Consultants' Perceptions on Construction Delay Analysis Methodologies

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Abstract: Resolving the delay claims that usually trail delayed completion of construction projects is beset with immense difficulties that often lead to disputes between the parties involved. The research reported in this paper is a part of a wider study aimed at developing a framework for reducing the attendant disputes and aiding cost-efficient dispute resolution. The focus of the part reported here is owner consultants' perceptions on existing methodologies for analyzing project delay. Based on a survey of U.K. construction consulting organizations, the study examined, among others, the awareness and use of these methodologies, their perceived reliability, expert involvement, and obstacles to their use. The main study findings are: (i) delay analysis is a multidisciplinary task, with the project quantity surveyor often playing the leading role on the owner's side; (ii) the simpler methodologies are used more often than the complex ones although the former are known to be less reliable than the latter; and (iii) the principal obstacles to the use of the sophisticated methodologies are: lack of adequate project information, the use of programmes not in CPM network form, and poorly updated programmes. It is thus argued that improvement in current programming and record-keeping practices will promote the use of the more reliable methodologies which, in turn, will facilitate smoother resolution of delay claims.

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Introduction

Modern construction projects are characterized by new standards, advanced technologies, multiparty participation, and frequent owner-desired changes (Abdul-Malak et al. 2002; Pickavance 2005). Coupled with this state are inherent uncertainties and complexities in the physical, financial, and economic environment in which most projects are performed (Howell et al. 1993; Gidado 1996). Such conditions have made completing projects on schedule and on budget a difficult task to accomplish, often leading to claims on cost compensations and time extensions (Schumacher 1995).

Most construction contracts deal with project delays and disruptions by providing in the contract that the contractor may submit claims for extension of time and recovery of costs after appropriate notice that events encountered are "likely to," or "are causing," or "have caused" delay to completion. The submission is made in the first instance to the contract administrator who is often an architect/engineer (A/E) appointed by the owner to manage the project on its behalf, including evaluation of claims submitted by contractors. The nature of the issues raised in such evaluations are usually complex (Leary and Bramble 1988; Pickavance 2005), making it extremely difficult for the parties to reach agreement on the events that actually affected the contractual completion date (Galloway and Nielsen 1990; Schumacher 1995). Contractors typically tend to shift the responsibility of the whole project delay to the owner, while in defending, the latter and its A/E often raise the issue of "concurrent delay" by asserting that the project was delayed by multiple causes not all of which were the owner's responsibility. Consequently, delay claims often evolve into litigation or other forms of dispute resolution. Delay analysis (DA) has developed as a means of providing the justification and quantification of the time and/or cost consequences necessary for resolving the different contentions. It involves detailed investigation of project records, programmes, and their updates, often on retrospective basis, and with the aid of a number of different approaches commonly termed "delay analysis methodologies" (DAMs).

The difficulty in DA that owners and their contractors grapple with is also evident by the considerable studies done in this subject area. The agenda of most of these studies have been driven by the need to:

1. Develop approaches to dealing with concurrent delays (Kraiem and Diekman 1987; Galloway and Nielsen 1990; Arditi and Rubinson 1995; Bubshait and Cunningham 2004; Mbabazi et al. 2005);
2. Detect and deal with possible migration of the critical path (Finke 1999; Bordoli and Baldwin 1998; Gothand 2003; Hegazy and Zhang 2005);
3. Develop alternative modeling techniques to capture more accurately the dynamic behavior of feedback loops caused by delay and disruption events (Ackerman et al. 1997; Williams et al. 2003; Eden et al. 2004);
4. Develop computer-based and knowledge-based expert systems to assist DA (Diekmann and Kim 1992; Mazerolle and Alkass 1993; Yates 1993; Lucas 2002);

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5. Take account of uncertainties in activity durations using fuzzy set theory (Oliveros and Fayek 2005);
6. Address ancillary contentious issues such as acceleration, productivity losses, float ownership and resources allocation (Arditi and Patel 1989; Lee et al. 2005; Al-Gahtani and Mohan 2005; Ibbs and Nguyen 2007); and
7. Understand how practitioners deal with some of the contentious issues involved (Scott 1997; Harris and Scott 2001; Bordoli and Baldwin 1998; Scott and Harris 2004; Kumaraswamy and Yogeswaran 2003).

As can be observed from above, the bulk of current knowledge on DAMs has centered on weaknesses in existing methodologies and development of new improved approaches and/or guidance for addressing those weaknesses. There is, however, little reported research into how practitioners view the application of these methodologies in practice other than individual experiences captured in expert commentaries in journals and a handful of textbooks. Based on review of literature published between 1987 and 2004, Arditi and Pattanakitchamroon (2006), for instance, compiled the views of researchers and practitioners in respect of the strengths and weaknesses of four of the most common DAMs. Studies have also been carried out to compare and clarify the application procedures of these methodologies, based on hypothetical case studies (see, Leary and Bramble 1988; Alkass et al. 1996; Bubshait and Cunningham 1998; Stumpf 2000). These studies suggest the methodologies produce different results for any given claims case, further contributing to the difficulties in delay claims resolution. These characteristics of the methodologies have encouraged debate in the industry over the years as to which is the best or most acceptable DAM. The outcome of the debates so far demonstrates that there is currently no consensus among practitioners with regard to an answer to this question (see for example, Society of Construction Law 2006; Hallock and Mehta 2007).

