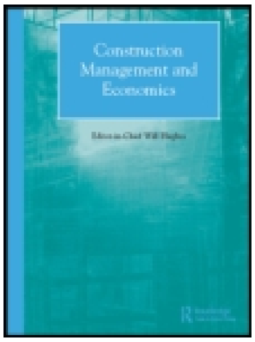

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The nature and effects of construction delays

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The nature and effects of construction delays

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A method for assessing delay claims, regularly used in the USA, is described, together with procedures which have been proposed for dealing with concurrent delays. These treatments are reviewed to identify their shortcomings which in some instances stem from a view of the nature of delays which is not consistent with the way in which delays actually occur. The various types of delay are examined to consider how these treatments might be amended to provide more realistic solutions. It is suggested that concurrent delays need only be separately considered when they affect a single activity, and the concept of parallel critical paths in an as-built network is thought to be invalid. The delays themselves are not always fixed in when they might have their effects and it is felt to be important that this be recognized. Finally a procedure is suggested to select days of exceptional adverse weather artificially, so that critical path method (CPM) analyses may be carried out.

Keywords: Construction, delay claims, concurrent delays, CPM assessment of delays.

Introduction

An important measure of success in the management of construction projects is the achievement of the completed project within the prescribed time scale. Projects which are late will typically produce financial penalties, either in lost profits that would have accrued through use of the project, or through expected benefits to the public not being realized. This tardiness in completion will probably be a direct result of delays that have occurred throughout the construction process and which have had a knock-on effect on the project as a whole.

Some delays will not have any knock-on effect on the whole project, their impact being solely in the cost of resources standing or working at a reduced efficiency. It is said that in such instances, the delays have only consumed available float time within the programme, and thus their influence is limited. For delays that do impact on the project completion, however, the financial implications may be much greater. Depending on who is seen to be responsible for such delays, the consequences can range from an agreed extension to the project time with payment of the Contractor's overhead costs, to the deduction of liquidation damages from the Contractor.

In practice, the situation is invariably very complicated. Most conditions of contract recognize two separate types of delay and provide remedies for their effects in terms of their impact on completion of the whole project. If it is also recognized that any delays for which the Contractor is responsible should not give any relief from timely completion, we can then see delays as represented in three categories. These are summarized in Table 1.

Clearly, it is dangerous to generalize on contractual matters, and for any particular contract it is the actual conditions used that must be consulted to determine liability for these delays. For example, the right to an extension of time under the ICE Conditions of Contract 6th edition (Institution of Civil Engineers, 1991) for type N delays other than exceptional adverse weather (which is specifically covered) may be dependent on the Engineer's interpretation. However, provided this is understood, such an approach to delay categorization is a helpful means of representing the situation. Compensation in terms of an increased time in which to complete the contract, with or without reimbursement of overheads, will of course only be due where it can be shown that individual delays have actually caused the whole project to be delayed. Therein lies the crux of the problem.

In the UK, it is recognized that these problems lend

Table 1 Common remedies for delays

Delay type	Examples	Remedy
Employer responsible (E)	Variations, failure to provide site/ information	Extension of time with recovery of overhead costs
Contractor responsible (C)	Insufficient labour/plant, remedial works	No compensation in either time or cost
Neither party responsible (N)	Strikes, riot, exceptional adverse weather, force majeure	Extension of time to defray deduction of liquidated damages, but no costs

themselves to solution using the critical path method (CPM) of project planning but no clearly defined procedure for arriving at such solutions has been found (Scott, 1991). By contrast, in the USA there is a history of adopting CPM for dealing with delay claims and a recognized approach has been in use for some time (Wickwire and Smith, 1974; Wickwire *et al.*, 1989). This approach will be outlined here, together with descriptions of methods for dealing with concurrent delays – an additional complication that may have to be considered when assessing the impacts of delays. These treatments of this complex problem area, which attempt to provide a prescription for all situations that might occur, fail in certain circumstances to recommend a sensible or manifestly just outcome. Each treatment will be considered in turn to identify these shortcomings. One of the main difficulties stems from the way in which these procedures assume that delays can be defined, and the final section of the paper considers the nature of delays.

Analysis of delay claims using CPM

This procedure, which is well accepted by boards of contract appeals and courts in the United States, entails the preparation of four CPM diagrams to determine each party's rights in a project where delays have occurred. These are:

1. a reasonable 'as-planned' CPM;
2. an 'as-built' CPM;
3. an 'as-built' CPM reflecting all delays – those for which the Employer, the Contractor and neither party are responsible;
4. an 'adjusted' CPM to establish the time for completion of the project in the absence of Employer delays.

Each diagram will only be discussed briefly here, but it is stressed by Wickwire and Smith (1974) that the procedure should be well documented in terms of an analysis of the project records and that it is unlikely that the diagrams alone will suffice if the aim is to convince a third party. The basic network used in the illustrations is a shortened version of that used in the paper by Kraiem and Diekmann (1987) and as in that paper, it has not been seen as necessary to define the activities or delays specifically. The CPM format adopted throughout is that of a time-scaled activity-on-arrow format as this is accepted as the most helpful system for these matters.

'As-planned' CPM

This diagram is constructed to determine the precise time schedule and sequence of construction that the Contractor planned to use in constructing the project. Although not necessarily the optimum plan when viewed in hindsight, it is suggested that it should be shown to be economical in both cost and time. Figure 1 is an example of an 'as-planned' CPM. Where errors in the plan are discovered during construction, it may be helpful to incorporate and correct such errors to produce a 'realistic' reasonable 'as-planned' CPM. As such a procedure would possibly cover up any Contractor-responsible delays, it has not been adopted in this case.

