A REVIEW OF INDUSTRY STANDARDS AND PUBLICATIONS/CHARTS FOR ADJUSTING PRODUCTIVITY LOSSES IN CONSTRUCTION CONTRACTS

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The analysis of lost labour productivity claims on construction projects is a difficult undertaking at its best. One of the accepted methods of quantifying productivity losses is the use of industry standards and publications/charts. The sources of these publications are studies based on data from a large number of projects of varying conditions thus raising questions on their general applicability. The aim of this paper is to review the various published studies in a view to offer guidance to practitioners as to their proper applications. The review examines how they were carried out, their strengths and limitations, which will provide guidance to practitioners as to their proper applications. A major limitation identified was that each of the studies applies to a very specific project environment for specific trades only and that there are many other projects types for which productivity studies are not available. Furthermore, most of the studies were carried out in the US whose construction environment is different from that of the UK making their applicability here tenuous. The paper therefore outlines directions for necessary future research.

Keywords: claims, delay, disruption, labour productivity, loss of efficiency.

INTRODUCTION

Loss of labour productivity in construction often results in more workhours being expended to perform a given scope of work, thereby increasing contractors' cost and reducing their profits (Finke, 1997). Where productivity is reduced due to circumstances for which the Employer is responsible, a claim for productivity loss often results. Such a claim can be sustained as damages for breach of contract or under an express term of the contract such as clause 25 of the JCT Standard Form of Building Contract (JCT, 1998).

Although lost productivity (also known as disruption) claims are not new, they are becoming more commonly encountered in recent times because of decline in productivity. For instance, the Egan report (Egan, 1998) states that recent studies in the UK, US and Scandinavian countries suggest that up to 30% of construction is rework, labour is used at only 40-60% of potential efficiency, accidents can account for 3-6% of total project costs and at least 10% of materials are wasted. Also, a study of 24 construction projects reported by Semple *et al.* (1994) found that 50% of the value of claims was for loss of productivity or disruption.

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However, it is often recognised that the analysis of productivity loss claims is difficult if not impossible (Schwartzkopf, 1995; Ibbs, 1997). A major cause of the difficulty is the fact that productivity losses are often attributable to multiple events and project participants (Leonard *et al*., 1988; Hanna and Heale, 1994) making it almost impossible to isolate the productivity lost due to each event with exactness and precision. There are a number of methodologies used in the industry for the analysis, one of which is Industry studies and guidelines. These studies are developed by researchers and various organisations (e.g. the US Corps of Engineers, Mechanical contractors' Association of America (MCAA), National Electrical Contractors Association of America (NECA), etc) from data collected on a range of projects. The method relies on the fact that sometimes specific comparative data is not available to discretely quantify or analyse labour productivity. Consequently, practitioners often look to published studies and publications for guidance to aid in their analysis. For instance, the MCAA manual lists several types of impacts that may occur on a project and for each impact assigns a percentage that represents labour productivity loss. The advantage of this method over other methods is that it allows a prediction of the most likely losses when negotiating variations prospectively. It is also very useful in evaluating lost productivity resulting from multiple impacts by enabling the analyst to isolate certain impact events and assign a particular value to them (Klanac and Nelson, 2004). There is thus growing acceptance of this methodology in proving inefficiency claims as demonstrated by some US cases (e.g. *Clark Concrete Contractors, Inc.v. General Services Admin.* (1999) GSBCA No. 14340, 99-1 BCA 630,829; *Hensel Phelps Const. Co v General Services Admin.*(2001) GSBCA 01-1 BCA 31,249. However, this methodology has certain inherent problems, primarily with respect to its subjectivity, and often the difficulty in validating the criteria used in the guidelines. Furthermore, productivity loss studies abound with varying degree of applicability in their usage. Knowledge and understanding of the circumstances in which the empirical studies were carried out and their limitations are therefore of paramount importance in attempt to use them as a basis of quantifying labour productivity loss claims. The primary purpose of this paper is to develop such knowledge and understanding using information elicited from in-depth review of the studies.

PUBLISHED STUDIES FOR QUANTIFYING PRODUCTIVITY LOSSES

A number of industry studies have been done to measure the likely effects of a variety of factors that impact on labour productivity. Productivity factors that have mostly being the subject of these studies include: Overtime, Crowding, Overmanning, Trade stacking and Congestion, weather, Variation (or Change) Orders, Learning curve. Table 1 outlines the various studies.

