THE ANALYSIS AND VALUATION OF DISRUPTION

BY DEREK NELSON

HKA

CONTENTS

INTRODUCTION

Complaints of 'disruption' and additional costs are routinely made during the course of a construction project, yet they remain notoriously difficult to prove.

One of the main reasons for this is that productivity losses are often difficult to identify and distinguish at the time they arise, as opposed to other money claims which are more directly concerned with the occurrence of a distinct and compensable event together with a distinct and direct consequence, such as an instruction for a discreet variation during the progress of the works or a properly notified compensation event.

As such, most claims for disruption are dealt with retrospectively and the claimant is forced to rely on contemporary records to try and establish a causal nexus for identified losses (cause and effect) which are all too often inadequate for the purposes of sufficiently evidencing a loss of productivity claim. When this happens the claimant is often forced into the situation where it advances a weak global or total cost claim of sorts to try and recover some of its losses.

The cause and effect burden of proof is the same for a claim for loss of productivity as for any other claim insofar as the claiming party must first establish that the event or factor causing the disruption is a compensable risk event under the contract. To do this, the contract needs to be reviewed to understand the basis of the agreement as certain productivity issues may have been foreseeable and therefore accounted for within the claimant's productivity allowances. The contract may also identify if a party expressly accepted certain productivity risks.

Where courts and tribunals have a clear focus on linking cause and effect, claims for disruption will come under greater scrutiny. It is unlikely that contractors and subcontractors will succeed where their claims for disruption are based simply on a global overspend on labour or plant for the whole of the contract working period. Sufficient detail is required to isolate the cause of the disruption complained of and evaluate the effects of that disruption.

WHAT IS DISRUPTION?

Disruption is loss of productivity, disturbance, hindrance or interruption to a Contractor's normal working methods, resulting in lower efficiency. In the construction context, disrupted work is work that is carried out less efficiently than it would have been, had it not been for the cause of the disruption. If caused by the Employer, it may give rise to a right to compensation either under the contract or as a breach of contract.[1]

Construction contracts have two major types of costs associated with them: fixed and variable.

Fixed costs are those costs that the contractor procures on a fixed-price subcontract or purchase order. Fixed costs are inherently lower in risk, because the contractor has fixed them through a contract. Risks do exist, such as the financial failure or default of either a vendor or subcontractor or the installation of defective or faulty work by a subcontractor or vendor, but the risks are much less than the risks in variable-cost items.

Variable costs are items such as the contractor's labour, equipment, and site overhead. Extensive literature has been published about delay claims, which principally are claims related to the extended duration of the job and the resulting extended site overhead costs. However, the major variable risk component on a construction project is labour, not extended site overhead. Equipment, on certain types of construction such as utility, heavy, and highway construction, can be a significant cost; however, equipment costs tend to be proportional to labour costs. It is uncommon to have significant increases in equipment costs without significant increases in labour costs.

On many construction projects, the largest single area of cost overrun is in labour costs. This is not surprising given that labour is frequently the largest variable cost for a contractor. Claims involving lost productivity are frequently referred to as disruption claims.

[1] SCL Delay and Disruption Protocol: October 2002.

WHAT IS PRODUCTIVITY?

Productivity = Production Output/Resource Input
= 4 m of 4" pipe/labour-hour

Productivity Ratio = Actual Productivity/Planned Productivity
= 3 m per hr/4 m per hr
= 0.75

WHY IS PRODUCTIVITY IMPORTANT?

Hypothetical Project Cost Components		
Labour	40%	Often the largest cost component; Most volatile cost component; and Most critical cost to control
Materials	40%	
General Conditions and Indirect Costs	10%	
Overhead	5%	
Profit	5%	
Total	100%	

Should the above project suffer a 12.5% overrun on the labour cost component:

Hypothetical Project Cost Components			
Labour	40%	→ 45%	Arising from a 12.5% overrun on labour content
Materials	40%		
General Conditions and Indirect Costs	10%		
Overhead	5%		
Profit	5%	0%	A 12.5% overrun on labour content Wipes out all profit on the project
Total	100%		

The existence of a labour cost overrun is not proof that an event entitling a contractor to damages has occurred. Clearly labour cost overruns can occur for a variety of reasons, not all of which entitle a contractor to compensation.

One of the most contentious areas in construction claims is the calculation or estimation of lost productivity. Unlike direct costs, lost productivity is often not tracked or cannot be discerned separately and contemporaneously. As a result, both causation and entitlement concerning the recovery of lost productivity can be difficult to satisfactorily establish.

Compounding this situation, there are numerous ways to calculate lost productivity and no uniform agreement within the construction industry as to a preferred methodology of calculating lost productivity. Many methods of calculation are open to challenge with respect to their validity and applicability to particular cases, thus making settlement of the issue on a particular project potentially problematic.[2]

Within the past 20 years, there has been significant research in construction labour productivity which provides an increasing body of empirical data as to the effects of various factors on construction labour productivity. Some of the difficulties in applying that data to a specific project is outlined herein.

BACKGROUND

Project changes, disruptions, cumulative impacts, and factors affecting labour productivity have strong interrelationships. They also play a vital role in establishing liability, causation, and resultant loss in lost productivity claims. Change is one crucial factor in a range of factors influencing labour productivity. The following is a brief discussion of these concepts.

FACTORS AFFECTING LABOUR PRODUCTIVITY

Labour productivity is a function of various controllable and uncontrollable factors. Schwartzkopf[3] listed these factors under six groups comprising:

(1) Schedule acceleration;
(2) Change in work;
(3) Management characteristics;

[2] Construction Industry Institute, An Analysis of the Methods for Measuring Construction Productivity, SD-13, Austin, Texas, 1984.
[3] Schwartzkopf, W. (1995). Calculating lost labor productivity in construction claims, Wiley, New York.

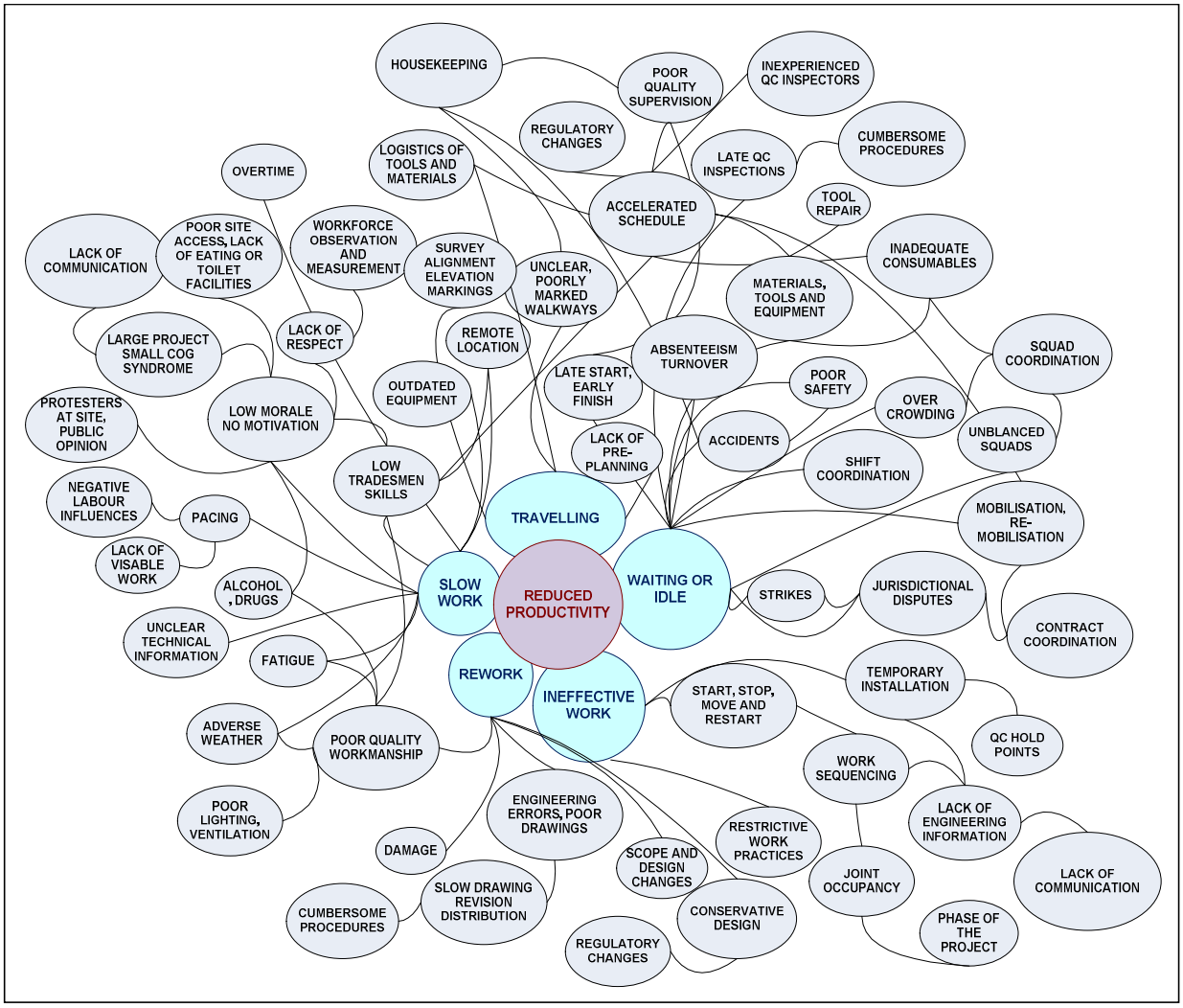
(4) Project characteristics;

(5) Labour and morale; and

(6) Project location/external conditions.

Borcherding and Alarcon[4] present a comprehensive review of quantitative information on factors influencing productivity. In addition, they categorised the major components of productivity loss as waiting or idle, travelling, working slowly, doing ineffective work, and doing rework.[5]

As noted previously, a number of factors may influence the actual productivity achieved on a given project:



[4] Borcherding, J. D., and Alarcon, L. F. (1991). "Quantitative effects on productivity." Constr. Lawyer, 11(1).

[5] Specific factors and their descriptions are available in Borcherding, J. D., and Alarcon, L. F. (1991). "Quantitative effects on productivity." Constr. Lawyer, 11(1), Mechanical Contractors Association of America (MCAA) (1994). "Factors affecting labor productivity." Labor estimating manual, bulletin No. PD2, Rockville, Md., 1–3, Schwartzkopf, W. (1995). Calculating lost labor productivity in construction claims, Wiley, New York, and Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.

Figure: Example factors affecting productivity[6]

Clearly not all disruption attracts the payment of compensation. The contractor may be entitled to compensation for the effects of lost productivity to the extent that a breach of obligation exists, a causal link to the offending party can be established and the effects of that disruption calculated appropriately.

Most standard forms of contract do not deal expressly with disruption. If they do not, then disruption may be claimed as being a breach of the term generally implied into construction contracts, namely that the Employer will not prevent or hinder the Contractor in the execution of its work. [7]

PROJECT CHANGE

Whilst a number of the factors impacting on labour productivity on a project are readily identifiable, the consequences of change are often underestimated and therefore specifically referenced here.

Change is normally defined as any event that results in a modification of the original scope, execution time, cost, and/or quality of work[8]. There are generally five types of changes, namely:

i. Change in scope;
ii. Differing site conditions;
iii. Delays;
iv. Suspensions; and
v. Acceleration.