Recently, two other major initiatives in the form of good practice documents/guide on delay and disruption analysis have been developed by renowned experts associated with DA on both sides of the Atlantic. These are the "delay and disruption protocol" and "forensic schedule analysis," published by the U.K.'s Society of Construction Law (Society of Construction Law 2002) and the U.S. Association for Advancement of Cost Engineering International (USA's AACEI 2007), respectively. These notable documents discuss, among others, the merits of existing DAMs and factors that influence their selection in practice.

The review of the literature suggests that very little attention has so far been given to the question of how practitioners view these methodologies in practice in terms of their awareness, usage, acceptance, and associated problems. The need for clarity on these issues thus forms a gap in the current body of knowledge on DA. Knowledge on these matters will not only provide useful up-to-date information on this subject matter for researchers in this area but also has the potential of benefiting industry practitioners as well. This includes serving as a checklist against which common understanding between employers and contractors on DAMs applications can be promoted. This will enhance the chances of speedy and amicable settlement of delay claims, particularly in the United Kingdom where case law for providing guidance on methodological issues is limited (Pickavance 2005).

Based on the definition of research conceptual framework as described by Miles and Huberman (1994), the above reasons formed the framework within which the writers' research, part of which is reported in this paper, is examined. This paper is on the aspect of the study designed to obtain feedback from construction consulting organizations on the following issues:

- The involvement of different functional experts in DA;
- The extent of their awareness and use of existing DAMs;
- Their perceptions on reliability of these methodologies in terms of settlement of claims without disputes that require resolution by a third party; and
- Obstacles to the use of the methodologies in practice.

Parallel feedback on these issues from contracting organizations has already been reported (Ndekugri et al. 2008).

The paper is structured as follows. The next section gives a brief overview of existing DAMs. This is followed by a description of the research methodology adopted in carrying out the study. Analysis and discussions of the data collected are then presented, including the limitations of the study and how they were addressed. Finally, a summary and the conclusions of the paper are presented. The term "programme" is used to mean "schedule" as understood in the United States.

Overview of Existing DAMs

In essence, the purpose of performing DA is to assess the consequences of various delaying events on the project completion date. According to Schumacher (1995) and Wickwire and Groff (2004), the questions that need to be addressed in this inquiry include: what was supposed to happen?; what actually happened?; what were the variances from the planned performance on the relevant activities?; and how did they affect the project schedule? All the available DAMs, which are referred to in the literature by different names, seek to provide answers to these questions, although they do so with varying degrees of detail and accuracy (Ndekugri et al. 2008).

In this paper, only the most widely recognized methods in the literature are described; they are: as-planned versus as-built, impacted as-planned, collapsed as-built, window analysis, and time impact analysis. Their application involves different operational procedures including impacting different forms of construction programme in CPM network form with delays to understand their effect on the programme actually being worked to at the time of the delay. Three main forms of programmes are often used for this operation: the as-planned programme, the as-built programme, and updated programmes.

Fig. 1 summarizes how the most mentioned methodologies make use of these programmes in performing DA. The following further describes them briefly including their strengths and weaknesses.

The *as-planned versus as-built* methodology analyses the impact of various delays on project completion by examining variances in activities (critical or near critical ones) of the as-planned programme and that of the as-built with regard to their start dates, finish dates, and durations. The causes of the variances are then investigated to determine the responsibility of the project delay. The main advantages of this methodology are that it is relatively 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 (Lovejoy 2004; Pickavance 2005).

On the other hand, the *impacted as-planned* methodology incorporates delay events alleged to have caused late completion of the project into an as-planned CPM programme. The delays can be added chronologically in turn or in a single shot to the baseline programme to demonstrate how a project completion date is being