Table 1: Studies on the impacts of various productivity factors

Factor	Study Author	Source/project information	Limitations
Overtime	Kossoris (1947)	Study by US department of Labor in 1947. 78 separate cases covering 2,445 men and 1,060 women were examined.	Study was carried out in manufacturing industries.
	MCAA (1994)	Relied on the above study data to produce guidelines (Larew, 1998).	Limitations of the above study apply.
	NECA (1962)	289 members of NECA in the US were surveyed on overtime issues.	Study not based upon actual empirical field data (i.e. a subjective data). Also the sample size is small.

Table 1 continued

Factor	**Study Author**	**Source/project information**	**Limitations**
Overtime	O'Connor (1969)	Overtime study by Foster Wheeler on large central station boilers in the US from 1963-1968.	No information was given as to how and under what circumstances the data were obtained (Horner and Talhouni, 1995).
	Howerton (1969)	Overtime study conducted in 1964 in the US.	Information of the project's location and trades involved are unknown.
	The Business Roundtable (BRT, 1980)	Data collected in series of short jobs over a period of ten years in a single project in the US in the 1960s.	The results are based entirely on data from a single construction project with gaps in the period of study. Also the nature of the construction activities and the trades involved are unknown (Brunies and Emir, 2001).
	AACE (1973); GSSA (1979)	Relied on the BRT data for their overtime charts (Larew, 1998).	the limitations of the BRT study are applicable.
	Construction Industry Institute (CII, 1988)	Study examined crew performance on seven different heavy US industrial projects between 1984 and 1988 using the crafts: insulators, pipe fitters, electricians, carpenters, ironmongers and labourers.	The curves of this study are of inconsistent patterns making it difficult to draw defensible conclusions with respect to overtime inefficiency.
	CII (1994)	CII study based on 151 weeks of data collection from 4 active industrial construction projects in US from 1989 to 1992.	Early and start-up phases of the works were excluded.
	The US Army Corps of Engineers (ACE, 1979)	US Army Corps of Engineers overtime chart in their "Modification Impact Evaluation Guide".	the study was rescinded in 1996 (Jackson *et al*., 1996).
	Blomberg (1988).	Study based on 3 process plants construction undertaken by the New Jersey section of AACE.	Adjustment of the data to eliminate the effects of other factors was not based on any known acceptable criteria but rather purely on judgements.
	Hanna *et al*. (2005)	Data from 88 mechanical and electrical projects located across the US.	The study cannot be used to predict productivity under a combination of crew schedules.
Crowding, Overmanning, and Congestion	Joint Industry Board for the Electrical construction Industry (JIB, 1970)	Data collected between 1968 and 1970 from 76 different sites in the UK using activity sampling to study Overmanning.	There is a lack of consistency about the results for sites employing fewer than 20 men.
	ACE (1979)	US Army Corps of Engineers chart on crew overcrowding.	Implicit assumption that the original schedule manpower is the optimum manpower.