The costs of performing changed work consist of both:

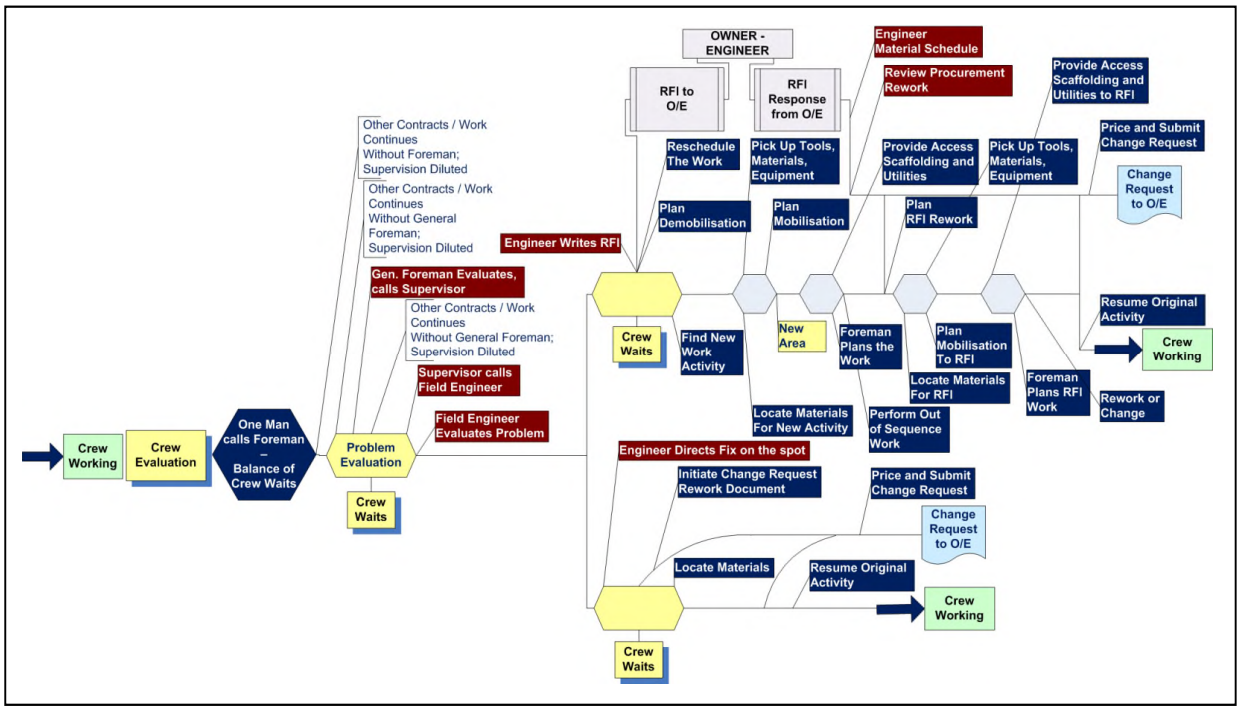
- Those costs directly related to the accomplishment of the changed work; and
- Those costs arising from the interaction between the changed work and unchanged work[9].

[6] The figure presented is intended as illustrative only of the type of matters that may influence productivity on a given site. Adapted from a presentation by Dr. Ibbs "Measuring Productivity for Improved Project Performance", 2009.
[7] SCL Delay and Disruption Protocol: October 2002.
[8] Ibbs, C. W., and Allen, W. E. (1995). "Quantitative impacts of project change."; Revay, S. O. (2003). "Coping with changes." AACE Int. Transactions, CDR.25, 1–7.
[9] Triple "A"South, ASBCA No. 46866, 94-3 BCA ¶27,194, at 135,523.

Notwithstanding that most forms of contract recognise and provide for the valuation of work relative to the circumstances under which it is being executed, this second aspect is often significantly underestimated or undervalued by both Contractors or Employers and their Representatives.

The costs and schedule impacts of a change occur in four phases:

Phase One is the time prior to the recognition of the change. An example would be a tradesman determining that the plans do not fit the situation encountered. The tradesman first attempts to determine if he is misreading the plans, then will seek direction from the supervisor who, if the supervisor cannot resolve the problem, will then seek direction from the engineer or the owner. After some period of time, a clarification may be issued. It may be determined that a change is necessary to deal with the situation. During the period before a change is recognised, costs and delays can be incurred. The process of finding a problem and implementing the solution is outlined in summary below[10].



Attachment 1 presents a larger scale of the above process diagramme.

Phase Two occurs after the need to make a change is recognised. During this period, materials are procured and the work is scheduled. Tradesmen may either be doing other work

[10] Developed from William Schwartzkopf, Calculating Lost Labour Productivity in Construction Claims, 2nd Edition, Aspen.

while waiting to perform the change or working around the change. Either of these actions can cause inefficiencies.

Phase Three is the actual execution of the changed work. The costs incurred during this phase are generally referred to as the direct cost of the change. These costs represent the time required and cost to perform the changed work.

Phase Four represents the work performed after the changed work has been performed. The cost and schedule effects during this phase and the first phase are indirect and are often referred to as impact costs. The amount of these impact costs is often the subject of considerable disagreement. By comparison, the direct costs during the third phase can frequently be measured and, therefore, the cost of the labour, materials, equipment, and other items can be determined. If a project is impacted by multiple changes, it may be necessary to analyse the effect of all of the changes simultaneously because of the interaction of the various changes.

EXTENT OF PROJECT CHANGE

The degree of project change varies according to each project but can be significant. Among 24 construction projects in western Canada, project costs increased by at least 30% for more than half and 60% on a third of projects[11]. Several projects suffered delays over 100%. A study of the Joint Legislative Audit and Review Commission[12] on approximately 300 road construction projects in Virginia revealed that the average financial project change was more than 11%.

The amount and timing of change are also significant factors affecting productivity. Analysis of 90 construction disputes in 57 independent projects[13] showed that there was a significant direct correlation between the percentage of change order hours to contract hours and the percentage of lost productivity. Ibbs[14] found that:

i. The greater the amount of change, the less the efficiency is; and
ii. Late project change more adversely affects labour productivity than early change.

[11] Semple, C., Hartman, F. T., and Jergeas, G. (1994). "Construction claims and disputes: Causes and cost/time overruns." J. Constr. Eng. Manage., 120(4), 785–795.
[12] Joint Legislative Audit and Review Commission (JLARC). (2001). "Review of construction costs and time schedules for Virginia highway projects." House Document No. 31, Commonwealth of Virginia.
[13] Leonard, C. A. (1987). "The effect of change orders on productivity." Revay Rep., 6(2), 1–4.
[14] Ibbs, C. W. (1997). "Quantitative impacts of project change: Size issues." J. Constr. Eng. Manage., 123(3), 308–311, Ibbs, W. (2005). "Impact of change's timing on labor productivity." J. Constr. Eng. Manage., 131(11), 1219–1223.

This finding was also confirmed by later studies[15].

DISRUPTIONS AND CUMULATIVE IMPACTS

In Coastal Dry Dock & Repair Corp., disruption is noted as the "cost effect upon, or the increased cost of performing, the unchanged work due to a change in contract"[16]. In some studies[17], disruptions are defined as the occurrence of events that are acknowledged to negatively impact on labour productivity. More broadly, the AACE; Recommended Practice standard[18] defines "disruptions as an action or event which hinders a party from proceeding with the work or some portion of the work as planned or as scheduled."

As noted previously, disruptions can be caused by change. These changes can reduce labour productivity and extend the project duration[19]. Disruptions caused by change can be both foreseeable and unforeseeable. The foreseeable or local disruptions can occur at the same time and either the same place or within the same resource as the changed work, whereas unforeseeable or cumulative disruptions can also occur at a time or place, or within resources, different from the changed work[20]. The words "cumulative disruption" and "cumulative impact" can be used interchangeably.

Cumulative impact has been described as being "…the unforeseeable disruption of productivity resulting from the 'synergistic' effect of an undifferentiated group of changes. Cumulative impact is referred to as the 'ripple effect' of changes on unchanged work that causes a decrease in productivity and is not analysed in terms of spatial or temporal relationships"[21]. Jones[22] argued that when the Board states that cumulative impact cannot be analysed in terms of spatial or temporal relationships, it means that cumulative impact costs cannot be secured within individual contract changes.

---

[15] E.g., Hanna, A. S., Russell, J. S., Gotzion, T. W., and Nordheim, E. V. (1999). "Impact of change orders on labor efficiency for mechanical construction." J. Constr. Eng. Manage., 125(3), 176–184.
[16] Coastal Dry Dock & Repair Corp., ASBCA No. 36754, 91-1 BCA ¶23,324, at 116,989, 1990.
[17] Thomas, H. R., and Napolitan, C. L. (1995). "Quantitative effects of construction changes on labor productivity." J. Constr. Eng. Manage., 121(3), 290–296.; Thomas, H. R., and Raynar, K. A. (1997). "Schedule overtime and labor productivity: Quantitative analysis." J. Constr. Eng. Manage., 123(2), 181–188.
[18] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.
[19] Hanna, A. S., Lotfallah, W. B., and Lee, M. J. (2002). "Statistical-fuzzy approach to quantify cumulative impact of change orders." J. Comput. Civ. Eng., 16(4), 252–258.
[20] Finke, M. R. (1998). "A better way to estimate and mitigate disruption." J. Constr. Eng. Manage., 124(6), 490–497.
[21] Centex Bateson Construction Co., VABCA No. 4613, 99-1 BCA ¶30,153, at 149,259, 1998.
[22] Jones, R. M. (2001). "Lost productivity: Claims for cumulative impact of multiple change orders." Public Contract Law J., 31(1), 1–46.

Pricing of the direct impact due to local disruptions and cumulative impacts due to cumulative disruptions is different. The direct impact costs are prepared on a forward pricing basis. The cumulative impact costs, on the other hand, are more often priced on a backward pricing basis as a contractor cannot foresee or readily quantify the impact. In other words, a cumulative impact claim addresses the changed work's effect on working conditions that will indirectly influence the unchanged work, whereas a direct impact claim covers the impact of changed work on unchanged work[23].

The AACE Recommended Practice[24] notes: "contractors tend to blame such losses on owners and ask to be compensated. Owners, on the other hand, often blame a bad bid or poor project management and thus deny additional compensation for lost productivity. Given this situation the root cause of lost productivity is frequently a matter in dispute between owners, contractors and subcontractors."

This paper seeks to set out appropriate approaches and recognised practices designed to overcome those inherent obstacles in analysing and quantifying the effects of such disruption.

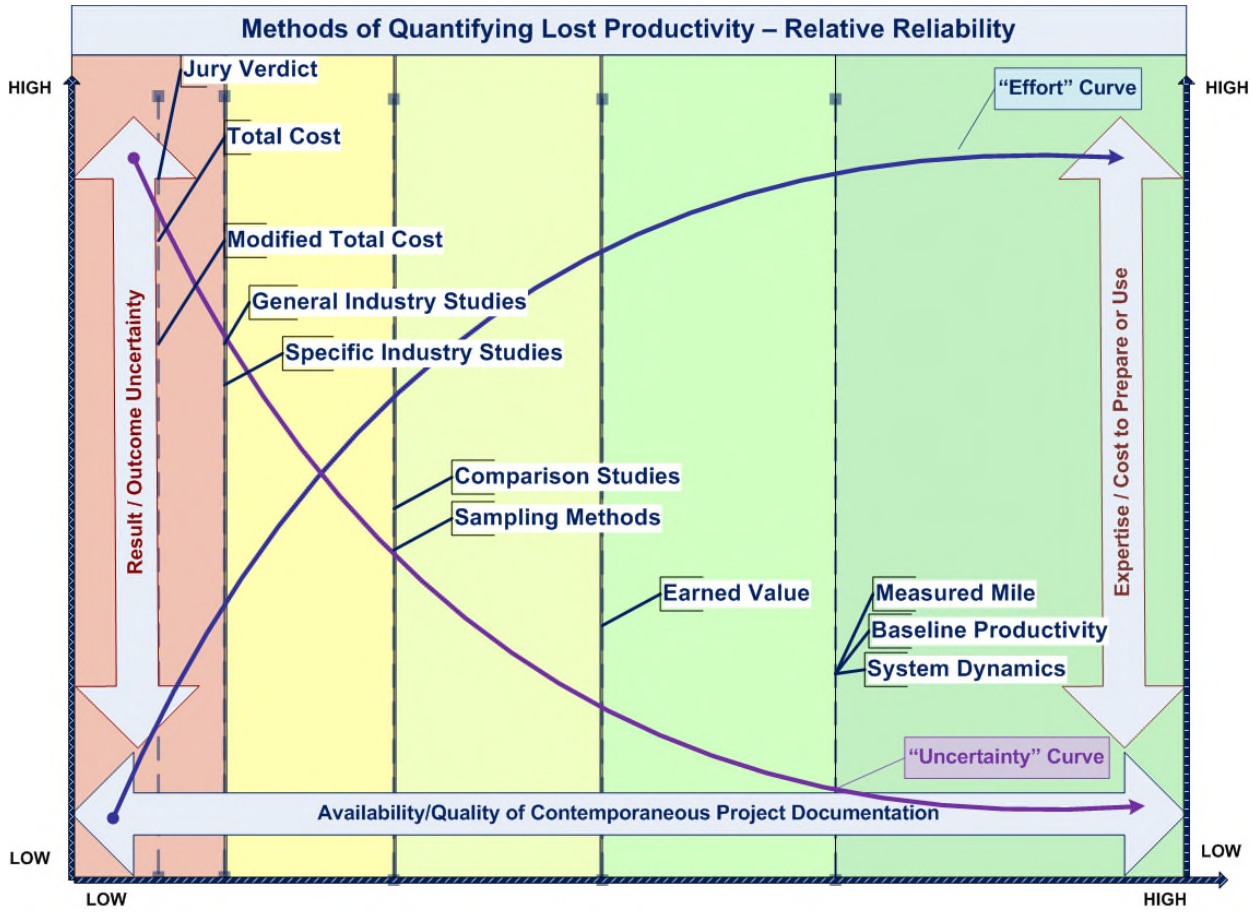
METHODS OF QUANTIFYING LOST PRODUCTIVITY

The construction industry has developed and employed a number of methodologies for estimating lost labour productivity. Based on the appropriate data input, these methods can be classified into three major groups; namely:

i. Project practice based;
ii. Industry based; and
iii. Cost based methods.