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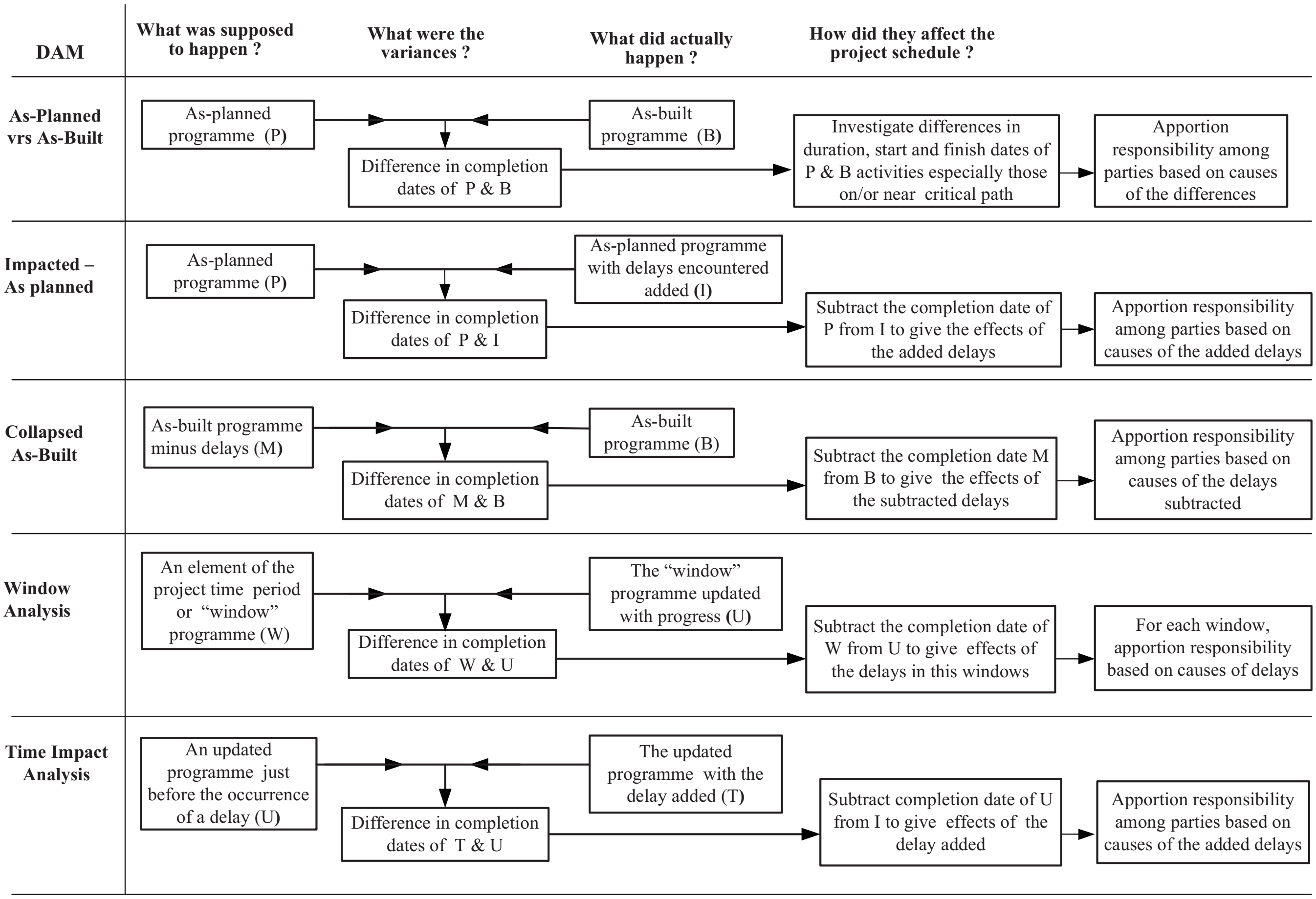

Fig. 1. Different forms of programmes for resolving DA inquiries

delayed by those delays. The amount of project delay due to each delaying event is determined as the difference between the schedules completion dates before and after the additions (Pickavance 2005). The major drawbacks of this approach include failure to consider any changes in the critical path and the assumption that the planned construction sequence remains valid (Lovejoy 2004; Wickwire and Groff 2004).

Unlike the impacted as-planned methodology, the *collapsed as-built* methodology uses the as-built CPM programmes as the baseline for measuring the impacts of delaying events. Delays are removed from this programme, chronologically or in a single shot, to create a "collapsed" as-built programme, which indicates how the project would have progressed but for those delays. The difference between the completion date of this programme and that of the original as-built programme is then calculated as the amount of project delays caused by those delays subtracted. Although this methodology has an advantage of relying on a programme that shows what actually happened on site, it has major limitations. These include ignoring the possibility of migration of the critical path and the great effort required in identifying the as-built critical path (Lovejoy 2004).

For the *window analysis*, the total project duration as given by as-built CPM schedule is first divided into a number of time periods or "windows." This division is often dictated by major project milestones, significant changes in the critical path, occurrence of major delay events, and dates for issuance of schedule revisions or updates (Finke 1999; Hegazy and Zhang 2005). The analysis begins with updating the schedule within the first window using as-built information including all the delays encountered in that window, while 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 delay events encountered during 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 lies in its ability to take care of the dynamic nature of the critical path. However, it is relatively more expensive to perform due to considerable amount of time, effort, and project records needed for the analysis (Lovejoy 2004).