Table 1 continued

Factor	Study Author	Source/project information	Limitations
Crowding Overmanning, and Congestion,	Thomas and Jansma (1985)	Data collected from 2 Nuclear power plant stations sites with labour forces of over 1000 men to study Overmanning.	No information exists about the quality of the data.
	Smith (1987)	AACE congestion study based on 16 data points.	No information exists about the quality of the data.
Weather	Clapp (1966)	Study based on 5 housing sites each with between 50-120 houses in the UK from 1953 to 1956.	What constitute bad weather as used in the study was not explained.
	OECD (1967)	study of climate and productivity loses in various cold weather conditions in Poland, Sweden and Germany for a number of construction trades.	Information about the source of the study data is not known (Schwartzkopf, 1995).
	NECA (1974)	Study based on productivity of 2 selected electricians performing the same tasks in an environmentally controlled chamber.	Sample size of the study is considered small making it difficult to generalise the results.
	Grimm and Wagner (1974)	Data collected on temperature and humidity over 9-month period and correlated with the work output of 51 masons constructing 283 test wall panels in the US between 1973 and 1974.	No information exists about the quality of the data.
	Kuipers (1976)	Data on climatological factors collected to develop a model for forecasting changes in productivity as climatological factors vary.	The model has not been subject to any detailed testing against actual field data (Schwartzkopf, 1995).
	Hancher and Abd-Elkhalek (1998)	Study based on the US Army Corps of Engineers' hot weather productivity model.	There is no information on the data source of the US Army Corps Engineers model.
Variation (change) orders	Moselhi *et al*. (1991)	Study involved the analysis of 90 actual claims and expert reports from 57 different projects in the US and Canada.	Data collected from claim consulting firms suggesting that the disputes were more contentious than normal.
	Thomas and Napolitan (1995)	Study based on 3 industrial projects (representing 522 workdays) in the US between 1989-1992.	Early and start-up phases of the projects were excluded in the study.
	Ibbs and Allen (1995)	Data obtained from 104 different projects from 35 different companies who are members of the CII in the US.	The study assumes the ratio between installed material cost and the installed total cost as an indication of the size of a change making it inapplicable to situations where changes do not consume materials.
	Hanna *et al.* (1999a)	Data obtained from 61 projects from 26 mechanical contractors in the US.	The study failed to consider the effects of lead-time in their analysis though they mentioned this factor as having significant effect on change.

Table 1 continued

Factor	Study Author	Source/project information	Limitations
Variation (change) orders	Hanna *et al.* (1999b)	Data obtained from 61 electrical projects from 13 separate contractors in the US.	Experience of the project manager (in years) as one of the independent variables in the resulting model, can be challeged because managers are unlikely to improve in exactly the same fashion during their career.
	Hanna and Gunduz (2004)	Data obtained from 34 electrical and mechanical small projects across the US.	The study concentrated on projects with less than 5000 actual man-hours.
	Moselhi (2005)	Study developed a neural network model using data from Moselhi *et al*. (1991).	The limitations of Moselhi *et al*. (1991) study are applicable.

Learning curve

The basic principle of learning curves is that time, cost and man-hours for accomplishing repetitive and subsequent tasks decrease in each repetition, according to a predictable learning rate (Thomas *et al*., 1986). Based on this principle, contractors often claim for productivity losses, for instance when repetitive actions are delayed, interrupted or disrupted by the employer, resulting in forgetting or diminishing of the learning curve. This leads to higher cost of performing the units than otherwise would have been the case.

However, the existing learning curve models for quantifying the losses were developed in the manufacturing industry (Wright, 1936; Carlson, 1973) raising questions of their applicability in the construction industry. The models found in research literature are the straight–line model, the Stanford "B" model, the cubic model, the piecewise model, the exponential model and the Boeing curves (Thomas *et al.* 1986; Couto and Teixeira, 2005). Much of the research effort on learning curves in the construction industry has been limited to comparing the performance of these models against case studies. For instance, Thomas *et al.* (1986) using 65 labour intensive activities indicated that the cubic model is the best predictor whilst the often cited linear model was unreliable. However, studies by Everett and Farghal (1994) showed that the straight-line model offers better prediction while the cubic models offer better correlation with past information. The linear model has also proven reliable in predicting the performance of crew (Duff, *et al*., 1987; Couto and Teixeira, 2005). Based on the assumption that the linear model is reliable, Verschuren (1985) determined the learning rate for a variety of construction activities through the analysis of 230 data sets from 25 projects in the Netherlands. There is therefore some uncertainty as to which of the models is the most reliable, and this can be a major source of dispute in proving productivity claims.

DISCUSSIONS AND RESEARCH DIRECTIONS

Inappropriate use of Industry studies and guidelines/charts in the analysis of disruption claims could lead to unsuccessful results in either negotiation of a variation order or in subsequent litigation. In a view to offer guidance to practitioners as to their proper applications, the foregoing review provides the knowledge and understanding of how these studies were carried out and what their limitations are.

As indicated in table1, some of the studies are not based on original data (e.g. MCAA and AACE overtime charts), and for those based on original data, each applies to a very specific project environment and for specific trades only. Data collections were limited to a number of trades only (mostly on electrical and mechanical trades) making them inapplicable in other trades. There are many other projects about which published data is not available, such projects include roadwork, pipelines, transmission lines or extensive cut and fill operations just to name a few.