The detailed data requirements and corresponding judicial acceptance generally increase as the approach adopted moves from cost based to project practice based methods.

[23] Jones, R. M. (2001). "Lost productivity: Claims for cumulative impact of multiple change orders." Public Contract Law J., 31(1), 1–46.
[24] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.



The above figure[25] outlines the relationships between the availability, quality and providence of the contemporaneous project documentation, the reliability of the methods of quantifying lost productivity and the cost and expertise generally required to record, prepare, and document the quantum of damages derived thereby.

The horizontal axis refers to the attributes of the project data. The two vertical axes refer to attributes of the methods available for calculating lost productivity.

The methods listed typically increase in precision as they move from the top to the bottom in the graph and from left to right, i.e. from a total cost approach to a measured mile approach. This also reflects the order of preference in the research literature[26].

[25] Adapted from Quantified Impacts of Project Change, Ibbs, Long, Nguyen and Lee, Journal of Professional Issues in Engineering Education and Practice 2007.
[26] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.

The cost, effort, and expertise required for quantifying the loss normally increases from left to right. Horizontally the availability and quality of contemporaneous documentation required increases as the more detailed methods are used.

Before embarking on a productivity loss analysis, the claimant should carefully consider whether the loss can be recast as an impact of specifically definable extra work. If that is the case, then that productivity loss should be incorporated into the estimate for the extra work and resolved in that manner.

Tribunals appear to be more favourably impressed by damage calculations related directly to the project in dispute and supported by contemporaneous project documentation.[27] Therefore, recommended practice for preparing a lost productivity calculation is to utilise, if possible, one of the techniques listed in the category of **Project Practice Based Methods** set out below.

These methodologies are project specific and supported by people and records directly involved at the time of the dispute or the disputed work. That direct relationship to the work and the events in question are what gives the approach its appeal to a tribunal in favour of a more theoretical or generalist approach.

If there is insufficient information available from contemporaneous project documentation to support one of these techniques, recommended practice then is to use one of the methods listed under the category **Project Comparison Studies**. These methodologies, too, are project specific but rely upon different forms of contemporaneous documentation.

Unfortunately appropriate contemporaneous project documentation is not always available. Estimated costs are, of course, recognised as a legitimate way to calculate damages once entitlement and causation are sufficiently proven. Legal systems generally recognise that damages cannot always be calculated with mathematical certainty. Further, it is recognised that contractors frequently have to prepare and live with cost estimates. Therefore, in the absence of other proof of damages, the legal system may allow estimates to establish damages.[28]

Estimated damages may be acceptable, under appropriate circumstances, but are more subject to challenge than direct project costs. Of the damage calculation and estimating methods

[27] For a more thorough discussion of this point see Schwartzkopf, William and John J. McNamara, Calculating Construction Damages, 2nd Edition, Aspen Law & Business, New York, 2001, §1.03. See also, Wickwire, Jon M., Thomas J. Driscoll, Stephen B. Hurlbutt and Scott B. Hillman, Construction Scheduling: Preparation, Liability and Claims, 2nd Edition, Aspen Law & Business, New York, 2003, §12.04 et. seq. See also, Roy S. Cohen, Survey of Court's Reactions to Claims for Loss of Productivity and Inefficiency, Session 612, ABA Public Construction Superconference, December 10, 1998.
[28] Schwartzkopf, ibid, §1.03[B].

available, recommended practice is to use first, one of the studies listed in the **Specialty Industry Studies** category. These are specialty studies of specific types of problems and are, generally, based on a number of actual construction projects. Of course, to utilise one of these studies, the causation of the lost productivity should be appropriate for the particular problem studied.

If none of the specialised studies are applicable to the situation in question recommended practice is to utilise one of the studies listed in the **General Industry Studies** categories.

These studies are subject to greater challenge because they are industry wide and not subject or project specific. In addition, the basic data is sometimes derived from a non-construction environment. Finally, these studies were largely intended as "forward pricing guides", as such, their intended purpose was distinctly different.

Notwithstanding these criticisms, in the absence of more reliable techniques, claimants have been allowed to use these studies once entitlement and causation have been sufficiently proven.

If the contractor preparing a lost productivity damages calculation can demonstrate entitlement and causation but is unable to utilise one of the techniques previously noted, recommended practice is then to use one of the methods listed in the **Cost Basis** category.

To successfully utilise one of these techniques, the claimant generally has to overcome some difficult legal hurdles, discussed in more detail below. But, if these challenges can be met, then these techniques may be allowed as a measure of lost productivity.

PROJECT PRACTICE BASED METHODS

Measured mile analysis, baseline productivity analysis, system dynamics modelling, earned value analysis, sampling studies, and comparison studies are all project practice based approaches whose calculations are drawn from the project records.

As such, they are expected to be more credible than alternative general approaches. Courts and other tribunals therefore prefer estimations of damages that are directly linked to the disputed project and supported by its contemporaneous documentation[29]. The types of contemporaneous documentation required are generally different from one method to another.

[29] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.

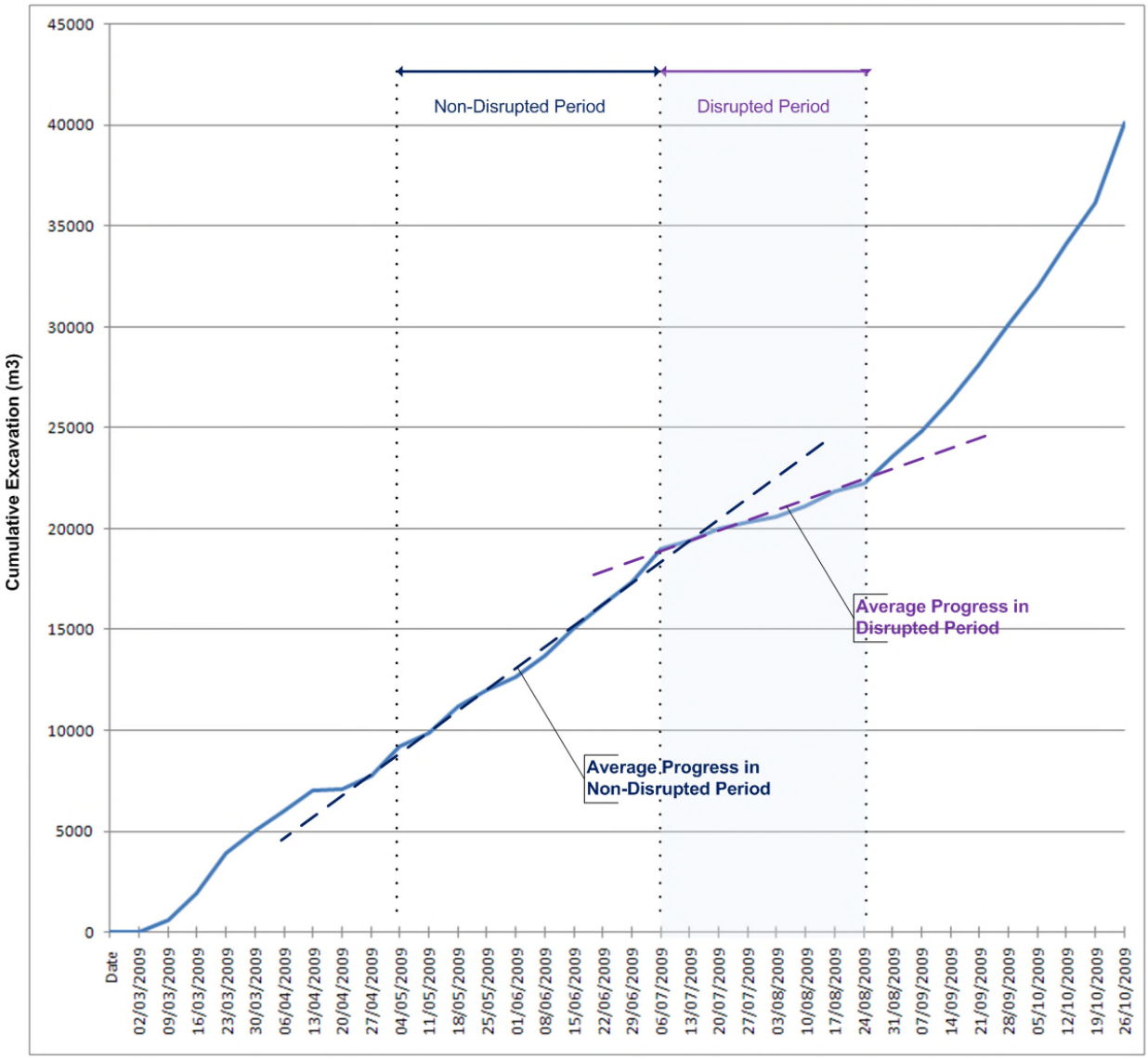
That is, the most suitable method for a given project can only be determined based upon the available project data.

MEASURED MILE ANALYSIS

The measured mile approach[30] is widely acknowledged as the most acceptable method for calculating lost productivity costs.

The analysis compares identical tasks in impacted and non-impacted periods of the project to estimate the productivity loss caused by the impact of a known series of events[31]. It is based on an extrapolation of actual work hours spent[32]. The measured mile calculation might include comparison of similar work activities and achieve court acceptance[33]. The attraction of the measured mile is that the actual contract performance rather than the initial estimate is used for the calculations. As such it compares actual performance on site with actual performance, not some theoretical planned performance.

[30] Sometimes referred to as differential studies or measured productivity comparisons.
[31] Schwartzkopf, W. (1995). Calculating lost labor productivity in construction claims, Wiley, New York.
[32] Zink, D. A. (1986). "The measured mile: Proving construction inefficiency costs." Cost Eng., 28(4), 19–21.
[33] Jones 2003; Calvey and Zollinger 2003; Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.



The above illustrates a non-disrupted period of excavation and a later disrupted period where the volume of excavation per unit of time has been adversely affected by operational and access restrictions imposed upon the Contractor.

There are several assumptions and prerequisites underlying the measured mile technique:

i. First, there must be a non-impacted or least impacted period, so-called “measured mile” period, for the specific type of work being assessed. The adverse factors affecting productivity during the measured mile period, if any, must be solely attributable to the contractor;

ii. Second, the length of this period should be significant compared to the impacted period and the course of work. It would be unreasonable to extrapolate 2% of progress into 80% of expected costs[34];

iii. Third, sufficient amounts of contemporaneous project data should be available for the analysis. At most the physical units of work completed have to be periodically recorded so that the cumulative labour hours can be plotted through the course of work.

iv. Fourth, the project data are assumed to be error free. That is, the contemporaneous documentation must be accurately recorded by the contractor; and

v. Finally, all disruptions during the impacted period are due to one party's (say, the owner's) actions or inactions. It is extended that other factors unrelated to the claimed impacts have to be accounted for and removed from the impacted period analysis to the degree these factors occurred during the measured mile period[35].

Considerable limitations are embedded in these assumptions. The measured mile analysis becomes unreliable or even impossible when either a non-impacted period simply does not exist or that period is not sizeable. The fact that the analysis requires identical or substantially similar activities for comparisons can hamper its applicability as the method is inappropriate for unique and complex tasks[36]. The reliability of the method is challenged if inaccurate contemporaneous project data is used for the analysis. Unfortunately reporting errors are commonplace in projects[37].

Other limitations are more implicit. Projected cumulative labour hours can be extrapolated differently due to different options of the time frame. Gulezian and Samelian[38] pointed out that:

i. Different time frame and segments selected within the measured mile period may produce different numbers; and

ii. Variation of daily productivity is concealed to varying extents by the cumulating nature of the measure mile analysis.

They also argue that the measured mile does not necessarily reflect the productivity normally achieved by the contractor due to the smoothing effect of successive cumulative data and the

[34] Zink, D. A. (1986). "The measured mile: Proving construction inefficiency costs." Cost Eng., 28(4), 19–21.
[35] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.
[36] Loulakis, M. C., and Santiago, S. J. (1999). "Getting the most out of your 'measured mile' approach." Civ. Eng. (N.Y.), 69(11), 69.
[37] Thomas, H. R., and Sanvido, V. E. (2000). "Quantification of losses caused by labor inefficiencies: Where is the elusive measured mile?" Constr. Law Bus., 1.
[38] Gulezian, R., and Samelian, F. (2003). "Baseline determination in construction labor productivity-loss claims." J. Manage. Eng., 19(4), 160–165.

nature of variation in unit productivity values. In addition, the two average productivity rates, which are readily calculated and compared for non-impacted and impacted periods, may mask the fact that a contractor generally does not attain a single rate of productivity throughout a time period[39].

