Delay Analysis within Construction Contracting Organizations

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Abstract: Delayed completion of a construction project is often caused by a complex interaction of a combination of events, some of which are the contractor's risks and others are the project owner's. The apportionment of the liability to give effect to the risk allocation has therefore been a matter of great controversy. Many delay analysis methodologies have been developed over the years for performing this task. This paper reports on an empirical study into the current practice in the use of these methodologies in the United Kingdom, as part of a wider study aimed at developing a framework for improving delay claims analysis. The part of the study reported here was based on a questionnaire survey of key informants. The issues investigated include the categories of staff within contracting organizations who contribute to delay claims analyses, the awareness, use and reliability of existing delay analysis methods and the obstacles to their use in practice. The main findings of the study are that: (1) the preparation of delay claims often requires input from commercial managers (quantity surveyors), schedulers, site managers, external claim consultants and estimators; (2) commercial managers have the greatest involvement; (3) claims analyzed using the as-built versus as-planned and the impacted as-planned techniques are often successful although there is considerable literature on the shortcomings of these techniques; and (4) the main obstacles to the use of the methods relates to deficiencies in project records and scheduling practice.

DOI: 10.1061/(ASCE)0733-9364(2008)134:9(692)

CE Database subject headings: Claims; Delay time; Construction management; Damage; Scheduling.

Introduction

A number of reports indicate that most construction projects are delayed (HMSO 1995; OGC 2003). Notable recent examples in the United Kingdom include the British Library, the Millennium Building, the Scottish Parliament, the West Coast Mainline Upgrade for Network Rail, and the Wembley Stadium. To a project owner who counted on revenue from the project commencing from a specific date in order to comply with the schedule for repayment of the project finance, delay of even a week is not only an embarrassment, but also a serious risk of financial failure of the whole enterprise. As protection against this risk, project owners invariably state in their contracts with their contractors the amount that will be payable in the event of delayed completion from a cause for which the contractor is responsible.

On the contractor's side, delay in completion entails increased overheads over those budgeted for (e.g., cost of supervisory personnel and site infrastructure required over the extended duration) and loss of the opportunity of taking on other profit-earning projects with the resources tied down on the delayed project. Where the cause of the delay is the project owner's responsibility, the contractor would be entitled to compensation against these losses. The large sums usually involved and the multiplicity of causes of delay that may occur simultaneously often make the determination of each party's responsibility a matter of the greatest difficulty and this often results in disputes requiring resolution through arbitration or other forms of dispute resolution forums (Schumacher 1995; Rubin et al. 1999; Bramble and Callahan 2000).

The task of investigating the events that led to project delay for the purpose of determining the financial responsibilities of the contracting parties arising from the delay is referred to as "delay analysis" (DA). Various techniques for analyzing delay have been developed over the years. Such a technique is referred to in this paper as a "delay analysis methodology" (DAM). Developments in computer technology along with the availability of more advanced and user-friendly project planning software have enhanced the capabilities of these techniques over the past decade (Pickavance 2005). Although these techniques have been very useful, they have wide differences as to their capabilities and the accuracy of the results produced. These differences, coupled with the inherent subjective nature of aspects of DA, have been a major source of disputes (Leary and Bramble 1988; Kumaraswamy and Yogeswaran 2003). With the aim of providing guidance on the appropriate use of DAMs, the United Kingdom's Society of Construction Law (SCL) drafted a protocol briefly describing them and factors to be considered in selecting an appropriate technique for analyzing any delay situation (SCL 2002).

There has been a surge of research interest in DA, which is testimony to the great challenge that project delays pose to project owners and contractors at all levels of the supply chain.

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Note. Discussion open until February 1, 2009. Separate discussions must be submitted for individual papers. The manuscript for this paper was submitted for review and possible publication on July 25, 2007; approved on January 9, 2008. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 134, No. 9, September 1, 2008. ©ASCE, ISSN 0733-9364/2008/9-692–700/$25.00.