A variant of the window analysis is the *time impact analysis*. The difference is that in the latter, the analysis concentrates on a specific delay or delaying event not on time periods containing delaying events as in the former (Alkass et al. 1996). The approach evaluates the effects of the delays chronologically, by incorporating each delay event into an updated CPM baseline programme that represents the actual status of the project just before the advent of the delay. The amount of project delay caused by each of the delaying events is successively determined by the difference between the project completion date of schedule resulting from each delay addition and that prior to the addition. This approach has significant merit making it probably the most reliable technique (Society of Construction Law 2002). However, it is relatively time consuming and costly to operate, particularly in situations where large number of delaying events are involved.

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Research Methods

A number of factors informed the research methodology adopted in carrying out this study. These include the objectives of the study, type of research questions to be addressed, and resources available for undertaking the study as highlighted by authors such as Gill and Johnson (2002) and Creswell (2003).

The aim and objectives of the study, part of which is outlined in the introduction section, are multifarious in nature requiring diverse types and sources of data to be collected. Coupled with this is the fact that very little information is available in the literature on the issues being investigated. These conditions suggested a mixed method research design (i.e., a combination of both qualitative and quantitative strategies) as the most appropriate research methodology to adopt. The underpinning philosophy was largely that of "postpositivism theory," which assumes, among others, that knowledge is shaped using data, evidence, and rational considerations obtained by instruments based on measures completed by the participants or by observations recorded by the researcher (Creswell 2003).

Data was collected at two different stages consecutively, as typically described in the literature for mixed methods (see e.g., Tashakorri and Teddlie 1998; Creswell 2003). The first stage involved the use of a quantitative research strategy, a cross-sectional survey, to explore current DA practice; aspects of which are reported in this paper. The second stage involved an in-depth qualitative investigation of issues informed by the survey using face-to-face interviews. An important factor that influenced the choice of the survey strategy was the large and diverse nature of the research population given that delay claims are experienced by many different types and sizes of construction organizations (consultants, contractors, subcontractors, and their employers). Surveys are known to be the best when it comes to collecting information about such a large population (see, e.g., Burns 2000; Rea and Parker 1997). This approach also makes it possible to generalize the results to the study population while enabling comparisons between target groups to be made (Burns 2000). Differences or otherwise in the opinion and job perceptions between the main protagonists in delay claims, contractors and owners' consultants, were of a particular concern in this study.

Various methods available for obtaining survey data were also carefully considered in deciding upon the most appropriate one. The main methods include sending questionnaires by post, fax, internet, and administering the same by face-to-face or telephone interviews (Rea and Parker 1997; Gill and Johnson 2002). Given the time and resource constraints of this research combined with the need for a better response rate, postal questionnaire survey was selected as the most appropriate method. However, this approach is not without shortcomings. To overcome these, the questionnaire was designed in line with best practice advocated in the literature (see for example, Rea and Parker 1997; Burns 2000). This mainly involved: (1) making sure the questionnaire is easy to read and understand and without any hidden bias, confusion, or ambiguity and (2) reviewing the questionnaire in a pilot survey of acknowledged DA experts with regards to its clarity, relevance, and the practicality of its completion by respondents.

Sampling

Very little was known about the composition and size of the study's population. This characteristic of the population requires the adoption of nonprobability sampling techniques (Rea and Parker 1997).

To start with, a list of 2000 construction organizations of different sizes was compiled from the *Kompass Register* (Kompass 2006), *NCE Consultants file 2006* (New Civil Engineer 2006), and the 2002 *RICS Directory* (Royal Institute of Chartered Surveyors 2002). This list was then divided into six geographical regions of the United Kingdom (North East, North West, South East, South West, Midlands, and Scotland) to ensure that the findings are a good representative for the U.K. construction industry. Finally, a total of 600 construction organizations comprising of 300 contractors and 300 consultants were selected using a combination of *quota* and *purposive* nonprobability sampling techniques as described typically by Rea and Parker (1992). Quota sampling involves selecting sample according to a given quota in order to ensure that a given characteristics of the population is well represented. The specific characteristic of interest (e.g., turnover) was first decided and the quota set according to the distribution of this characteristic in the population. In purposive sampling, sample selection is done based on a purpose; for instance, by targeting respondents with high experiences on the issues under investigation.

The questionnaires were addressed to the managing directors of the selected organizations with an accompanying cover letter, explaining the purpose of the survey and requesting that senior staff members with major involvement in claims preparation or assessment be encouraged to complete it.

Data Analysis

The questionnaire mainly required respondents to rate a number of variables in respect of the research questions using a 5-point Likert scale. The responses were thus ordinal in nature, which often violates normality assumptions (Siegel and Castellan, Jr. 1988). This type of data cannot be dealt with using parametric statistics unless precarious and, perhaps, unrealistic assumptions are made about the underlying distributions (Siegel and Castellan, Jr. 1988). Therefore, nonparametric statistics involving frequencies, relative index analysis, Kendall's concordance, chi-square, and Spearman rank order correlation tests were used for the data analysis.