Example Measured Mile Calculation Comparison of Unit Cost for Impacted and Non-impacted Areas[40]

The Contractor planned to perform all of the cross taxiway paving on an uninterrupted basis, and to use paving machines for all of the concrete paving except for the fillet areas, which were to be done by hand pours.

Because of the engineer's changes in the taxiway lighting and a requirement to put pavement-sensing devices in the concrete for a long-range pavement wear study, the work on the south taxiways was performed on a sporadic and intermittent basis. In fact, much of it was performed on a hand basis rather than using the large concrete slip form paving spread. This caused a substantially greater cost of performing the work on the south taxiways than could be reasonably anticipated.

The work on the north taxiways was performed under normal conditions, since the changes were all made prior to the start of work on the north taxiways and the pavement wear study would not be conducted on the north taxiways. Runway's cost as a result of these changes can be calculated by comparing the unit cost of labour for the north taxiways (which were essentially non-impacted) with the unit cost of labour for the south taxiways (which were substantially impacted). Both the north and south taxiways were performed during normal paving periods under good weather conditions. The same labour force and the same equipment (with the exception that the slip form paving spread could not always be used due to the change) was used on both areas. However, the unit labour cost on the north taxiways, which were non-impacted, was approximately half of the cost incurred on the south taxiways.

On the above information and the following simplistic analysis, the Contractor is entitled to be paid $549,155 in additional costs that it incurred, as illustrated in the following formula:

[39] Finke, M. R. (1998). "Statistical evaluations of measured mile productivity claims." Cost Eng., 40(12), 28–30.
[40] Drawn from Schwartzkopf, Calculating Lost Labor Productivity in Construction Claims, 2nd Edition.

	Actual North Cross Taxiway Production	Actual South Cross Taxiway Production
Hours	10,116.00	51,969.00
Square Metres Produced	102,256.00	281,746.60
Hours/Square Metre	.099	.184
Increase in Unit Labour Rate		0.086
Quantity Affected by Blockout and Light Change		281,746.60
Increased Rate		0.086
Manhour Increase Due to Change		24,096.32
Labour Cost per Manhour		$22.79
Total Additional Labour Cost		$549,155.17

BASELINE PRODUCTIVITY ANALYSIS

This approach was proposed in order to avoid some of the limitations and impractical assumptions of a current measured mile analysis. Similar to the measured mile method, baseline analysis relies on the contractor's actual performance of the project being analysed. A central point of this analysis is to establish the baseline productivity. It represents the best and most consistent productivity the contractor was able to achieve on the project[41]. Analysing a 42 project database[42] revealed that the baseline productivity mainly depends on the complexity of the design and the work methods used. Unlike the measured mile analysis, a baseline analysis neither needs defined non-impacted and impacted periods nor be consecutive reporting periods in the baseline time frame[43]. In other words, the baseline analysis can be more flexible and hence more applicable in current practice[44].

However, the process has not obtained consensus among studies though it is generally agreed that using individual productivity values is better than cumulative productivity for the calculations. This may be due to varying views on the baseline productivity. Unlike Thomas and

[41] Thomas, H. R., and Završki, I. (1999). "Construction baseline productivity: Theory and practice." J. Constr. Eng. Manage., 125(5), 295–303.
[42] Thomas, H. R., and Završki, I. (1999). "Construction baseline productivity: Theory and practice." J. Constr. Eng. Manage., 125(5), 295–303.
[43] Thomas, H. R., and Završki, I. (1999). "Construction baseline productivity: Theory and practice." J. Constr. Eng. Manage., 125(5), 295–303
[44] A determining process of the baseline productivity can be found in Thomas and Završki (1999), Thomas and Sanvido (2000), and Gulezian, R., and Samelian, F. (2003). "Baseline determination in construction labor productivity-loss claims." J. Manage. Eng., 19(4), 160–165.

Završki[45], Gulezian and Samelian[46] noted that the baseline productivity reflects the normal operating performance of a contractor.

Thomas and Završki[47] and Thomas and Sanvido[48] determine the baseline productivity as "the median of the individual productivity values in the baseline subset." Gulezian and Samelian[49] calculate it as "the mean productivity of the points falling within the control limits" after applying an iterative process of an individuals' control chart to deal with different sources of variation of periodically reported productivity values.

Although the baseline analysis solves several problems associated with the measured mile approach, it is still limited. The way of calculating the baseline productivity should be more scientific and straightforward, subject to properly dealing with the reliability of reported data, variation of productivity values, and casual linkages to disruptions and inefficiency. Some shortcomings are related to the establishment of the baseline sample as in Thomas and Završki[50] and Thomas and Sanvido[51]. They are:

i. The baseline sample is identified according to the best daily output instead of the best daily productivity; and
ii. The 10% requirement for the baseline sample size is arbitrary and not based upon scientific principles[52].

In addition it is agreed that the baseline analysis is a cause and effect analysis, yet it is qualitative or very roughly approximate in nature as in Thomas[53]. There has been no sound method for which damages induced by the owner and contractor are classified and quantified during a disputed period. Especially, multiple and/or simultaneous owner and contractor-caused disruptions are not uncommon in real life.

---

[45] Thomas, H. R., and Završki, I. (1999). "Construction baseline productivity: Theory and practice." J. Constr. Eng. Manage., 125(5), 295–303.
[46] Gulezian, R., and Samelian, F. (2003). "Baseline determination in construction labor productivity-loss claims." J. Manage. Eng., 19(4), 160–165.
[47] Thomas, H. R., and Završki, I. (1999). "Construction baseline productivity: Theory and practice." J. Constr. Eng. Manage., 125(5), 295–303.
[48] Thomas, H. R., and Sanvido, V. E. (2000). "Quantification of losses caused by labor inefficiencies: Where is the elusive measured mile?" Constr. Law Bus., 1.
[49] Gulezian, R., and Samelian, F. (2003). "Baseline determination in construction labor productivity-loss claims." J. Manage. Eng., 19(4), 160–165.
[50] Thomas, H. R., and Završki, I. (1999). "Construction baseline productivity: Theory and practice." J. Constr. Eng. Manage., 125(5), 295–303.
[51] Thomas, H. R., and Sanvido, V. E. (2000). "Quantification of losses caused by labor inefficiencies: Where is the elusive measured mile?" Constr. Law Bus., 1.
[52] Ibbs, W., and Liu, M. (2005). "Improved measured mile analysis technique." J. Constr. Eng. Manage., 131(12), 1249–1256.
[53] Thomas, H. R. (2005). "Causation and cause-effect analyses." Construction claims online, WPL, 3(4).

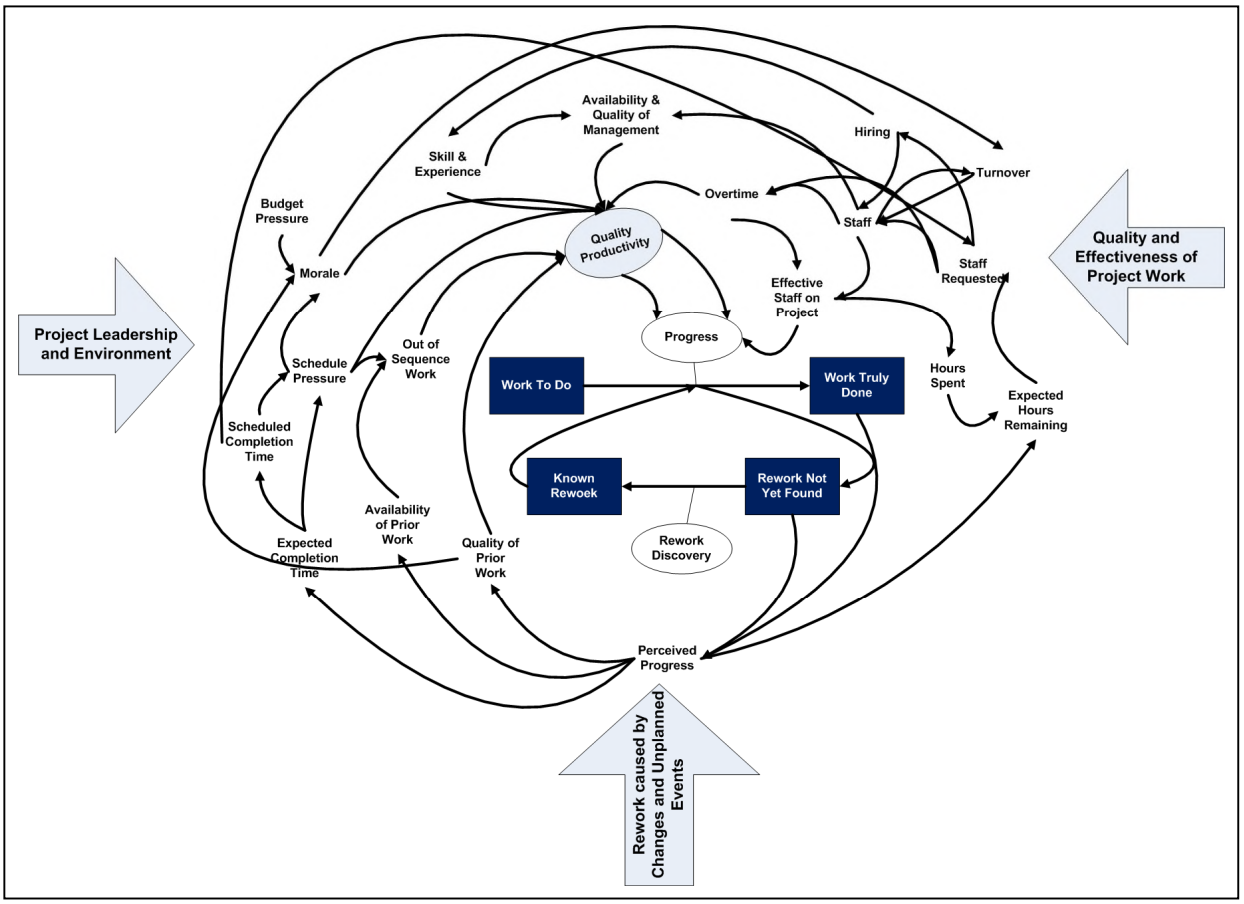
SYSTEM DYNAMICS MODELLING

System dynamics ('SD') modelling has been employed to understand the behaviour of various natural, social, and engineered systems[54]. Developed at MIT[55] in the late 1950's, SD is widely used in the defence industry.

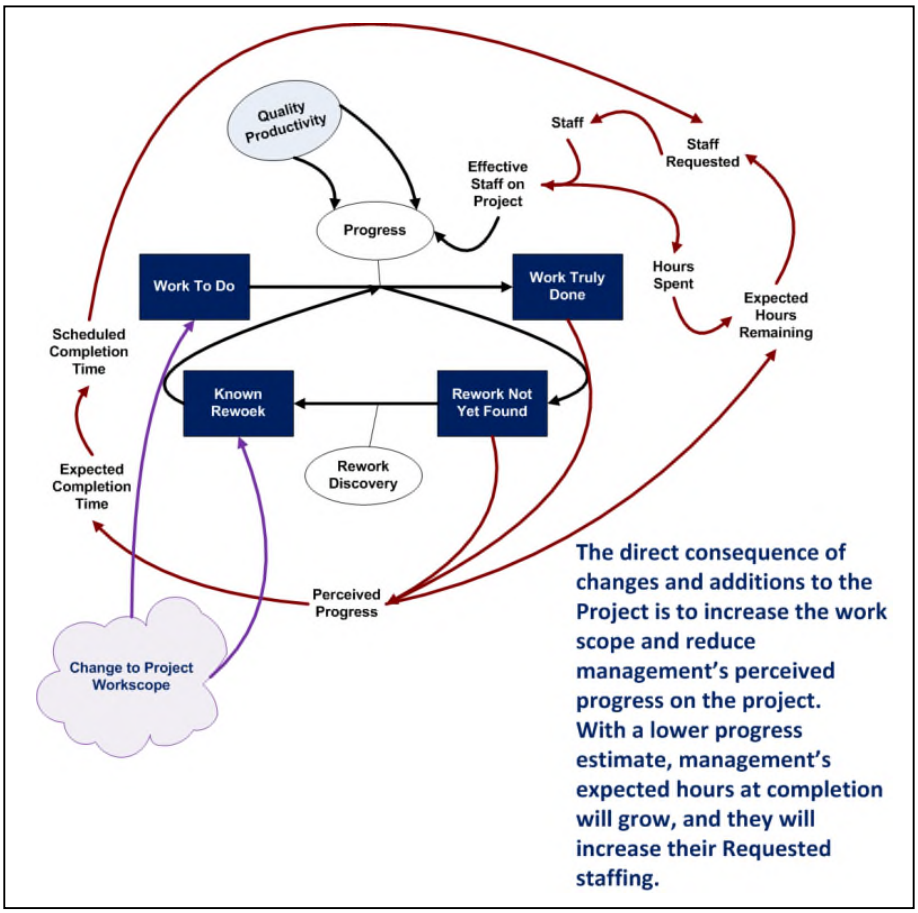
A number of delay and disruption claims have been successfully settled with extensive support of SD modelling. One such successful story was the development and application of a SD computer simulation model to resolve a $500 million shipbuilder claim consisting of the direct impact and the "ripple effects" between Ingalls Shipbuilding and the U.S. Navy in the 1970s[56]. Other successful applications of SD modelling in delay and disruption claims and lawsuits have also been reported[57].