The studies undertaken can be classified under four categories. The first, and most populated, consists of those studies aimed at refinements to the existing methodologies to address issues of concurrent delays, ownership of float, the migration of the critical path, productivity losses and resources allocation (Kraiem and Diekmann 1987; Galloway and Nielsen 1990; Arditi and Robinson 1995; Chehayeb et al. 1995; Alkass et al. 1996; Bordoli and Baldwin 1998; Finke 1997, 1999; Shi et al. 2001; Gothand 2003; Sandlin et al. 2004; Mbabazi et al. 2005; Al-Gahtani and Mohan 2005; Hegazy and Zhang 2005; Kim et al. 2005; Lee et al. 2005; Ibbs and Nguyen 2007). The second group of studies analyzes causation using systems dynamics to model the impact of events (Ackermann et al. 1997; Williams et al. 2003; Eden et al. 2004; Cooper et al. 2004). The question of causation concerns the need for a claimant to prove not only that a risk allocated to the other party occurred, but also that it caused the complained delay. The third category has been aimed at development of Information and Communication Technology support tools, such as knowledge-based systems (Raid et al. 1991; Diekmann and Kim 1992) and other decision support systems (Bubbers and Christian 1992; Mazerolle and Alkass 1993; Yates 1993; Battikha and Alkass 1994; Alkass et al. 1995; Lucas 2002; Oliveros and Fayek 2005). Finally, there have been surveys into aspects of some of the existing methodologies (Bordoli and Baldwin 1998; Harris and Scott 2001; Kumaraswamy and Yogeswaran 2003).

A review of the literature suggested a need for more empirical research to complement and extend existing knowledge, understanding and use of the most common methodologies. The research reported in this paper was undertaken as part of a wider study aimed at doing this toward the development of an appropriate framework for improving current delay analysis practice. The part of the research reported was designed to produce answers to the following questions:

- To what extent is industry aware of these methodologies?
- To what extent are the methodologies used in practice?
- What are their success rates in terms of settlement of claims without disputes that require resolution by a third party?
- Which types of staff in construction organizations provide input into the production of delay claims?
- What are the obstacles to the use of the methodologies in practice?

It is anticipated that the answers to these questions will assist, not only the preparation of claims, but also the defense of unmeritorious claims. By far, a more important benefit is to promote common understanding between the project owner and the contractor, thus enhancing the chances of speedy amicable settlement.

A mixed method research design as described typically by Tashakorri and Teddlie (1998) and Creswell (2003), involving the collection and analysis of qualitative and quantitative data, was adopted. The rest of the paper is organized in sections covering: an overview of existing DAMs; the research design and methods followed in carrying out the research; discussion on the results of the analysis of the data collected; and conclusions.

Overview of Existing Delay Analysis Methodologies

Delay is any occurrence that affects contractor's progress or makes it work less efficiently than would otherwise have been the case. Delay is classified in various ways depending on the issue of interest of the analyst. The most common classifications include: (1) "critical" or "noncritical" delay, depending on whether it is on the critical path of the project and would therefore cause delay to the overall project completion date; (2) "excusable" or "nonexcusable," depending on whether the contractor is entitled to extension of time on account of that delay; and (3) "compensable" or "noncompensable" delay, depending on whether the contractor would be entitled to recovery of the cost of inefficiency consequent upon the delay (Alkass et al. 1996; Bramble and Callahan 2000; Kumuraswamy and Yogeswaran 2003).

The common aim of all DAMs has been to investigate how delays experienced by the various project activities affect others and the project completion date and then to determine how much of the overall project delay is attributable to each party (see, for instance, Alkass et al. 1996; Bubshait and Cunningham 1998; Stumpf 2000). By this, time and/or cost compensations for the contracting parties, as a result of the project delay, can be apportioned, although the various methodologies achieve this at different levels of accuracies. It is generally held that for contractors to recover such entitlements they have to prove that the delay events were at the risk of the owner, according to terms of the contract, and that they also affect the project completion date. The latter requirement provides a basis for the high importance attached to the use of critical path method (CPM) of scheduling for proving or disproving time-related claims, such as extension of time and prolongation cost (Wickwire et al. 1989; Bramble and Callahan 2000).

Table 1 summarizes the existing DAMs identified from the literature and the different labels used to describe them. The methodologies most commented upon in the literature are:

- As-planned versus as-built;
- Impacted as-planned;
- Collapsed as-built;
- Window analysis; and
- Time impact analysis.

The following briefly discusses these methodologies. For readers who are interested in further details, the literature listed in Table 1 provides a sound introduction.

As-Planned versus As-Built

This methodology simply compares the activities of the original CPM baseline schedule with those of the as-built schedule for detailed assessment of the delays that occurred. The main advantages of this methodology are that: it is inexpensive, simple, and easy to use or understand (Lovejoy 2004). Its limitations include failure to consider changes in the critical path and inability to deal with complex delay situations (Stumpf 2000; Zack 2001).