Valid percentage ratings of the research variables were first computed with the help of Statistical Package for the Social Sciences (SPSS). Eq. (1) was then used to calculate their rank indices for purposes of ranking them

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

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 degree of agreement among the respondents in their rankings was also determined using Kendall's coefficient of concordance (W). This coefficient gives the measure of consensus or agreement between respondents on a scale of zero to one; "0" indicating no agreement and "1" indicating perfect agreement. With the rankings from each respondent, W was computed using Eq. (2) (Siegel and Castellan, Jr. 1988). The statistical significance of W was tested using chi-square approximation of the sampling distribution given by Eq. (3) with $N-1$ degrees of freedom (Siegel and Castellan, Jr. 1988)

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Table 1. Respondents Organization and Designation

Type of organization	Frequency	Percent[a] (%)
Firm of architects	6	9.0
Firm of engineers	10	14.9
Firm of quantity surveyors	28	41.8
Firm of claims consultants	23	34.3
Organization annual turnover (£m)		
<5	29	43.3
5–25	22	32.8
26–100	6	9.0
>100	10	14.9
Respondent designation		
Planning engineer	2	3.0
Project quantity surveyor	24	35.8
Project architect/engineer	17	25.4
External claims consultant	20	29.8
Managing director/partner	4	6.0

[a]Of the total response from consulting firms.

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

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

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 67; and T_j=correction factor required for the jth set of ranks for tied observations given by $T_j = \Sigma_{i=1}^{gj}(t_i^3 - t_i)$, where t_i is the 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.

Finally, Spearman rank order correlation test was employed to identify any relationship between: extent of awareness of DAMs and their extent of use and likewise between their frequency of challenge and success rate.

Survey Results and Discussions

Survey Response

Of the total questionnaires addressed to consulting firms only 82 responded. Out of this, only 67 were properly completed that could be used for analysis, representing a response rate of 22%. This rate is within the expected range of 20–40% typical of similar surveys (Furtrell 1994). Most of the remaining 15 respondents stated that they have little experience in DA and therefore not well placed to respond to the survey.

Characteristics of the Respondents and Their Organizations

Table 1 shows the distribution profile of the respondents in terms of their designations and organization's types and sizes. The response was not uniformly distributed with majority coming from quantity surveying (QS) and firms offering consulting services on claims (referred to hereafter as claims consultant). There was less response from engineering and architectural firms. This low response is probably because they do not actively carry out most delay claims assessments by themselves as a previous study suggests (Vidogah and Ndekugri 1998).

The size of the organizations was captured in terms of their annual turnovers. On this basis, the response was also not uniformly distributed, with over 60% coming from organizations having less than £26 million annual turnover. The designation of the respondents covers a wide variety of professions of relevance to DA. The majority had experience in roles as employer's quantity surveyor while planning engineers and senior managers had the lowest representation. This aspect of the data is consistent with the fact that quantity surveyors formed the largest category of respondents.

Their years of experiences with respect to a number of relevant functions were also captured as shown in Table 2. As can be observed, experience levels on claims preparation/assessments and contract management were the highest (over 16 years), which is highly relevant to DA. It would thus be reasonable to conclude that the results of this study reflected the reasoned judgment of some of the most knowledgeable and skilled construction professional in the United Kingdom in relation to DA.

Involvement in DA

DA requires teamwork by professionals experienced in various aspects of project management such as the interpretation of contract terms, contract administration, project planning, and site management (Gould 2004). To verify this multidisciplinary feature of DA, respondents were asked to rank the level of involvement of relevant experts in the evaluation and settlement contactors' delay claims assessments on a scale of 1–5; "1 = very low" to "5 = very high." Table 3 shows a summary of the results. The level of agreement among the respondents in their rankings was high and significant.

Project QSs scored the highest degree of involvement. There is evidence in the literature that further supports this conclusion.

Table 2. Experience of Respondents on Delay Analysis Related Functions

	Years of experience							
Function	0	1–5	6–10	11–20	21–30	>30	Mean years	Standard deviation
Estimating	14	17	17	9	5	5	9.4	10.2
Planning and programming	7	21	18	12	5	4	9.9	9.4
Site management	19	22	18	4	3	1	5.7	7.1
Measurement	15	10	15	14	5	8	11.6	11.3
Claims preparations/assessments	4	9	12	19	14	9	16.3	10.4
Contract management/legal support	4	7	9	25	15	7	16.5	9.4

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Table 3. Level of Involvement of Owners' Consultants

Expertise	Involvement rank index	Rank
Project quantity surveyor	80.0	1
External claims consultant	60.7	3
Employer's in-house construction lawyer	35.5	6
External construction lawyer	51.0	4
Project A/E	74.9	2
Client (or other employer personnel)	40.0	5
Test statistics	Kendall's $W=0.61$ $\chi^2_{sample}=288.33$; $\chi^2_{critical}(\alpha=0.001)=20.52$	