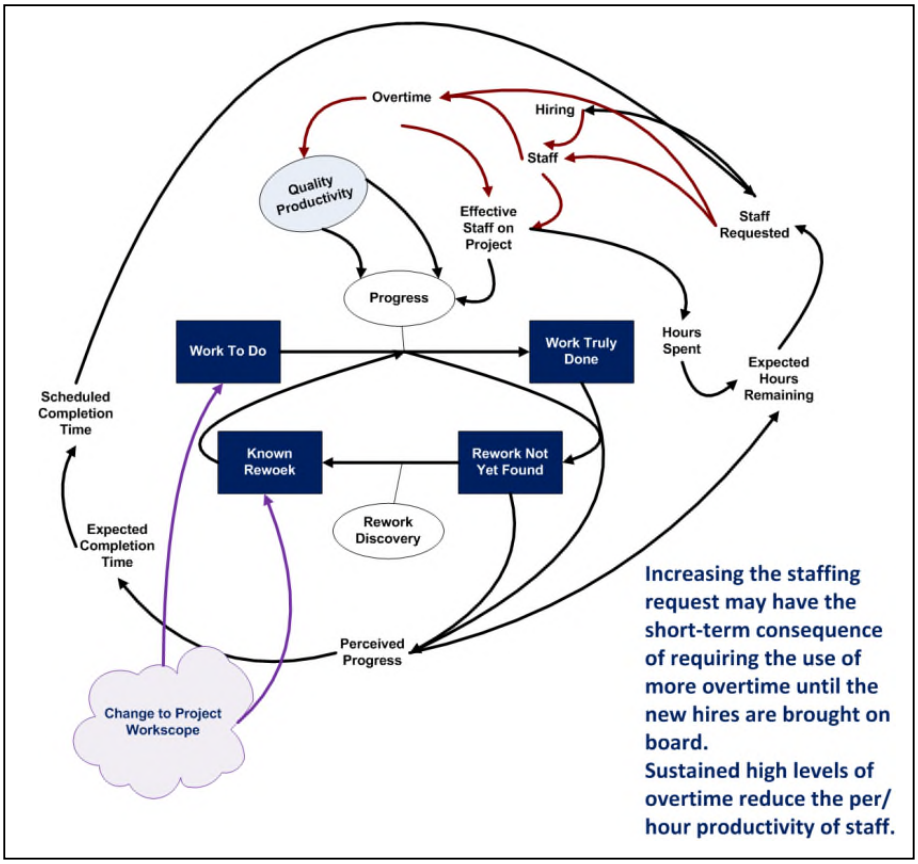
The SD approach seeks to create a computer model of the project that maps all relationships and feedback loops in a comprehensive dynamic model. A simplistic representation of that model may look something like:

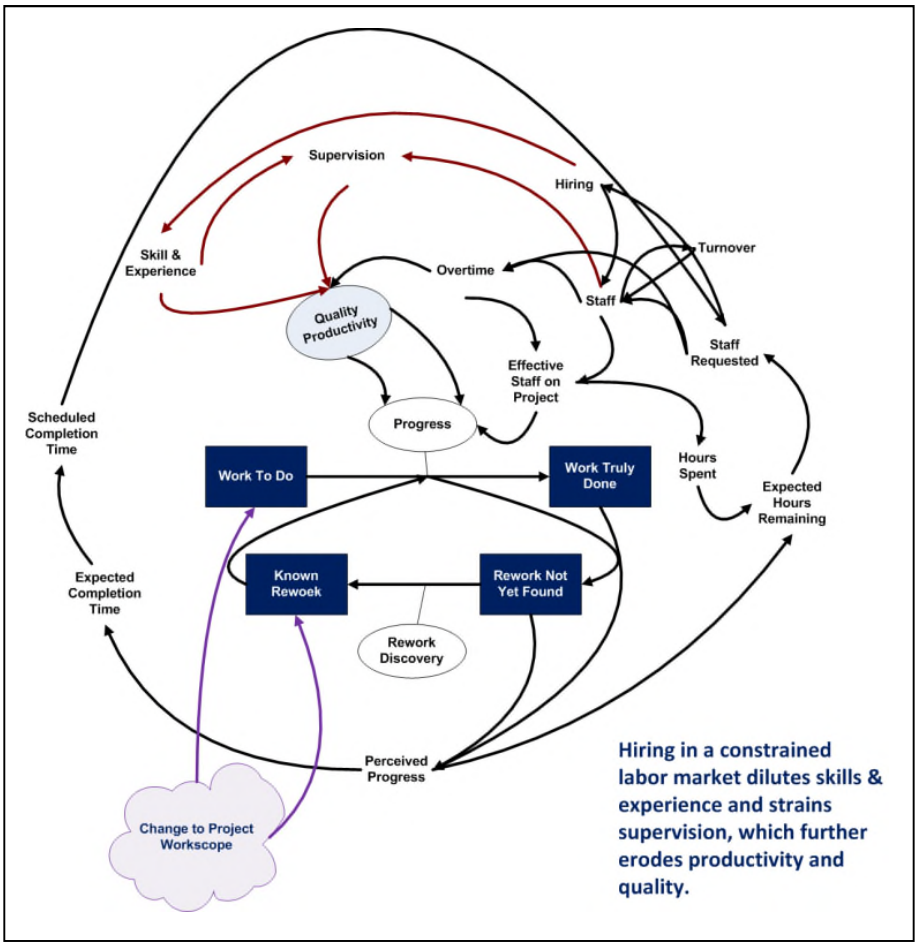
[54] Its principles, concepts, and tools can be found in Forrester, J. (1961). Industrial dynamics, Pegasus Communications, Waltham, Mass, Richardson, G., and Pugh, A. (1981). Introduction to system dynamics modeling with dynamo, Pegasus Communications, Waltham, Mass, and Sterman, J. D. (2000). Business dynamics, system thinking, and modelling for a complex world, Irwin McGraw-Hill, New York.
[55] Massachusetts Institute of Technology.
[56] Cooper, K. G. (1980). "Naval ship production: A claim settled and a framework built." Interfaces, 10(6), 20–36.
[57] Ackermann, F., Eden, C., and Williams, T. (1997). "Modeling for litigation: Mixing qualitative and quantitative approaches." Interfaces, 27, 48–65; Eden, C., Williams, T., Ackermann, F., and Howick, S.(2000). "On the nature of disruption and delay." J. Oper. Res. Soc. Jpn., 51, 291–300; Williams, T. M., Ackermann, F., and Eden, C. (2003). "Structuring a disruption and delay claim." Eur. J. Oper. Res., 148, 192–204.

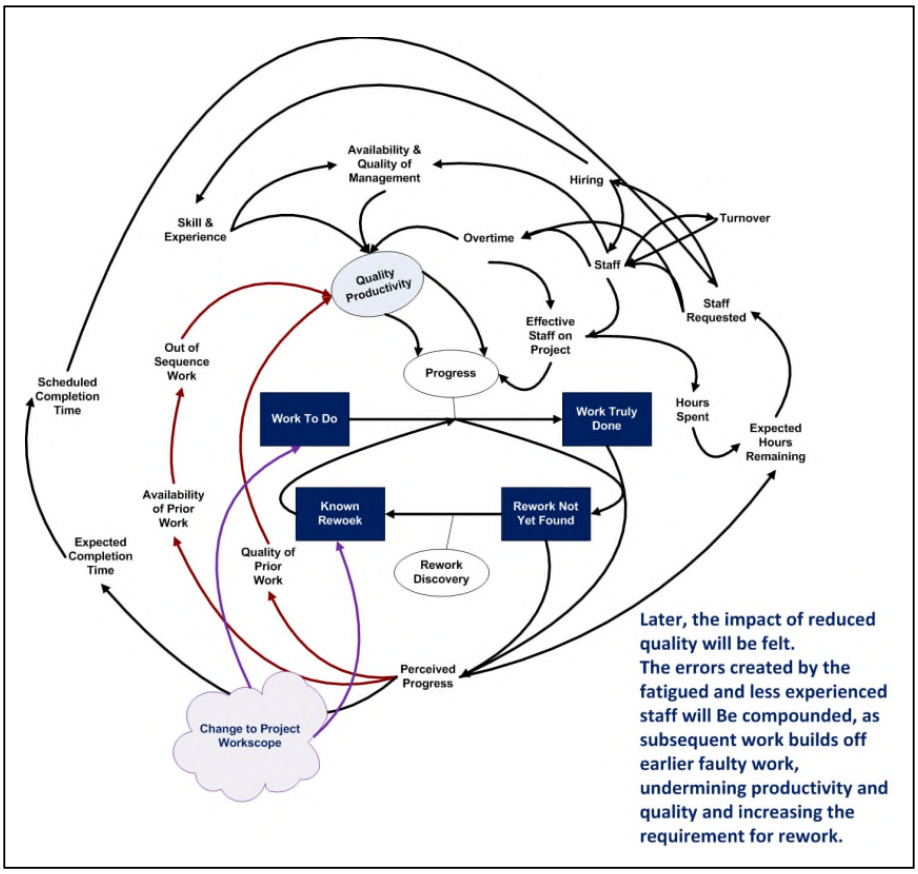


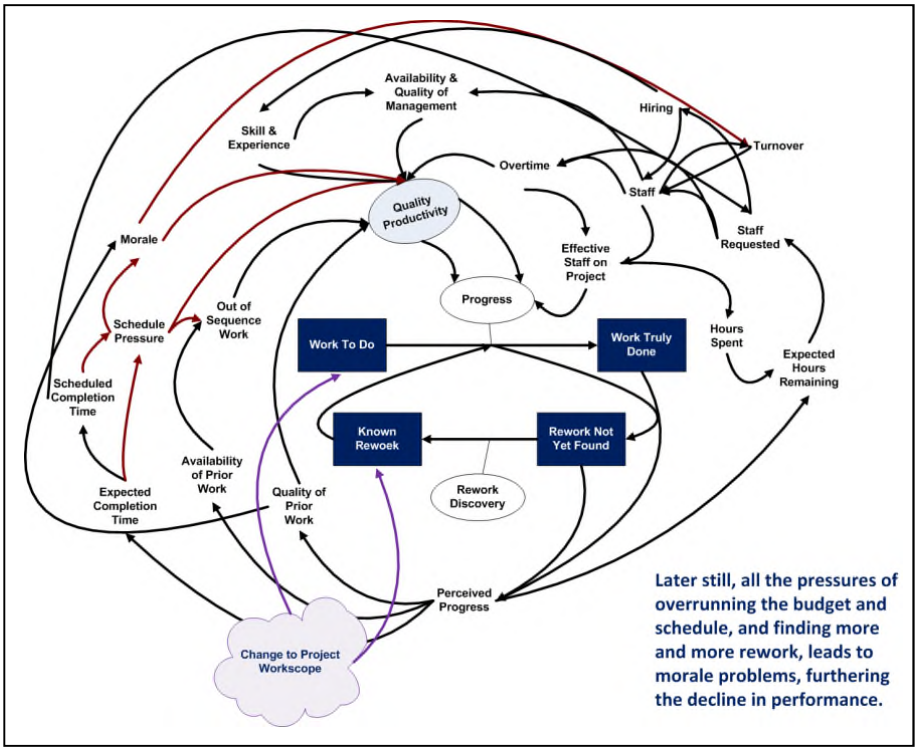
The sequence of modelled events may run along the following lines:


Quality Productivity
Staff
Staff Requested
Effective Staff on Project
Progress
Work To Do
Work Truly Done
Hours Spent
Expected Hours Remaining
Scheduled Completion Time
Known Rewoek
Rework Not Yet Found
Rework Discovery
Expected Completion Time
Perceived Progress
Change to Project Workscope
The direct consequence of changes and additions to the Project is to increase the work scope and reduce management's perceived progress on the project. With a lower progress estimate, management's expected hours at completion will grow, and they will increase their Requested staffing.