Impacted As-Planned

This methodology involves incorporating delays encountered as activities into an as-planned CPM schedule to demonstrate how a project completion date is being affected by those delays. The amount of project delay due to each delaying event is the difference between the scheduled completion dates before and after the addition (Trauner 1990; Pickavance 2005). Although this methodology does not need an as-built schedule to operate, it has major drawbacks, such as failure to consider any changes in the critical path and the assumption that the planned construction sequence remains valid (Stumpf 2000; Zack 2001; Wickwire and Groff 2004).

Collapsed As-Built

This methodology first creates an as-built CPM schedule including all the delays encountered. Delays are then removed from the

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Table 1. Names of Existing DAMs

Common name	Literature review	Alternative names used by different authors
Non-CPM based techniques		
S curve	Rubin et al. 1999	Dollar-to-time relationship (Trauner 1990)
Global impact technique	Leary and Bramble 1988; Alkass et al. 1995, 1996; Pinnell 1998	
Net impact	Leary and Bramble 1988; Alkass et al. 1995, 1996	Bar chart analysis (Zack 2001; Lucas 2002) As-built bar chart (Bordoli and Baldwin 1998)
CPM based techniques		
As-planned versus as-built	Stumpf 2000; Lucas 2002; Lovejoy 2004; Pickavance 2005	Adjusted as-built CPM (Leary and Bramble 1988; Alkass et al. 1996) Total time (Zack 2001; Wickwire and Groff 2004) Impacted as-built CPM (Pinnell 1998)
As-planned but for	Alkass et al. 1996; Pinnell 1998	
Impacted as-planned	Trauner 1990; Pinnell 1998; Lucas 2002; Lovejoy 2004; Pickavance 2005	What if (Schumacher 1995) Baseline adding impacts (Bordoli and Baldwin 1998) As-planned-plus delay analysis (Zack 2001; Chehayeb et al. 1995) As-planned CPM (Pinnell 1998)
Collapsed as-built	Pinnell 1998; Stumpf 2000; Wickwire and Groff 2004; Lovejoy 2004	But-for (Schumacher 1995; Zack 2001; Lucas 2002) As-built but-for (Pickavance 2005) As-built subtracting impacts (Bordoli and Baldwin 1998) As-built-minus analysis (Chehayeb et al. 1995) As-built less delay analysis (Zack 2001)
Window analysis	Galloway and Nielsen 1990; Bordoli and Baldwin 1998; Finke 1999; Lovejoy 2004; Pickavance 2005	Contemporaneous period analysis (Schumacher 1995; Lucas 2002; Zack 2001) Snapshot (Alkass et al. 1995; 1996) Periodic update analysis (Chehayeb et al. 1995) Watershed (Pickavance 2005)
Time impact analysis	Leary and Bramble 1988; Alkass et al. 1996; Pickavance 2005	End of every delay analysis (Chehayeb et al. 1995) Chronological and cumulative approach (Wickwire and Groff 2004)

schedule to create a "collapsed" as-built schedule, which indicates how the project would have progressed but for those delays. The advantage with this approach includes producing results of good accuracy (Lovejoy 2004). Its limitations, however, include: ignoring any changes in the critical path and the great deal of effort required in identifying the as-built critical path (Zack 2001).

Window Analysis

In this methodology, the total project duration as given by as-built CPM schedule is first divided into a number of time periods or "windows." The dates defining the boundaries of these windows are often determined by major project milestones, significant changes in the critical path, occurrence of major delay events and dates for the issue of schedule revisions or updates. These factors decide the number and durations of the windows for the whole project duration and the more windows there are or the shorter their durations, the better the accuracy of the analysis (Finke 1999; Hegazy and Zhang 2005).

The delay analysis begins first by updating the schedule within the first window using as-built information including all the delays encountered in that period, whereas maintaining the remaining as-planned schedule beyond this window. The difference between the project completion date of the schedule resulting from this and that prior to the review process gives the amount of project delay as a result of the delays within the first window. This analysis is repeated successively for each of the remaining windows to determine the effect of all other delay events on project completion. The main strength of this methodology is its ability to take care of the dynamic nature of the critical path. However, it is usually more expensive due to the amount of time and effort needed to perform it (Zack 2001).

