasted with say m² or m³ of floor, this being composed of several “commodity items”, therefore will lead to a less reliable analysis than using the unit rate for the applicable items only.

Step 10: Cause–effect analysis
Damages from a measured mile analysis can be compensable or non-compensable.

Rarely is there a single cause of inefficiency. Some inefficiency may be due to the contractor and are not recoverable and some may be precluded by the contract and are also not recoverable. It is therefore necessary to conduct a cause–effect analysis.

A cause–effect analysis starts with a review of the productivity curve (see Step 5). A review of the productivity curve will identify the period(s) of inefficiency. The productivity graph shows that the last half of this case study was impacted.

However, the impacted periods need to be consistent with the causes of inefficiency. For example, if late approval of shop drawings is the alleged cause of inefficiency, then the inefficiencies will need to have occurred when approval was pending.

A cause–effect analysis involves a search for the reasons why productivity degraded during the impacted period(s). In order to conduct a cause–effect analysis, the analyst will most likely have to review: diaries, production records, photographs and other relevant documents.

54 Dieterle and Gaines, n 27, 29-34.
55 Thomas and Barnard, n 13.
56 AACE International Recommended Practice, n 6.
57 Thomas and Barnard, n 13, 25.
58 Thomas and Barnard, n 13.
59 Appeal of Bay West, ASBCA No 54166, April 25, 2007; AACE International Recommended Practice, n 6.
60 AACE International Recommended Practice, n 6.
61 AACE International Recommended Practice, n 6.
62 Thomas and Barnard, n 13, 17.
63 Thomas and Barnard, n 13, 18.
64 Thomas and Barnard, n 13.
The analyst may also need to conduct interviews with: managers, project engineers, foremen and other relevant people.

A sample diary for the construction of the steel frame building is as follows:

**TABLE 2 Cause–effect of inefficiencies**

<table>
<thead>
<tr>
<th>Work day</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 hr delay – equipment; shakeout</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Rain</td>
</tr>
<tr>
<td>4</td>
<td>Hot-humid</td>
</tr>
<tr>
<td>5</td>
<td>Hot-humid; 2 hr delay – rework, fab errors</td>
</tr>
<tr>
<td>6</td>
<td>Hot; 1 hr delay – equipment</td>
</tr>
<tr>
<td>7</td>
<td>1/2 hr delay – rework, fab errors</td>
</tr>
<tr>
<td>8</td>
<td>1 hr delay – equipment</td>
</tr>
<tr>
<td>9</td>
<td>3 hr delay – equipment</td>
</tr>
<tr>
<td>10</td>
<td>Shower: 45 mins; rework – 2 hrs</td>
</tr>
<tr>
<td>11</td>
<td>Rework – 1 hr</td>
</tr>
<tr>
<td>12</td>
<td>3 hr delay – equipment (2 hrs) and weather (1 hr)</td>
</tr>
<tr>
<td>13</td>
<td>1/2 hr delay – rework, fab errors</td>
</tr>
<tr>
<td>14</td>
<td>2 hr delay – rework, fab errors</td>
</tr>
<tr>
<td>15</td>
<td></td>
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<td>16</td>
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<td>17</td>
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<td>18</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>2 hr delay – rework, fab errors</td>
</tr>
<tr>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>

At this point the analyst should not be interested in which party is at fault, only causation. It is necessary to explain all periods of disruption as some periods of inefficiency may have been caused by the contractor. Even though Days 2, 15 to 20 and 22 are incomplete, the analyst will identify that the main disruptive events affecting the steel erection are:

- Equipment breakdowns;
- Fabrication errors; and
- Adverse weather.
The next step is the apportionment of damages to a cause as follows (Days 1 and 12 to 22 are considered) in Table 3.

### TABLE 3 Apportionment of damages

<table>
<thead>
<tr>
<th>Work day</th>
<th>Inefficient Work hours</th>
<th>Equipment Breakdown</th>
<th>Fabrication Errors</th>
<th>Weather</th>
<th>Unexplained</th>
<th>Shakeout</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.0</td>
<td>8.0</td>
<td></td>
<td></td>
<td></td>
<td>22.0</td>
</tr>
<tr>
<td>12</td>
<td>32.0</td>
<td>16.0</td>
<td></td>
<td></td>
<td></td>
<td>16.0</td>
</tr>
<tr>
<td>13</td>
<td>45.5</td>
<td></td>
<td>45.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>38.0</td>
<td></td>
<td>38.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>39.6</td>
<td></td>
<td></td>
<td></td>
<td>39.6</td>
<td></td>
</tr>
<tr>
<td>16</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>37.5</td>
<td></td>
<td></td>
<td></td>
<td>37.5</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>13.1</td>
<td></td>
<td></td>
<td></td>
<td>13.1</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>38.2</td>
<td></td>
<td></td>
<td></td>
<td>38.2</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>9.0</td>
<td></td>
<td></td>
<td></td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>48.0</td>
<td></td>
<td>21.0</td>
<td></td>
<td>27.0</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>17.2</td>
<td></td>
<td></td>
<td></td>
<td>17.2</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>348.1</td>
<td>24.0</td>
<td>104.5</td>
<td>16.0</td>
<td>181.6</td>
<td>22.0</td>
</tr>
</tbody>
</table>

Inefficiencies on Days 13, 14 and 21 are straightforward as there is only one disruptive event identified and supported by the project records. Therefore, all the inefficient work hours on these days are attributed to that event. The inefficient work hours on Days 15, 17 to 20, and 22 are unexplained. Day 12 poses a unique problem because two disruptive events are noted. There is no procedure to apportion damages between two or more disruptive events so the damages are apportioned equally. As can be seen from this analysis, the contractor can only show potential entitlement for fabrication errors of 141.5 work hours.

**Step 11: Validate the analysis**

There must be a substantial correlation between the inefficient work hours being claimed (ie Days 12 to 22) and the causes of inefficiency. The inefficient work hours from Day 1 to 11 does not form part of the disruption claim and forms part of the measured mile baseline period.

This step therefore requires an analysis of the total timeframe for all impacted and unimpacted periods. The analyst must identify all actual causes of inefficiencies, owner-caused, contractor-caused, weather related or others.

A graphical representation of the inefficient hours per day is in Figure 5:
As can be seen, the total number of inefficient work hours for the total activity is 387. There is substantial correlation between the impacted hours and the diary entries. On balance, it would appear that the analysis is therefore valid and reliable.

**CONCLUSION**

If a measured mile analysis is conducted following the 11 steps set out above (subject to the data being available), the measured mile methodology is robust and is likely to be accepted by a judicial forum.