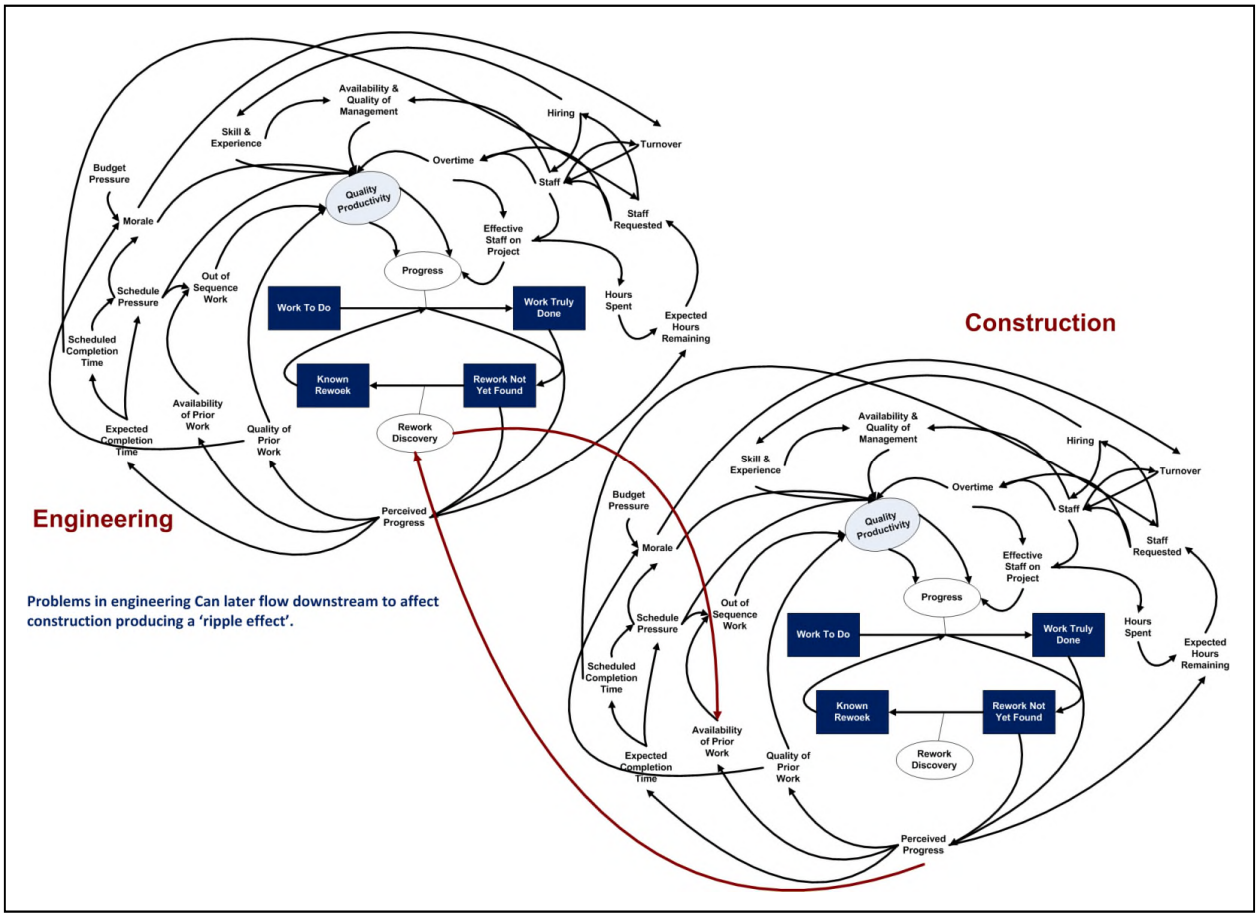

Overtime
Hiring
Staff
Quality Productivity
Effective Staff on Project
Staff Requested
Progress
Work To Do
Work Truly Done
Hours Spent
Expected Hours Remaining
Scheduled Completion Time
Known Rewoek
Rework Not Yet Found
Rework Discovery
Expected Completion Time
Perceived Progress
Change to Project Workscope
Increasing the staffing request may have the short-term consequence of requiring the use of more overtime until the new hires are brought on board.
Sustained high levels of overtime reduce the per/ hour productivity of staff.


Supervision
Hiring
Skill &
Experience
Overtime
Turnover
Staff
Quality
Productivity
Staff
Requested
Effective
Staff on
Project
Progress
Scheduled
Completion
Time
Work To Do
Work Truly
Done
Hours
Spent
Expected
Hours
Remaining
Known
Rework
Rework Not
Yet Found
Expected
Completion
Time
Rework
Discovery
Perceived
Progress
Change to Project
Workscope
Hiring in a constrained labor market dilutes skills & experience and strains supervision, which further erodes productivity and quality.


Availability & Quality of Management
Hiring
Skill & Experience
Overtime
Turnover
Staff
Quality Productivity
Staff Requested
Effective Staff on Project
Out of Sequence Work
Progress
Scheduled Completion Time
Work To Do
Work Truly Done
Hours Spent
Expected Hours Remaining
Availability of Prior Work
Known Rewoek
Rework Not Yet Found
Expected Completion Time
Quality of Prior Work
Rework Discovery
Perceived Progress
Change to Project Workscope
Later, the impact of reduced quality will be felt.
The errors created by the fatigued and less experienced staff will Be compounded, as subsequent work builds off earlier faulty work, undermining productivity and quality and increasing the requirement for rework.


Availability & Quality of Management
Hiring
Skill & Experience
Turnover
Overtime
Staff
Quality Productivity
Staff Requested
Morale
Effective Staff on Project
Progress
Out of Sequence Work
Schedule Pressure
Work To Do
Work Truly Done
Hours Spent
Expected Hours Remaining
Scheduled Completion Time
Known Rewoek
Rework Not Yet Found
Availability of Prior Work
Expected Completion Time
Quality of Prior Work
Rework Discovery
Perceived Progress
Change to Project Workscope
Later still, all the pressures of overrunning the budget and schedule, and finding more and more rework, leads to morale problems, furthering the decline in performance.

Problems early in the project propagate to downstream work. Change impacts originally isolated in the engineering phase may end up affecting construction as well. There another similar set of dynamics is triggered, with the addition of some physical impacts as well, such as crowding (congestion, 'trade-stacking'). All these dynamic effects in construction, as they affect labour productivity, can amplify the magnitude of disruption impacts from changes.



Illustrations drawn from Project Changes: Sources, Impacts, Mitigation, Pricing, Litigation & Excellence, PA Consulting Group

By using SD modelling quantification of cumulative impacts can overcome one of the limitations of the measured mile and baseline analyses. As noted earlier the two methods are not able to easily accommodate multiple and/or concurrent disruptions caused by different project parties. SD models can quantify owner-responsible delay and disruption impact costs and demonstrate the cause and effect relationship of the cumulative impacts[58]. A key feature of SD simulation modelling is that it allows and directs answering a pool of "what if" questions such as: What if one particular category of disruptions had not occurred but all others had? What if the owner

[58] Cooper, K. G. (1980). "Naval ship production: A claim settled and a framework built." Interfaces, 10(6), 20–36.

interventions had not occurred?[59]. In addition, it visualises causality and allows for validation of causal logic in quantitative terms and against actual data at any period of the project in dispute[60].

SD modelling has not achieved popularity in construction disputes compared to the measured mile analysis.

One main reason is that SD simulation models are not readily understood due to the dynamic complexity and quantitative nature of those models[61]. In addition, unless the SD model is properly validated, it is pointless, barely credible, and therefore useless.

Validation of a SD model is problematic and time consuming and requires extensive expertise of the SD methodology. In some circumstances, it is assumed that the reasonableness of the original estimate in SD modelling can draw inaccurate and unpersuasive quantum of damages. Also, although the causal coefficients indicating the relationships between activities are very important to the accuracy of a SD model, they are not easy to estimate[62].

EARNED VALUE ANALYSIS

Productivity measurement is sometimes difficult when there is insufficient information concerning the physical units of work installed on the project. In these situations, a simplistic form[63] of the earned value analysis method can be utilised to calculate estimated labour hours.[64] The contractor's estimate or alternatively the monetary value of payment applications, contract amounts or unit prices can be used to determine labour hours, when they were expended and, possibly, on what activities.[65] Physical units of work completed multiplied by budget unit rates can be used to determine earned hours. The earned hours are then compared to the actual

[59] Cooper, K. G. (1980). "Naval ship production: A claim settled and a framework built." Interfaces, 10(6), 20–3; 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, 135–139.
[60] 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, 135–139.
[61] Howick, S. (2005). "Using system dynamics models with litigation audiences." Eur. J. Oper. Res., 162, 239–250.
[62] Ibbs, W., and Liu, M. (2005). "System dynamic modeling of delay and disruption claims." Cost Eng., 47(6), 12–15.
[63] The use of the term "earned value" means different things to different people. In this context, "simplified earned value" is used to distinguish between form Earned Value as required by the US Government on many of their projects and earned value as practiced by many EPC contractors. See for example Kenneth K. Humphreys, Jelen's Cost and Optimization Engineering, Third Edition, McGraw Hill, New York, 1991; James M. Neil, Construction Cost Estimating for Project Control, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1982; and Skills and Knowledge of Cost Engineering, Fifth Edition, AACE International, Morgantown, West Virginia, 2004.
[64] See Stumpf, George, R., editor, AACEI Professional Practice Guide to Earned Value, AACEI, Morgantown, WV, 1999.
[65] See Cass, Donald J., Earned Value Programs for DOE Projects, Cost Engineering, Vol. 42, No. 3, February 2000.

hours expended for the period of the impact and the difference between the two may be used to calculate the productivity loss experienced.

Earned value measurement of contemporaneous project documentation, such as percentages complete from schedule updates or payment applications can assist with calculating labour productivity.[66] Additionally, the claimant may calculate the actual revenue per hour of labour versus the planned revenue per hour, as an alternative.[67] Earned value analysis may also be utilised to calculate estimated labour hours.[68]

When using the earned value analysis technique, it is cautioned that the budget used to generate the earned value metrics be carefully reviewed and verified for reasonableness. Any earned value analysis based upon an unreasonable budget is highly suspect. Finally, it is noted that a fully resource loaded (labour and quantities) CPM schedule is a good source for obtaining earned value metrics and allows for like-time causation analysis.

An earned value analysis can also be used to estimate the cumulative impacts, especially when the physical units of work completed have not been recorded adequately for employing a more reliable method like the measured mile and baseline analyses.

For a project, the difference between earned hours determined from the earned value analysis method and actual hours expended for an impacted period can be used to compute the inefficiency suffered[69]. As an earned value analysis is based on the percent complete and the budget, the credibility of the method can be questionable. The reasons are that:

i. The percent complete method is not as detailed and accurate as the physical units of work completed method[70] used in the previous quantifying methods; and
ii. The original estimate is likely to be unsubstantiated. Any earned value analysis relying on an unreasonable budget is very doubtful[71].

[66] See Fleming, Quentin W. and Joel M. Koppelman, Earned Value Project Management, Project Management Institute, Upper Darby, PA. 1996.
[67] See McCally, Bob M., Demonstrated Labor Efficiency: An Effective Cost Control and Analytical Tool, Cost Engineering, Vol. 41, No. 11, pp. 33 – 37, November 1999.
[68] See Jones and Driscoll, Ibid, page B-24.
[69] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.
[70] Schwartzkopf, W. (1995). Calculating lost labor productivity in construction claims, Wiley, New York.
[71] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.

SAMPLING METHODS

Two sampling methods used for estimating lost productivity are work sampling and craftsmen questionnaire sampling methods. Introduction to these methods can be found elsewhere[72].

Work sampling is a method in which a large number of direct observations of tradesmen are made to determine what they are doing at various points in time. Work sampling is defined as "An application of random sampling techniques to the study of work activities so that the proportions of time devoted to different elements of work can be estimated with a given degree of statistical validity."[73]

From these observations the claimant determines, on a percentage basis, how much time is spent between direct work (pay item work); support work (moving tools and materials to the work location); or delays (time when no work is being performed). By performing a number of work sampling studies, the analyst can draw comparisons of productivity before and after known events, between work activities or crews, etc. Work sampling has been offered as a means of determining productivity loss but it can only be performed during the life of the project and is not compatible with a hindsight analysis effort.[74]

The sampling methods are typically simple and inexpensive to analyse labour productivity. Although they can be used for lost productivity claims, their trustworthiness is not high as they are only a sampled measure of labour productivity.

For instance, an assumption of work sampling that there is a positive relationship between productive time and labour productivity was found to be false[75].

The questionnaire approach allows craftsmen to estimate the amount of lost productive time in the field on a daily or weekly basis, identifying the reason for the lost time. While, perhaps, not the most scientific of studies, this is contemporaneous documentation if administered properly.