Time Impact Analysis

This methodology is a variant of the window technique described earlier, except that in this, the analyst concentrates on a specific delay or delaying event not on time periods containing delays or delaying events (Alkass et al. 1996). The approach evaluates the effects of delays chronologically, starting with the first delay event, by incorporating each delay (sometimes using a "fragnet" or subnetworks) into an updated CPM baseline schedule that represents the actual status of the project before the advent of the delay. The amount of project delay caused by each of the delaying events is successively determined by computing the difference between project completion date of the schedule resulting from the addition of each delay and that prior to the addition. This approach has significant merit making it probably the most reliable technique (SCL 2002). However, it is time consuming and costly to operate, particularly in situations where large numbers of delaying events are involved.

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Research Design and Methods

The nature of a research topic, its aims and objectives and the resources available largely determine its design (Gill and Johnson 2002; Creswell 2003). A major factor considered in the design of this study was the multiplicity of its purposes: exploration of the awareness and use of the various DAMs; description of the people within contracting organizations that provide inputs into the preparation of delay claims and explanation of the differences in the extent of use of the techniques. As the study was centered on the social aspects of DA, which there is very little literature other than individual experiences captured in expert commentaries in journals and a handful of textbooks, it became apparent very early in the study that the data would be largely qualitative in nature. Superimposed on these characteristics of the research was the fact that the researchers, far from being detached observers as required by the positivist research inquiry philosophy, were strongly motivated toward improvement of practice in the analysis and settlement of delay claims. These characteristics of the study therefore belonged to those determined by Bogdan and Biklen (1992), Rossman and Rallis (1998), and Creswell (2003) as requiring adoption of the qualitative inductive research inquiry approach.

Another factor that influenced the choice of research design was the fact that delay claims are prevalent in different forms and in many different types of organizations (employers, contractors, subcontractors, and designers) across the United Kingdom. The research population is therefore very large and diverse. According to Rea and Parker (1997), there is no better method of research than a survey for collecting information about large populations. Survey research strategy also makes it possible to generalize the results to the research population, simultaneously enabling comparisons between target groups to be made (Burns 2000). In this study, differences in experiences and attitudes within and across contractors, owners and their architects/engineers were of particular interest. Further, surveys are viewed as the most appropriate method of studying participants' behavior and job perceptions (Mintzberg 1973; Rea and Parker 1997). However, the multiplicity of the research purpose and diversity in types and sources of data suggested a mixed methods research design with a survey as the dominant strategy being the most appropriate (Tashakorri and Teddlie 1998).

The main source of data was determined as the experience of relevant staff in construction organizations and their attitudes to the existing methodologies. The data collection methods most appropriate to qualitative research are participation in the setting of the study, direction observation, in-depth interviews and document reviews (Creswell 1998). Participation, observation and document reviews were eliminated as inappropriate on account of fragmentation of functional roles involved in DA, geographical dispersion of the participants and commercial confidentiality. This left the in-depth interview as the most appropriate data collection method. However, in the light of the time and resource constraints within which the research had to be completed, a cross-sectional postal questionnaire survey was carried out as a preliminary step to cross-sectional in-depth interviews. This questionnaire survey also provided quantitative data for the quantitative aspects of the study, simultaneously informing the selection of the issues to be investigated by interviews and identification of appropriate interviewees. To overcome the known limitations of postal questionnaire surveys, the questionnaire were designed in compliance with best practice advocated in the literature by, e.g., Moser and Kaltron (1986), Oppenheim (1992), and De Vaus (2002). This paper presents the findings of the postal questionnaire survey.

Table 2. Designation of Respondents

Designation	Frequency	Percent
Commercial manager/quantity surveyor	32	50.8
Planning engineer	10	15.9
Managing director	7	11.1
Project/site manager	6	9.5
External claims consultant	4	6.3
Contracts director	4	6.3
Total	63	100.0

Sampling

The absence of a specific sampling frame for construction organizations with experience of delay claims dictated use of nonprobability sampling techniques. The Kompass Register (Kompass 2006), NCE Consultant's file (2006), and the 2002 RICS Directory (2002), which together lists in excess of 5,000 providers of products and services in the industry, was the starting point of sampling. A list of 2,000 construction organizations of different sizes was compiled from these sources. The list was then divided into the six geographical regions of the United Kingdom (North East, North West, South East, South West, Midlands and Scotland). Using a combination of quota and purposive sampling as described typically by Patton (1990) and Barnet (1991), 600 construction organizations (300 contractors and 300 consultants) were selected based on a need to ensure that the outcomes are nationally applicable and cover the experiences and attitudes of contractors as well as consultants, especially engineers and architects in their roles as contract administrators.