Also, some of the studies do not provide information about the quality of the data used i.e. they are silent on questions such as: How the study was conducted? What were the conditions? What was the sample frame? What was the sampling margin of error? What other kinds of intervening variables could be at work? etc. Lack of such information about the studies may suggest that the studies were not rigorously undertaken.

Furthermore, the studies and guidelines by organisations like the NECA, MCAA and US Army Corps are silent on how they should be properly applied. For instance, the MCAA guide allocates 8% productivity loss for minor fatigue impacts whilst for severe instances the impact is 12% (MCAA, 1994). What constitutes “minor” and “severe” as used in the guide is not defined, which can be a potential source of dispute. Also, the fact that the sources of the data for these studies are not revealed suggests that they may be anecdotal and judgemental (Ibbs, 2005). In addition, there is the question of objectivity because they were developed by parties with vested interests and without the tempering perspective of the other project party. Contractor groups developed both the NECA and MCAA manuals whilst employer developed the US Corps Manual (Ibbs, 2005).

In view of these limitations, the application of Industry studies in disruption claims should be done with caution. Claimants asserting lost productivity claims have to understand and document the surrounding circumstances of a claim situation and compare this situation to that of the published study for similarity. Important questions that would guide one in choosing a study include: why/when/where was the study done? How closely does the study fit to the case at hand? In what way does the study not conform to the case at hand?

Notwithstanding the limitations, the appropriate application of the industry studies in prospectively costing a variation or acceleration order is considered helpful in avoiding disputes. Furthermore, the use of the published studies can be useful in demonstrating that there is a realistic basis for the contractor’s efforts to establish that a certain level of productivity could reasonably have been expected or that certain employer caused factors would be expected to adversely affect the productivity of the work force (Shea, 1989). However, the applicability of this methodology in the UK may be tenuous because most of the industry studies were carried out in the US whose construction environment is different from that of the UK. In view of this, the following areas of research have been identified for future work.

- productivity study on out-of-sequence work, trade stacking, cumulative impact of change, work stoppages, dilution of supervision, work overload, absenteeism, loss in productive rhythm, unbalanced crews, slow pace of work, excessive labour fluctuations and interference at work, as there is virtually no study on these factors;a UK-based study on overtime, weather, overmanning/congesting, and change orders because most of the published studies on these were carried out in the USA which has different environment, culture and construction practice;

- research into the development of accurate learning curve forecasting models due to the fact that little exist by way of research in the construction industry on estimating learning curve model parameters as a function of type of work, site conditions, or other management aspects.

CONCLUSIONS

Although lost productivity claims are more commonly encountered in recent times, it is often recognised that the resolution of such claims is difficult if not impossible. The use of industry standards and publications/charts for analysing these claims have been recognised by the courts and practitioners. However, these studies have certain inherent problems, primarily with respect to its subjectivity, and often the difficulty in validating the criteria used in the guidelines. Therefore, knowledge and understanding of the circumstances in which the empirical studies were carried out and their limitations are of paramount importance in attempt to use them as a basis of quantifying labour productivity loss claims. To develop such knowledge and understanding, this paper has sought to review the various published studies, in a view to offer guidance to practitioners as to their proper applications. A major limitation of the use of industry studies in quantifying productivity loss is that each of the studies applies to a very specific project environment for specific trades only and that there are many other project types for which published data is not available. Also, most of the industry studies and guidelines developed by organisations like the NECA, MCAA and US Army Corps are silent on how they should be properly applied and the underlying research methodologies are not explained. In view of these limitations, claimants asserting lost productivity claims have to understand and document the surrounding circumstances of a claim situation and compare this situation to that of the published study for similarity. Notwithstanding the limitations, the appropriate application of the studies/guidelines in prospectively costing a variation or acceleration order is considered helpful in avoiding disputes. They are also useful in demonstrating that there is a realistic basis for the contractor's efforts to establish that a certain level of productivity could reasonably have been expected or that certain employer caused factors would be expected to adversely affect the productivity of the work force. However, the applicability of this methodology in the UK may be tenuous because most of the industry studies were carried out in the US whose construction environment is different from that of the UK. In view of this, the paper finally identified areas of possible future research to help improve on the use of this methodology.

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