---

[72] e.g., Oglesby, C. H., Parker, H. W., and Howell, G. A. (1989). Productivity improvement in construction, McGraw-Hill, New York..

[73] American Institute of Industrial Engineers, American National Standard Z-94.11, Industrial Engineering Terminology 11-20 (1989).

[74] See Fwu-Shiun Liou and John D. Borcherding, Work Sampling Can Predict Unit Rate Productivity, Journal of Construction Engineering and Management, Vol. 112, No. 1, page 90 (March, 1986). See also, Jenkins, James L. and Daryl L. Orth, Productivity Improvement Through Work Sampling, Cost Engineering, Vol. 46, No. 3, pp. 27 – 32, (March 2004).

[75] Thomas, H. R. (1991). "Labor productivity and work sampling: The bottom line." J. Constr. Eng. Manage., 117(3), 423–444..

The claimant can then tie the results of such a survey to the entitlement and causation arguments.[76]

A variation of this method is the use of a Craftsmen Questionnaire at the end of the job, to confirm or modify a productivity loss analysis performed utilising another method. For example, a Board of Contract Appeals case allowed a Craftsmen Questionnaire to be used as a modifier of an industry-wide study and awarded lost productivity costs to a mechanical subcontractor on this basis.[77]

COMPARISON STUDIES

Comparison studies can be classified as comparable work and comparable project studies. AACE[78] also classifies the comparable work studies in two forms:

i. The contractor estimates lost productivity on the impacted period, and then locates an analogous or similar work activity on the same project, which was non-impacted and calculates its productivity; and
ii. The contractor compares productivities during the impacted period and of similar but non-impacted work performed by another contractor on the same project.

Comparable project studies are used to contrast the productivities of similar work activities on the project being analysed and a similar project.

The successful use of comparison studies can be difficult to secure given that the definition of similar work or a similar project are rarely agreed by project parties. As such baseline productivity analysis or system dynamics modelling should be considered for sizable claims when there is no clear non-impacted period. The other methods can be adopted as complementary and used to further substantiate the outcome results achieved. There may be times when they are the best alternative available.

INDUSTRY-BASED METHODS

Specialty industry and general industry studies are called the industry based methods. As their names imply a specialty, industry study employs results of specific studies directly related to the cause of damages, whereas a general industry study is based on industry-wide manuals and/or

[76] Luh-Mann Chang and John D. Borcherding, Evaluation of Craftsmen Questionnaires, Journal of Construction Engineering and Management, Volume 111, No. 4, page 426. (December, 1985)
[77] See Hensel Phelps Construction Co., GSBCA Nos. 14,744 & 14,877, 01-1 BCA ¶ 31,249. January 11, 2001.
[78] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.

reports. The specific studies can be about acceleration, learning curve, overtime, weather, and so forth[79]. The industry based analyses may be employed when there is insufficient project documentation. They can also be used with another method to augment supportive evidence of damages. In general, although the industry based methods are quick and inexpensive, their use in calculating lost productivity is not the first preference.

COST-BASED METHODS

If it is possible to demonstrate entitlement and causation but there is insufficient project documentation to support damage calculations using any of the above techniques, recommended practice is to use one of the costing methods set forth below. These methods require analysis of the project job cost records. The purpose of such preliminary analysis is to determine actual direct labour hours and costs (having stripped out materials, installed equipment, supplies, field and home office overhead, small tools and consumables, etc.).

Total cost and modified total cost methods are grouped into cost based methods. AACE80 further divides a total cost method into a total unit cost and a total labour cost method. Under the total cost method, the contractor subtracts its estimated labour costs from the costs actually incurred to arrive at the resulting overrun as the basis for its inefficiency claims81. The major difference between the total cost and modified total cost methods is that damages quantified by modified total cost calculation takes into account unreasonable estimates and/or inefficiencies due to contractor's problems. Thus, the second method, out of the two, is preferable.

Successful use of the cost based methods is limited. In order to employ a total cost analysis, a contractor generally has to prove the following requirements:

(1) The impracticability of proving actual losses directly;
(2) The reasonableness of its bid;
(3) The reasonableness of its actual costs; and
(4) Lack of responsibility for the added costs[82].

---

[79] Sources of these qualitative and/or quantitative studies for various subjects can be found in Borcherding, J. D., and Alarcon, L. F. (1991). "Quantitative effects on productivity." Constr. Lawyer, 11(1) and Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.
[80] Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004). "Estimating lost labor productivity in construction claims." AACE International Recommended Practice No. 25R-03.
[81] Jones, R. M. (2003). "Update on proving and pricing inefficiency claims." Constr. Lawyer, Summer, 3–11; Klanac, G. P., and Nelson, E. L. (2004). "Trends in construction lost productivity claims." J. Profl. Issues Eng. Educ. Pract., 130(3), 226–236.
[82] Centex Bateson Construction Co., VABCA No. 4613, 99-1 BCA ¶30,153 at 149,261, 1998.

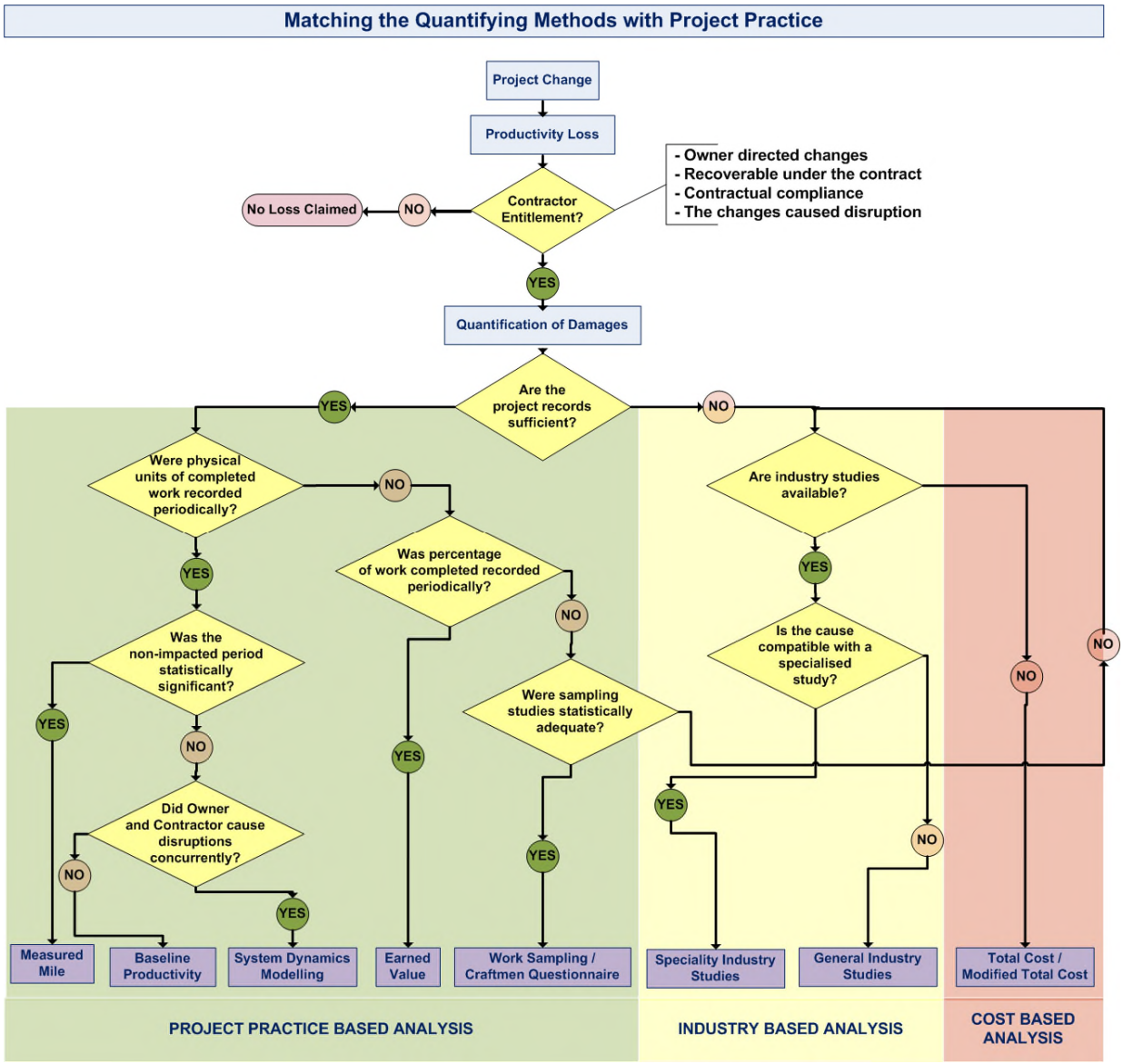
The requirements for the use of the modified total cost method are similar but the bid and actual costs should be reasonable after adjustment.

OTHER QUANTIFYING METHODS

There are other inefficiency estimations such as expert testimony and jury verdict. A considerable portion of lost productivity calculations is based primarily upon an expert's testimony[83]. Although this method might work, it is extremely uncertain due to a lack of supporting analysis. Similarly, the jury verdict approach that is occasionally applied by USA boards, courts, and other bodies to determine damages has no ground on which a contractor should rely.

[83] Sanders, M. C., and Nagata, M. F. (2003). "Assessing methodologies for quantifying lost productivity." AACE Int. Transactions, CDR.18, 1–8.

MATCHING THE QUANTIFYING METHODS WITH PROJECT PRACTICE



The above figure[84] presents a framework from which the suitability of available approaches for analysis and quantifying the effects of disruption may be discerned. This selection process is primarily based on the availability and the characteristics of information available set against the degree of reliability of the quantifying method. Available information can be from particular project practice and/or industry studies.

[84] Adapted from Quantified Impacts of Project Change, Ibbs, Long, Nguyen and Lee, Journal of Professional Issues in Engineering Education and Practice 2007.

A series of questions are asked to select the appropriate quantifying method. Accordingly, the matching process structures critical questions by various decision points. These decision points are organised in such a way that more general questions regarding project practice arise first so that available methods can gradually be classified in terms of their feasibility. Finally, the most advantageous method emerges among the feasible set for a certain type of project data and industry studies. The relative advantages and disadvantages of the lost productivity quantifying methods are discussed in the previous section. The above framework recommends the most favoured approach rather than a set of possible ones. This means that, for example, an earned value analysis can also be used in case a measured mile study is not available. However, the measured mile method is most favoured in that circumstance and hence is recommended. In addition, comparison studies do not appear in the possible outcomes of the framework since much more credible methods such as baseline productivity analysis and system dynamics modelling are preferred when time, available documents, and resources permit.

CONCLUSIONS

Under appropriate circumstances, all of the methods set forth herein are technically acceptable. Of all the methods identified above, the most reliable are those reliant upon the analysis of factual, contemporaneous information drawn from the specific project in question, i.e. Project Specific Studies.

These methods are based upon contemporaneous documentation and knowledge from the project. Thus, they are the closest to approximating actual damages from the project. All other methodologies discussed are estimating techniques with varying degrees of reliability. Therefore, they must be considered less robust. This again highlights the importance of keeping good records from the outset of the project.

To reliably quantify and successfully claim for lost productivity, damages have to be associated with cause. Resultant injury goes hand-in-hand with liability and causation to form the “triad of proof.”

ABOUT THE WRITER

DEREK NELSON

LLM (Construction Law) PGDipICArb FCIArb FSIArb FRICS FCInstCES FQSi CEngS FAE CCP FCMI MAPM BSc

Accredited Expert, Accredited Mediator, Accredited Expert Determiner

PARTNER

Derek Nelson is employer and contractor trained as a Chartered Quantity Surveyor and a Chartered Engineering Surveyor. He is an Accredited and Certified Expert Witness, an Accredited Mediator and Accredited Expert Determiner. His experience covers over 35 years in the construction industry.

He has extensive experience of providing a variety of construction cost, commercial, contract and dispute related services; supporting clients in the international arena by providing strategic independent expert advice or acting as an Expert Witness in the event of litigation and arbitration or other formal dispute resolution process on their international projects.

With over 35 years as a quantity surveyor working on or providing advice in relation to international projects, Derek's expertise is in matters of quantity surveying practice, valuation, damages, contract administration, contract management, commercial management and cost management in connection with on- and off-shore construction and engineering projects. That contract and quantum capability is married to his planning and delay analysis experience.

Derek's academic and professional qualifications coupled with his extensive and detailed experience of the construction process has led him to be appointed as an Independent Expert Witness both in Europe and Asia and he is often called upon to undertake independent reviews of projects in the role of Project Neutral.