Data Collection

The questionnaires were mailed during August of 2006 to the selected firms. They were addressed to the managing directors of the selected firms with an accompanying covering letter, explaining the purpose of the survey and asking that senior staff members with major involvement in claims preparation or assessment be encouraged to complete it. A total of 74 of the questionnaires addressed to contractors were returned; of these only 63 were properly completed and usable for analysis. The remaining 11 respondents stated either that it was company policy to decline to respond to surveys or that they have little experience in the analysis of delay claims. This represents a response rate of 21% (as shown in Table 2). This was within the expected range of 20–40% typical of similar surveys (Furtrell 1994).

Data Analysis

The respondents were asked to rate a number of variables in respect of the research questions using a five-point Likert scale (1–5). With data measured at ordinal level, it was found appropriate to analyze it using nonparametric statistics involving frequencies, relative index analysis, Kendall's concordance and chi-square tests. These were adopted in view of the fact that ordinal scales produce ranking data for which parametric methods are unsuitable (Siegel and Castellan 1988).

The Statistical Package for the Social Sciences (SPSS) was

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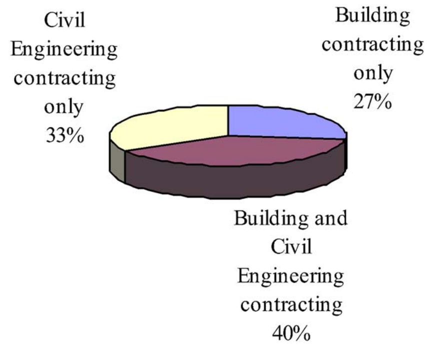

Fig. 1. Respondents organization

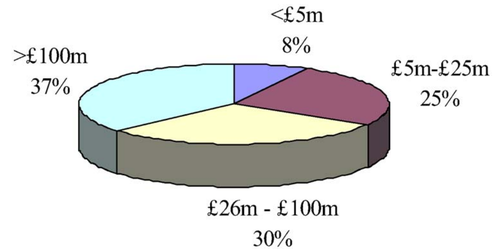

Fig. 2. Size of the organizations in terms of annual turnover (£ millions)

first used to calculate the valid percentage ratings of the research variables. Their ranking was facilitated by means of their rank indices (RI) computed using

$$\mathrm{RI} = \left[\sum_{i=1}^{i=5} w_i f_i\right] \times \frac{100\%}{n} \quad (1)$$

where f_i=frequency of response; w_i=weight for each rating (given by rating in the measurement scale divided by number of points in it; which is 5 in this case); and n=total number of responses. The RI is labeled differently depending upon the context, e.g., "involvement index," "awareness index," "success index," and "frequency index."

Kendall's coefficient of concordance (W) was used to determine the degree of agreement among the respondents in their rankings. This coefficient provides a measure of agreement between respondents within a survey on a scale of zero to one, with "0" indicating no agreement and "1" indicating perfect agreement or concordance. Using the rankings by each respondent, W was computed using (Siegel and Castellan 1988)

$$W = \frac{12\sum R_i^2 - 3k^2N(N+1)^2}{k^2N(N^2-1) - k\sum T_j} \quad (2)$$

where ΣR_i^2=sum of the squared sums of ranks for each of the N objects being ranked; k=number of sets of rankings, i.e., the number of respondents, which is 63; and T_j=correction factor required for the jth set of ranks for tied observations given by $T_j = \Sigma_{i=1}^{g_j}(t_i^3 - t_i)$, where t_i=number of tied ranks in the ith grouping of ties, and g_j is the number of groups of ties in the jth set of ranks.

To verify that the degree of agreement did not occur by chance, the significance of W was tested, the null hypothesis being perfect disagreement. The chi-square approximation of the sampling distribution given by the following equation with $(N-1)$ degrees of freedom is used for testing this hypothesis at a given level, for $N > 7$ (Siegel and Castellan 1988):

$$\chi^2 = k(N-1)W \quad (3)$$

Calculated χ^2 value greater than its counterpart table value implies that the W was significant at the given level of significance and as such the null hypothesis of disagreement is not supported and thus has to be rejected.

Discussion of Findings

Characteristics of the Respondents and Their Organizations

Fig. 1 shows the percentage breakdown on the types of organizations that participated in the survey. The response was fairly uniformly distributed although the group with the highest frequency was involved in both building and civil engineering projects followed by those involved in only civil engineering projects. The lowest percentage came from those involved in building projects only.