The study by Vidogah and Ndekugri (1988), for instance, revealed that A/Es often delegate claims assessment services to QSs for the main reason that they lack the relevant expertise. It can thus be reliably concluded that QSs make the highest input in claims assessment as opposed to this being the result of their highest response rate. This position stands in stark contrast to the provisions in most construction contracts that the obligation of contractors' claims assessment is the responsibility of the project A/E or other authorized individuals such as an employer's agent in design and build contracts. However, such delegation is not always authorized under the applicable contract. There is therefore the risk that a contractor may raise an objection to assessment of a claim by a person other than the A/E or other authorized individual, thus delaying settlement of the claim settlement or even escalating it into a dispute [for examples of the raising of the issue of unauthorized delegation in disputes not only referred to arbitration but also appealed from the arbitration to the court, see *Anglian Water Authority v. RDL Contracting* (1988) 43 BLR 98; 27 Con LR 77 and *Cantrell v. Wright and Fuller* (2003) EWHC 1545; (2003) BLR 412]. Furthermore, the delegation may in itself cause delay where the person to whom the assessment is delegated is unable to work to the timetable either specified in the contract or reasonably to be expected.

The responses indicate that the extent of use of construction lawyers is much less than for other functional experts. A possible explanation for such low level of involvement of lawyers is probably the relatively high engagement of external claims consultants, who often possess relevant legal knowledge required in DA. Furthermore, as the main area for input by lawyers is entitlement in principle, the responses suggest that the evaluation entitlement is much less contested than the issues of quantum on which the other functional experts are more knowledgeable than lawyers.

The low level involvement of personnel in the employer's organization is understandable in the sense that A/Es and project quantity surveyors are often contracted by employers as their representatives for administering the contract including claims assessment responsibility, as pointed out before. Indeed, the employer in many contracting systems is under a duty not to interfere with these project staff in the exercise of their professional judgment. However, this role of the A/E, is often criticized on the basis that they can hardly act as truly independent claims assessors, particularly where they are responsible for the events giving rise to the claim. Despite these considerations, research suggests that employers who are more directly involved in the settlement of claims achieve a higher rate of amicable settlement than those who maintain a detached stance (European Construction Institute 1992). The challenge for employers is therefore in gauging how to engage proactively with claims without interfering with the professional judgment of the independent project staff.

Awareness and Extent of Use of DAMs

Most of the comments by researchers and expert commentators on the DAMs concern their strengths and limitations in their use in DA. However, very little is known about the extent to which these characteristics have influenced their use in practice. To investigate this, the respondents were asked to rank their extent of

Table 4. Level of Awareness and Extent of Use of the Methods

Methodology	Awareness: Awareness rank index	Awareness: Rank	Usage: Usage rank index	Usage: Rank	Correlation between awareness and use
S-curve	68.8	8	37.2	7	0.468[a]
Global	75.7	4	36.7	8	0.375[b]
Net impact	69.3	7	39.7	6	0.228[b]
As-planned versus as-built	86.3	1	56.3	2	0.198[b]
Impacted as-planned	77.6	3	54.1	3	0.410[b]
Collapsed as-built	78.5	2	63.0	1	0.277[a]
Window analysis	71.2	6	48.9	5	0.431[a]
Time impact analysis	74.3	5	52.5	4	0.289[a]
Test statistics	Kendall's $W=0.63$ $\chi^2_{sample}=296.84$ $\chi^2_{critical}=24.32$ at $\alpha=0.001$		Kendall's $W=0.82$ $\chi^2_{sample}=386.61$ $\chi^2_{critical}=24.32$ at $\alpha=0.001$		

[a]Significant at 0.01 level.

[b]Significant at 0.05 level.

Table 5. Claims Success Rate and Frequency of Challenge Associated with the Methods

Methodology	Success: Success rank index	Success: Rank	Challenge: Challenge rank index	Challenge: Rank	Correlation between challenge and success
S-Curve	33.6	6	71.8	4	−0.352[a]
Global	32.8	8	82.6	1	−0.298[b]
Net impact	33.5	7	78.4	2	0.443[a]
As-planned versus as-built	53.6	3	72.9	3	−0.366[a]
Impacted as-planned	51.1	5	67.3	6	−0.256[b]
Collapsed as-built	52.2	4	65.4	8	−0.281[b]
Window analysis	57.8	2	66.0	7	−0.488[a]
Time impact analysis	60.3	1	67.6	5	−0.321[b]
Test statistics	Kendall's $W=0.68$ $\chi^2_{\text{sample}}=318.77$ $\chi^2_{\text{critical}}=24.32$ at $\alpha=0.001$		Kendall's $W=0.64$ $\chi^2_{\text{sample}}=300.53$ $\chi^2_{\text{critical}}=24.32$ at $\alpha=0.001$		

[a]Significant at 0.01 level.