REFERENCES

Analysis of Change Order Markup Allowances on Stipulated Price Building Contracts, Aminah Robinson Fayek; Moses Y. Nkuah, Cost Engineering Journal, Vol. 44/No. 1 January 2002

Analyzing the Cumulative Impact of Changes, David D. Reichard; Cheryl L. Norwood, AACE International Transactions, 2001

Analyzing the Impact of Change Orders on a Schedule, Jeffrey A. Veenendaal, Cost Engineering Journal, Vol. 40/No. 9 September 1998

Appropriate Risk Allocation in Lump-Sum Contracts - Who Should Take the Risk?, Dr. Francis T. Hartman, PE; Patrick Snelgrove, P.Eng.; Dr. Rafi Ashrafi, Cost Engineering Journal, Vol. 40/No. 7 July 1998

Assessing Methodologies for Quantifying Lost Productivity, Mark C. Sanders, PE; Mark F. Nagata, AACE International Transactions, 2003

Baseline Determination in Construction Labor Productivity-Loss Claims, Ronald Gulezian, Frederic Samelian, Journal of Management in Engineering, Vol. 19, No. 4, October 2003

Calculating Construction Damages, Second Edition, William Schwartzkopf, John J. McNamara, 2001, 2005 Cumulative Supplement, Aspen Publishers ISBN-13 978-0-7355-1480-5, ISBN 0-7355-5506-0 (supplement)

Calculating Loss of Productivity Due to Overtime Using Published Charts – Fact or Fiction, Regula Brunies, Zey Emir, The Revay Report Volume 20, Number 3, November 2001

Calculating Lost Labor Productivity In Construction Claims, Second Edition, William Schwartzkopf, 2004 Aspen Publishers, ISBN 0-7355-4893-5

Causation and Delay in Construction Disputes, 2nd Edition, Nicholas J. Carnell, Blackwell Science, 2005, ISBN 13: 978-1-4051-1861-3

Change Management Best Practices for the Engineering and Construction Industry, Oracle White Paper, April 2009

Change Orders Impact on Construction Cost and Schedule, George Suhanic, AACE Transactions, 1980

Change-Order Management, Bob M. McCally, AACE International Transactions, 1997

Claim Evaluation for Combined Effect of Multiple Claim Factors, Amarjit Singh, Cost Engineering Journal, Vol. 43/No. 12 December 2001

Consequential Cost Effects, Paul R. Heather, CCE; Michael D. Summers, CCE, AACE International Transactions, 1996

Construction Contracts: Shifting Risk or Generating a Claim?, Donald F. McDonald, Jr., PE CCE; John O. Evans III, AACE International Transactions, 1998

Construction Productivity: A Survey of Industry Practices, George F. Jergeas; Mohammad S. Chishty; Marko J. Leitner, AACE International Transactions, 2000

Construction Productivity: Major Causes of Impact, Charles A. Leonard; Dr. Paul Fazio; Dr. Osama Moselhi, AACE Transactions, 1988

Construction Projects: Change Order Management, Dr. Calin M. Popescu, AACE Transactions, 1986

REFERENCES

Construction Scheduling: Preparation, Liability and Claims, Second Edition, Jon M. Wickwire, Thomas J. Driscoll, Stephen B. Hurlbut, Scott B. Hillman, Aspen Publishers, 2003, ISBN 0-7355-2994-9

Constructive Changes, Anthony J. Werderitsch; James E. Krebs, AACE International Transactions, 2002

Contractors' Protection Against Construction Claims, Dr. George F. Jergeas, PE; Francis T. Hartman, PE, AACE Transactions, 1994

Coping with Changes, Stephen O. Revay, CCC, AACE International Transactions, 2003

Coping with Extras, Stephen O. Revay, The Revay Report Volume 21 Number 2 September 2002

Cost Guidelines for Change Orders, Ronald F. Cilensek, CCE, AACE Transactions, 1986

Delay and Disruption in Construction Contracts, Keith Pickavance, 3rd Edition, LLP, 2005, ISBN 1–84311–426–7

Delay and Disruption: Legal Considerations, Stuart C Nash, Society of Construction Law, August 2002

Delay In The Performance Of Contractual Obligations, Dr John E Stannard, Oxford University Press, 2007, ISBN 978-0-19-928265-4

Demonstrated Labor Efficiency: An Effective Labor Cost Control and Analytical Tool, Bob M. McCally, AACE International Transactions, 1998

Disruption Claims, Hamish Lal, Hill Internation/CIOB Masterclass May 2008

Dynamic Change Management for Fast-tracking Construction Projects, Moonseo Park, Assistant Professor, Department of Building, School of Design & Environment, National University of Singapore. NIST SP 989; September 2002.

Effective Management of Project Change Orders, Edward E. Douglas III, CCC, AACE International Transactions, 2003

EP 415-1-3 Modification Impact Evaluation Guide, 2 July 1979, DEPARTMENT OF THE ARMY, Office of the Chief of Engineers, Washington, DC 20314

Estimating and Negotiating Change Orders, Leonard A. McMahon, CCE, AACE Transactions, 1984

Estimating the Cost of Change Orders, Dr. Osama Moselhi, PE, AACE International Transactions, 1998

Estimating the Cost of Change Orders, Osama Moselhi, PE, Cost Engineering Journal, Vol. 45/No. 8 August 2003

Evidence,The City Law School, City University, London, Editor James Griffiths, Oxford University Press, 2008, ISBN 978-0-19-955353-2

Forward Pricing Impact on Construction Projects, Brian E. Kasen; Victor C. Oblas, PE, AACE International Transactions, 1996

Going the Extra Mile, Walter Bauer, P.Eng., AACE International Transactions, 2004

Guidelines for the Management of Major Construction Projects, NEDO, 1991, ISBN 0 11 701219 X

Impact of Change Orders on Construction Productivity, Osama Moselhi, Charles Leonard, Paul Fazio, CAN. J. CIV. ENG. VOL. 11, 1991

REFERENCES

Impact of Change's Timing on Labor Productivity, William Ibbs, Journal of Construction Engineering and Management ASCE / November 2005

Impacts And Construction Inefficiency, Dwight A. Zink, Cost Engineering Journal, Vol. 32/No. 11 November 1990

Inefficiency, Zartab Z. Quraishi, PE CCE, AACE International Transactions, 2003

Labor Productivity Impacts: A Case Study, Robert D. Kelly, AACE International Transactions, 2000

Labor Productivity, Disruptions, and the Ripple Effect, Dr. H. Randolph Thomas, PE; Dr. Amr A. Oloufa, PE, Cost Engineering Journal, Vol. 37/No. 12 December 1995

Learning Curve in Construction, Zey Emir, The Revay Report Volume 18, Number 3, October 1999

Liquidated Damages and Extensions of Time in Construction Contracts, Third Edition, Brian Eggleston, Wiley-Blackwell, 2009, ISBN 978-1-4051-1815-6

Loss of Learning in Disruption Claims, David A. Norfleet, CCC, AACE International Transactions, 2004

Managing Changes in Construction Projects, Research funded by the Engineering and Physical Sciences Research Council (EPSRC): University of the West of England: Professor Ming Sun, University of Salford: Dr Martin Sexton, Professor Ghassan Aouad, Andrew Fleming, Sepani Senaratne, University of Loughborough: Professor Chimay Anumba, Professor Paul Chung, Dr Ashraf El-Hamalawi, Dr Ibrahim Motawa, Mei Lin Yeoh, 2001-2004

Managing Changes in Construction, NRCC, RR-258, Hao, Q., Shen, W., Neelamkavil, J., June 1, 2008.

Managing Changes in Large Programs, Ashish Kumar, AACE International Transactions, 2000

Managing Contract Changes, Gerard Boyle, The Revay Report Volume 23 Number 3 December 2004

Managing Project Change: A Best Practice Guide, D Lazarus, R Clifton, CIRIA C556, 2001, ISBN 0 86017 556 1

Measured Mile Analysis and International Mega-Projects, Dan Crowley; John C. Livengood, AACE International Transactions, 2002

Measured Mile Labor Analysis, Timothy T. Calvey, PE; William R. Zollinger III, PE, AACE International Transactions, 2003

Measured Mile Process Project Controls to Support Equitable Recovery of Production Inefficiency Claims, Thomas W. Presnell, CCC, Cost Engineering Journal, Vol. 45/No. 11 November 2003

Monitoring Job-Site Productivity, Brian Foster, The Revay Report Volume 19, Number 2, May 2000

Monitoring the Adequacy of the Amount and Productivity of Engineering and Construction Manpower, Dwight A. Zink, CCE, AACE Transactions, 1980

More For Less: A Contractor's Guide To Improving Productivity In Construction, Horner, R M W, Duff, A R, Construction Industry Research and Information Association, C566, 2001, CIRIA, ISBN 0 8601 7 566 9

Practical Analyses in Proving Damages, Jack W. Harris; Andrew Ainsworth, AACE International Transactions, 2003

REFERENCES

Practical Risk Analysis in Scheduling, Abhi Basu, PE, AACE International Transactions, 1998

Proactive Change Order Management, Frank Kettlewell, AACE International Transactions, 2003

Project Changes: Sources, Impacts, Mitigation, Pricing, Litigation & Excellence, PA Consulting Group, 2007

Proof of Damages in Construction Claims, Richard J. Long, AACE Transactions, 1988

Putting the SCL Delay and Disruption Protocol into Practice - is it what the industry wants? Keith Pickavance, Society of Construction Law, September 2004

Quantifying and Managing Disruption Claims, Hamish Lal, Thomas Telford, 2003, ISBN: 0 727731653

Quantifying Disruption through Simulation and Heuristics, Kenneth G. Cooper; Kimberly Sklar Reichelt; Jonathan Moore, AACE International Transactions, 2004

Quantifying the Effect of Change Orders on Electrical Construction Labor Efficiency, Dr. Awad S. Hanna, PE; Dr. Jeffrey S. Russell, PE; David Thomack, Cost Engineering Journal, Vol. 40/No. 2 February 1998

Recommended Practice No. 25R-03 "Estimating Lost Labor Productivity in Construction Claims", AACE International, AACE International Recommended Practice, 2004

Statistical Evaluations of Measured Mile Productivity Claims, Michael Ross Finke, Cost Engineering Journal, Vol. 40/No. 12 December 1998

System Dynamic Modeling of Delay and Disruption Claims, William Ibbs, Min Liu, Cost Engineering Vol. 47/No. 6 June 2005

System Dynamics Modeling in the Legal Arena: Special Challenges of the Expert Witness Role, Craig A. Stephens, Alan K. Graham, James M. Lyneis PA Consulting Group, 2002

The Cumulative Effect of Change Orders on Labour Productivity – the Leonard Study “Reloaded”, Gerald McEniry, The Revay Report Volume 26 Number 1 May 2007

The Effect Of Change Orders On Productivity, Charles A. Leonard, The Revay Report Volume 6 Number 2 August 1987

The FIDIC Forms of Contract, Third Edition, Nael G. Bunni, Blackwell Publishing Ltd, 2005, ISBN 13: 978-14051-2031-9

The Measured Mile: Proving Construction Inefficiency Costs, Dwight A. Zink, Cost Engineering Journal, Vol. 28/No. 4, April 1986

The NEC 3 Engineering and Construction Contract: A Commentary, 2nd Edition, Brian Eggleston, Blackwell Science, 2006, ISBN978-0-632-05386-5

The Productivity Baseline, Ronald Gulezian; Frederick Z. Samelian, AACE International Transactions, 2003

The Quantum Aspects of Delay, David Kyte, Keith Strutt, Hill Internation/CIOB Masterclass May 2008

The Role of the Cost Engineer and the Change Order Process, Alfred L. Dellon, CCE, AACE Transactions, 1986

REFERENCES

The Society of Construction Law Delay and Disruption Protocol (Revised Edition), October 2002, ISBN 0-954383-1-7

Trends in Construction Lost Productivity Claims, Gerald P. Klanaca and Eric L. Nelsonb, Journal of Professional Issues in Engineering, Education and Practice ASCE / July 2004

Understanding project dynamics – cutting project costs, PA Consulting Group, 2008

Understanding Risk to Mitigate Changes and Avoid Disputes, L. Adam Winegard; Stephen P. Warhoe, PE CCE, AACE International Transactions, 2003

Up-Front Cost Estimating of Change Orders, Osama Moselhi; Ihab Assem; Khaled El-Rayes, AACE International Transactions, 2002

Use of Productivity Factors in Construction Claims, Robert Dieterle, CCE; Alfred DeStephanis, AACE Transactions, 1992

Using Industry Studies To Quantify Lost Productivity, Mark G. Jackson, Carl W. LaFraugh, Robert P. Majerus, West Group Construction Briefings, No. 2001-12 December 2001

Variations, Time Limits and Unanticipated Consequences, Ronan Champion, Society of Construction Law, May 2007

1. ATTACHMENT