With regards to the size of the organizations, four groups were identified based on their annual turnovers (see Fig. 2). Although this shows that the survey covered a wide spectrum of construction organizations, the distribution of the responses was not uniform. Over 60% of the construction firms had annual turnovers of over £26 million (i.e. the majority were medium to large construction contractors). This suggests that larger construction firms are more familiar with delay claims analysis than smaller firms.

Table 2 shows the designations of the respondents, which cover a wide variety of professions with involvement in DA. The largest group acts as commercial managers or quantity surveyors for contractors, with some occupying senior management positions.

Table 3. Experience of Respondents on DA Related Functions

	Years of experience							
Function	0	1–5	6–10	11–20	21–30	>30	Mean years	Standard deviation
Claims preparations	0	7	12	24	15	5	16.6	9.1
Contract management/legal support	8	4	10	23	10	8	15.6	10.7
Measurement	9	17	6	11	13	7	13.4	11.9
Site management	11	10	22	8	8	4	10.7	10.1
Planning and scheduling	12	12	20	9	8	2	9.7	9.2
Estimating	12	22	16	5	5	3	8.0	9.3

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Table 4. Level of Involvement of Experts

Expertise	Involvement index	Rank
Commercial manager/quantity surveyor	86.1	1
Contractor's project/site manager	69.1	2
Head of planning department or his/her nominee	57.8	3
External claims consultant	53.6	4
Head of estimating department or his/her nominee	50.8	5
External lawyer	42.0	6
In-house lawyer	30.7	7

Note: Test statistics: Kendall's $W=0.74$ $\chi^2_{\text{sample}}=327.22$; with $df=6$ $\chi^2_{\text{critical}}(\alpha=0.001)=22.46$.

Table 3 shows their experiences with regards to a number of relevant functions. As can be seen, the average experience on claims preparation /assessments is the highest (over 16 years). This suggests that most of the respondents have been dealing with claims for considerable number of years and thus were well suited to comment on the issues dealt with in the survey. The average years of experience of measurement was higher than scheduling and site management, reflecting the fact that the largest category of respondents was made up quantity surveyors or commercial managers by profession.

Involvement in Delay

The issues to be dealt with, as far as the analysis of claims on delay and disruptions are concerned, are complex, requiring an understanding of contract law, contract forms, contract administration, project planning techniques, and an appreciation of how construction activity typically takes place (Scott et al. 2004). This multidisciplinary nature of DA suggests that a variety of people with a range of types of expertise would have to work together in a team to ensure adequate analysis and settlement of delay claims. Respondents were therefore asked to rank the level of involvement of relevant experts in their organizations in DD claims preparation or assessment on a five-point scale from "very low" (1) to "very high" (5). Table 4, which gives a summary of the results for construction and consulting firms, respectively, shows that there was a strong and significant degree of agreement among the respondents in their rankings (as given by $W=0.74$; $\alpha=0.001$).

The contractor's commercial manager scored the highest degree of involvement followed by the project manager or site manager. This suggests that DA is still the domain of commercial managers although, with the development of user-friendly project planning software, programmers/schedulers appear to be making a significant contribution. The involvement of construction lawyers received the lowest ranking. This low involvement may be explained by the relatively high degree of involvement of external claims consultants (ranked fourth) who often possess relevant legal knowledge.

Level of Awareness and Extent of Use of the Methods

An important consideration that can affect the use or implementation of any DAM is the level of industry's awareness of it. Respondents were thus first asked to rank their level of awareness of the various methods on a five-point scale from "unaware" (1) to "very aware" (5). They were also asked to rank their extent of use of the methods from "low" (1) to "high" (5). Table 5 shows a summary of the results obtained.

Table 5. Level of Awareness and Extent of Use of the Methods

	Awareness		Usage	
Methodology	Awareness index	Rank	Usage index	Rank
As-planned versus as-built	86.4	1	81.9	1
Impacted as-planned	79.6	3	70.2	2
Global	79.9	2	54.6	3
Net impact	72.9	4	51.7	4
Collapsed as-built	59.6	5	47.1	5
Time impact analysis	46.4	6	37.5	6
Window analysis	40.0	8	31.4	7
S curve	40.9	7	30.2	8

Note: Test statistics: Kendall's $W=0.79$ $\chi^2_{\text{sample}}=327.57$; with $df=7$ χ^2_{critical} $(\alpha=0.001)=24.32$ Kendall's $W=0.91$ $\chi^2_{\text{sample}}=403.72$; with $df=7$; $\chi^2_{\text{critical}}(\alpha=0.001)=24.32$.