[b]Significant at 0.05 level.

use of the various methodologies on a 5-point scale form "low" (=1) to "high" (=5). Because level of awareness of the methodologies has a direct link to their usage level, the respondents were first asked to rank them on a similar scale from "unaware" (=1) to "very aware" (=5). Summary of the results are shown in Table 4. As shown, the degree of agreement among the respondents in their rankings was high and significant.

The as-planned versus as-built methodology is the most well-known methodology followed by the collapsed as-built technique and then the impacted as-planned. The least known is the *S* curve followed by the net impact approach. On extent of use, collapsed as-built ranked as the most popular followed by the as-planned versus as-built methodology with the global approach being the least popular methodology.

Unexpectedly, the window analysis and time impact analysis methodologies are not widely used despite their wide approval by practitioners on account of their robustness in DA (see e.g., Society of Construction Law 2002; Pickavance 2005). This is probably because they require accurate and complete project records for their application, which unfortunately are often lacking in practice (Kangari 1995; Vidogah and Ndekugri 1988; Scott and Assadi 1999). This problem of records was further confirmed by the respondents in ranking "lack of adequate project information" as the number one obstacle to the use of DAMs (see Table 6).

There was a significant positive relationship between awareness level and extent of use suggesting that respondents employ the methodologies to the same extent as they are aware of them. This positive correlation between awareness and use concurs with common sense, providing considerable support for the validity of the ranking results. Correspondingly, it is arguable from this finding that training in the use of the more sophisticated methods is likely to increase their adoption.

Reliability of the Methodologies in Delay Claims Resolutions

It is often lamented that there is paucity of U.K. case law on the right methodologies for analyzing delays (see e.g., Harris and Scott 2001; Pickavance 2005). The chances for practitioners to learn from the practical experience of others in their use of DAMs, particularly on their acceptability or reliability, have therefore been limited. A section of the questionnaire thus sought to examine respondents' views on reliability of the methodologies in terms of settlement of claims without disputes that require resolution by a third party. On this, respondents were first asked to rank the methodologies on the level of claims' success associated with their use, using the scale of 1–5 (1 representing low and 5 is for high). They were also asked to rank the same on the frequency of challenge posed by opposing parties to claims analyzed by them, using a similar scale from "1 = never" to "5 = always." Table 5 shows summary of the results, which indicate high and significant degree of agreement among the respondents in their rankings.

The sophisticated methods (collapsed as-built, window analysis and time impact analysis) are generally perceived as more reliable than the simplistic methods (global impact, net impact and as-planned versus as-built). This view is consistent with that of researchers and expert opinions in the literature (see e.g., Alkass et al. 1996; Pickavance 2005; Society of Construction Law 2002). However, the irony about this finding is the fact that the methodologies perceived as being the most reliable by the respondents are not widely used. The response presented in the next section suggests that lack of project records required for their application is a major obstacle to their use, leaving analysts with little option but to apply the less reliable methodologies as their use is much less demanding in terms of availability of records.

There was a significant inverse correlation between methodology rankings on the challenge level they pose and the rate of claims' success associated with their use. This suggests that the more a claim, as analyzed by a methodology, is vulnerable to challenge by the opposing party, the less likely there would be a successful claims settlement without disputes. This concurs with common sense, underlining the validity of the ranking results.

Obstacles to the Use of the Methodologies

A good starting point in the design of a framework for improving DA is to know the critical problems affecting the use of DAMs, especially the most reliable ones. As a means of identifying these problems, a number of factors often perceived by commentators as obstacles to the successful use of the methodologies were presented to the respondents to rank on the frequency with which

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Table 6. Obstacles to the Use of DAMs

Obstacle	Frequency index	Rank
Lack of adequate project information	76.4	1
Poorly updated programmes	73.0	2
Baseline programme without CPM network	69.9	3
High cost involved in their use	67.5	4
High time consumption in using them	64.5	5
Difficulty in the use of the techniques	62.1	6
Unrealistic baseline programme	60.0	7
Lack of familiarity with the techniques	53.5	8
Lack of suitable programming software	47.5	9
Lack of skills in using the techniques	44.1	10
Test statistics	Kendall's $W=0.87$ $\chi^2_{\text{sample}}=386.09$; $\chi^2_{\text{critical}}(\alpha=0.001)=24.32$	

they are encountered in practice, using the 5-point Likert scale (where "1=not frequent" to "5=very frequent"). The questionnaire also requested respondents to add and rank any other obstacles not included in the list. Table 6 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 their ranking was strong and significant. The section following is devoted to discussions on the top five obstacles.

Lack of Adequate Project Information

The highest rank given to this factor was not unexpected given that record keeping on construction sites has been criticized over the years for their insufficiency, inaccuracies, and poor sources (Kangari 1995; Vidogah and Ndekugri 1988; Scott and Assadi 1999). This high ranking is more detrimental to the use of sophisticated DAMs such as time impact analysis due to the detailed records they require. This is a major reason for the greater use of the less sophisticated methodologies.