The as-planned versus as-built methodology received the highest level of awareness with window analysis receiving the lowest. Generally, the respondents were more aware of the simplistic methods (global impact, net impact, and as-planned versus as-built) than the sophisticated methods (impacted as-planned, collapsed as-built, window analysis, and time impact analysis). On the extent of use, the as-planned versus as-built technique was ranked first followed by the impacted as-planned technique. The results are consistent with the findings of previous studies that the simplistic techniques are more commonly used in practice (Bordoli and Baldwin 1998; Harris and Scott 2001; Kumaraswamy and Yogeswaran 2003). Possible reasons responsible for their popularity are that they: are simple to use and understand; do not require complete project records, which are often unavailable (Alkass et al. 1996; Lovejoy 2004) and require fewer resources to use.

As indicated in Table 6, there was significant agreement among the respondents in both sets of rankings ($W=0.79$ and $W=0.91$) at 99% confidence level.

Reliability of the Methods in DA

The DAMs were also assessed with respect to their reliability or success rates in terms of settlement of claims without disputes that require resolution by a third party. Two main aspects, which

Table 6. Level of Success and Challenge to Claims Settlement Using the Methods

	Success		Challenge	
Methodology	Success index	Rank	Challenge index	Rank
Global	45.8	5	90.9	1
Net impact	54.1	3	75.3	2
As-planned versus as-built	80.3	1	67.6	3
Impacted as-planned	67.7	2	64.7	4
Collapsed as-built	49.6	4	54.1	5
S curve	27.1	8	52.0	6
Window analysis	30.9	7	48.5	7
Time impact analysis	37.9	6	46.9	8

Note: Test statistics: Kendall's $W=0.66$ $\chi^2_{\text{sample}}=289.50$; with $df=7$ χ^2_{critical} $(\alpha=0.001)=24.32$ Kendall's $W=0.59$ $\chi^2_{\text{sample}}=262.97$; with $df=7$; $\chi^2_{\text{critical}}(\alpha=0.001)=24.32$.

Table 7. Obstacles to the Use of the Methods

Factors	Frequency index	Rank
Lack of adequate project information	75.9	1
Lack of familiarity with the techniques	75.0	2
Poorly updated schedules	74.4	3
Lack of skills in using the techniques	69.9	4
Baseline schedule without CPM network	67.5	5
High cost involved in their use	66.3	6
Difficulty in the use of the techniques	66.0	7
Lack of suitable scheduling software	65.7	8
Unrealistic baseline schedule	57.5	9
High time consumption in using them	52.0	10

Note: Test statistics: Kendall's $W=0.75$ $\chi^2_{\text{sample}}=330.67$; with $df=7$; $\chi^2_{\text{critical}}(\alpha=0.001)=24.32$.

complement each other, were studied: the level of claims' success associated with each of the methods by rating them on a 1–5 scale (1 representing low and 5 representing high) and the extent of challenge posed by opposing parties to claims analyzed using them on a similar scale from "never" (=1) to "always" (=5). A summary of the results after analysis is shown in Table 6, which shows significant agreement among the respondents in their rankings ($W=0.66$ and $W=0.59$) at 99% confidence level.

The as-planned versus as-built methodology was ranked as the most effective in ensuring success of claims followed by the impacted as-planned technique. This finding contradicts the opinions of some commentators that, on account of various shortcomings, such as insufficient attention to the critical path and lack of capability to deal effectively with concurrency, acceleration and work resequencing, they are considered unreliable (Stumpf 2000; Zack 2001; Pickavance 2005). A possible explanation for this unexpected result is that the high ranking is a reflection of the fact that it is the most widely used methodology, as indicated in Table 5.

On the frequency of challenge posed by opposing parties to delay claims the global method received the overall highest score followed by the net impact technique. This finding corroborates published commentaries (Alkass et al. 1996; SCL 2002). Generally, as had been expected, the sophisticated methods were ranked as less susceptible to challenge than the simpler methods, thus suggesting that the former are more reliable than the latter.

Obstacles to the Use of the Methods

Some commentators have sought to explain the relatively low use of some techniques by pointing out perceived obstacles to their successful usage. To investigate the validity of these commentaries respondents were asked to score the perceived obstacles on the frequency with which they are encountered in practice on a five-point Likert scale (where "1=not frequent" to "5=very frequent"). Respondents were also given the opportunity to add to these factors. Table 7 shows the rankings of the obstacles obtained from analysis of the results. As indicated by the test statistics, the degree of agreement among the respondents in ranking was significantly strong. The five highest ranked obstacles deserve further comment.