Poorly Updated Programmes

Accurate analysis of delay requires programmes relied upon to be up-to-date, capturing actual progress to date and the plan for performing the remaining activities (Leary and Bramble 1988; Finke 1999). This requirement is particularly important for the implementation of the sophisticated methods. The high ranking of this obstacle further explains the low level of use of these methodologies. This ranking corroborates the views of researchers and expert commentators that contractors often fail to update their programmes properly (Nahapiet and Nahapiet 1985; Winter and Johnson 2000).

Baseline Programme without CPM Network

The CPM is now a well recognized vehicle for undertaking DA mainly on the account of their ability to ascertain whether delay events or occurrences encountered actually impacted on project duration (Leary and Bramble 1988; Wickwire and Groff 2004). Previous U.K. studies suggest that most contractors often employ this tool for programming of their works (Aouad and Price 1994; Kelsey et al. 2001). The third rank of this obstacle therefore came as a surprise and thus requires further research attention.

High Cost Involved in Using the Methodologies

The requirement for multidisciplinary expertise and skills makes DA an expensive task to undertake in the sense that individual analysts are unlikely to possess all the required know-how, necessitating the involvement of other experts possibly by hiring. The high ranking of this factor was therefore not unexpected. The cost is relatively high for sophisticated methods such as the time impact analysis which requires detailed and meticulous analysis procedures, access to expensive and complex software packages and competence in using them (Lucas 2002).

Time Requirements

Time is an aspect of costs. However, it was decided to include the time necessary to apply the methods as a separate variable to focus on the fact that most contracts impose a timetable within which evaluation of a delay claim must be completed. The software tools available to support critical path analysis are now so powerful that they facilitate DA operations in a much faster manner than has been the case before (Pickavance 2005). The fifth ranking of this factor suggests that DA is not just about feeding information about a construction programme into a software system for the computer to determine the critical path. It often also calls for detail consideration of issues such as the reliability of the baseline programme, float consumption, concurrent delays, and changes in the critical path (Leary and Bramble 1988; Wickwire and Groff 2004; Pickavance 2005). Such considerations have become more essential in recent times due to the increasing awareness of arbitrators and the courts on the shortcomings in applications of the CPM. As Schumacher (1995) puts it, "*triers-of-facts will no longer naively accept as fact complicated and unintelligible evaluations based on fancy computer-generated printouts and charts*."

Study Limitations and Their Rectifications

In view of the fact that the available DAMs are known by different terminologies, there was the risk that responses on the methodologies might not exactly reflect the actual views held about them. To avoid the confusion associated with the terminological fluidity, a glossary of the methodologies, as commonly defined in the literature, was attached to the questionnaire as an appendix. Respondents were prominently directed to refer to the terminology in the appendix before completing the questionnaire. Another limitation was that there were some incomplete responses probably on account of the length of the survey questionnaire. This limitation was readily addressed by adjusting the computations of the percentage ratings to account for the varying number of re-

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sponses for each question using SPSS. Despite these limitations, the study has brought to light interesting insights on current use of DAMs, which should be of interest to those involved in DA as practitioners or researchers.

Summary and Conclusions

Completing a project late is a common feature of most modern construction and engineering projects and this often results in significant financial losses to all stakeholders. The factual situation surrounding the causes of the delay is often complex and convoluted often leading to difficulties and disputes in deciding on time-related compensations among contracting parties. In resolving this problem, most contractors and consultants (usually on behalf of employers) often rely on various DAMs. Although this subject has received considerable attention in terms of research and commentaries, there is very little research into the use of these methodologies in practice and associated problems. This paper reports on such a study based on a survey of U.K. consulting organizations, as part of a wider research aimed at developing a framework for improvement. The main findings of the study can be summarized as follows:

1. Assessing contractors' delay claims is a multidisciplinary task involving many parties. The employer's quantity surveyor plays a leading role in this as oppose to the common provision in contracts that the project A/E is the main party responsible for the assessment.
2. The most well-known and widely used methodologies for the assessment are the as-planned versus as-built, collapsed as-built, and the impacted as-planned although these are known to have major flaws. Conversely, methodologies perceived as the most reliable, the time impact analysis and window analysis, are not widely used.
3. The respondents indicated that factors often presenting obstacles to the use of the methodologies are lack of adequate project information, poorly updated programmes, baseline programme without CPM network and time and cost involved in their application.

It is thought that an important consideration that will reduce the chances of disputes on delay claims is for the parties to employ more reliable DAMs. This is because these methodologies are capable of producing accurate results which will facilitate smooth settlement of the claims. However, this study suggests that such methodologies are not widely used mainly due to a number of problems related to improper programming and record keeping practices. Improvement in this practice is therefore an essential requirement in determining what framework might be appropriate for promoting better DA practice toward reducing disputes. Such improvement is likely to involve further studies and this is an area the authors have been working on.

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