Lack of Adequate Project Information

The highest rank given to this factor corroborates commentaries on the poor quality of project records (Kangari 1995; Vidogah and Ndekugri 1998) and the difficulty they pose to achieving the standard of proof required of delay claims (Jergeas and Hartman 1994; Kangari 1995).

Lack of Familiarity with the Techniques

Most construction contracts in the United Kingdom do not require the contractor to produce schedules using CPM (Pickavance 2005) or to produce delay claims by any particular method. Also, the private nature of the methods for resolving disputes from delay claims does not encourage development of awareness of the value of these techniques. The high ranking of this factor suggests a need for remedial review of the curricula of the institutions that provide construction management education. In this respect, industry appears to be taking the lead, as industry-based providers of continuing professional development are increasingly offering high quality courses on DA.

Poorly Updated Schedule

The ideal way of proving delays is to determine the effect of individual delays on project at the time that they occurred (Trauner 1990; Finke 1999). For this to be achievable, the schedule has to be maintained properly by updating it periodically to keep track of important information such as changes in the critical path, actual start and finish dates, and percentage complete for each activity; reassessed activity durations; and logic changes from previous updates. The ranking of lack of proper updated schedules as the third most frequent obstacle to the application of the DAM concurs with the literature relating to poor scheduling and progress report practice (Jaafari 1984; Nahapiet and Nahapiet 1985; Mace 1990).

Lack of Skills in Using the Techniques

It should be clear from the discussion so far that the preparation and negotiation of delay claims requires high levels of multidisciplinary skills, particularly in the areas of scheduling, work methods, costing and information technology. The high ranking of lack of skills in using the techniques was therefore to be expected. Also, such ranking may be inferred from the high ranking accorded to unfamiliarity with the techniques.

Baseline Schedule without CPM Network

The power of CPM-based schedules for proving construction delay claims analysis can be traced back to the early 1970s in the United States (Wickwire et al. 1989). Such schedules allow for the determination of critical path(s) and the interrelationships among multiple causes of delay (Wickwire et al. 1989; Bramble and Callahan 2000). A study by Aouad and Price (1994) showed that most contractors plan and manage construction projects using critical path planning methods. The high ranking of this factor was therefore unexpected. Possible explanations include that the CPM schedules are withheld from delay claims because they tend to contradict the contractor's claim.

Limitations of the Study and How They Were Rectified

Considering the numerous terminologies by which existing DAMs are known by practitioners, there was a considerable risk that responses concerning the methods may be incorrectly answered. This problem was addressed by including, as an appendix to the questionnaire, a glossary of DAMs for the respondent's reference. A second limitation is that the length of the survey led to some incomplete responses. This was readily addressed by adjusting the computations of the percentage ratings to account for a varying number of responses for each question. SPSS has a facility for such adjustment. Notwithstanding these limitations, valuable information on current DA practice and problem areas have been identified that would be of interest to researchers and the construction industry.

Conclusions

Delayed completion of a project often causes loss of some of the revenue budgeted for as well as the incurrence of unanticipated costs on both sides of the contracting chain. Although most contract documents allocate the risk of the underlying causative events between the parties, in many cases the delay is caused by a complex interaction of a combination of events some of which are the contractor's risks, whereas other are the project owner's. The apportionment of the liability to give effect to the risk allocation has therefore been a matter of great controversy. Many DAMs have been developed over the years for performing this task. This paper reports on an empirical study into current practice in the United Kingdom in the use of these methodologies.

The three most well-known methodologies are the as-planned versus as-built, global, and the net impact methodologies. Extent of usage generally corresponds to the degree of awareness of the technique. Although they are also the most prone to challenge they are also those that most frequently lead to winning claims. This is the consequence of a relatively very low usage of the most accurate techniques.

Appropriate use of the methodologies requires multidisciplinary knowledge, understanding, and skills, particularly in the areas of scheduling, construction methods, estimating, costing, construction law, and information technology tools. Quantity surveyors and commercial managers, which are the nearest equivalent of cost engineers in the United States, have the greatest involvement in the preparation and settlement of delay claims within contracting organizations. Respondents reported that poor levels of the required knowledge, understanding and skills often present obstacles to winning delay claims. Other sources of even more frustrating obstacles include inadequate project information, poorly updated schedules, and schedules relied upon not being CPM networks.

The next stage of the research entails semistructured interviews to investigate these issues in more depth.

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