'As-built' CPM

Here the actual starts and ends of all activities are represented on the CPM diagram, and although sources of delay are not highlighted, the effects of delay are evident in the dates used. At this stage, the actual critical path(s) that dictated the project completion date may be identified.

'As-built' CPM reflecting all delays

This diagram may be considered as an overlay on the previous 'as-built' CPM that serves to segregate the delays and any knock-on effects encountered into those for which the Employer, the Contractor or neither party were responsible (delays type E, C and N respectively). Figure 2 is an example of an 'as-built' CPM reflecting all delays.

'Adjusted' CPM

If we wish to know the effect which the delays attributable to the Employer (type E) had on the

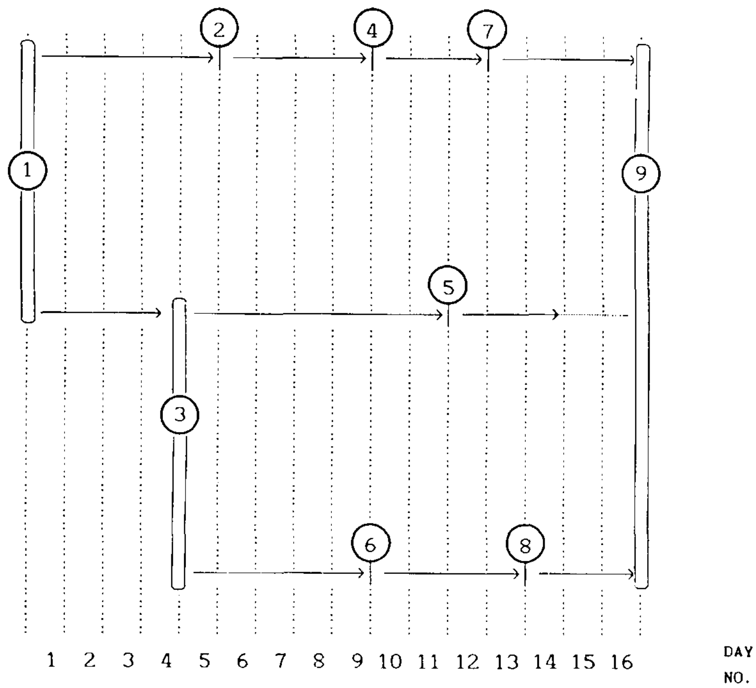

Figure 1 'As-planned' CPM. (See Fig. 2 for key)

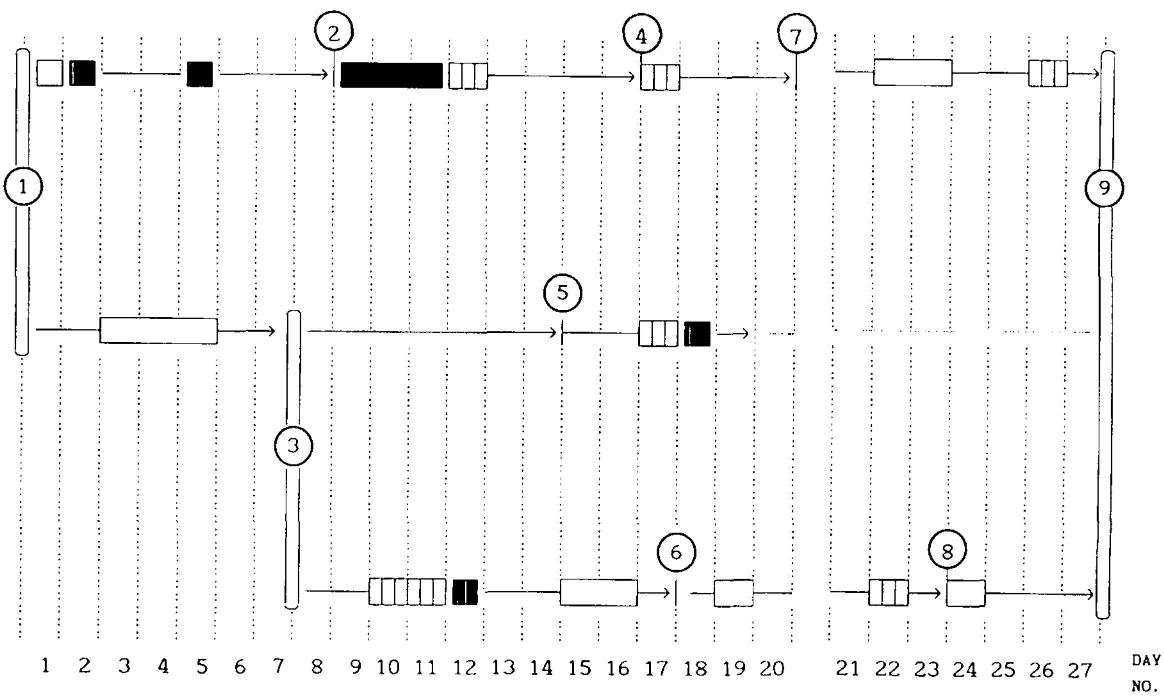

Figure 2 'As-built' CPM reflecting all delays: , Delay for which the employer is responsible; , delay for which the contractor is responsible; , delay for which neither party is responsible; , activity; , float; , , events.

completion of the project, the argument adopted is that we must pull out, from the 'as-built' CPM reflecting all delays, those type E delays that affected the critical path(s). This having been done, however, what remains may not be sensible, as the type E delays may have so changed the sequence of construction that both activity durations and sequences may have to be adjusted before a reasonable plan results. When this procedure has been

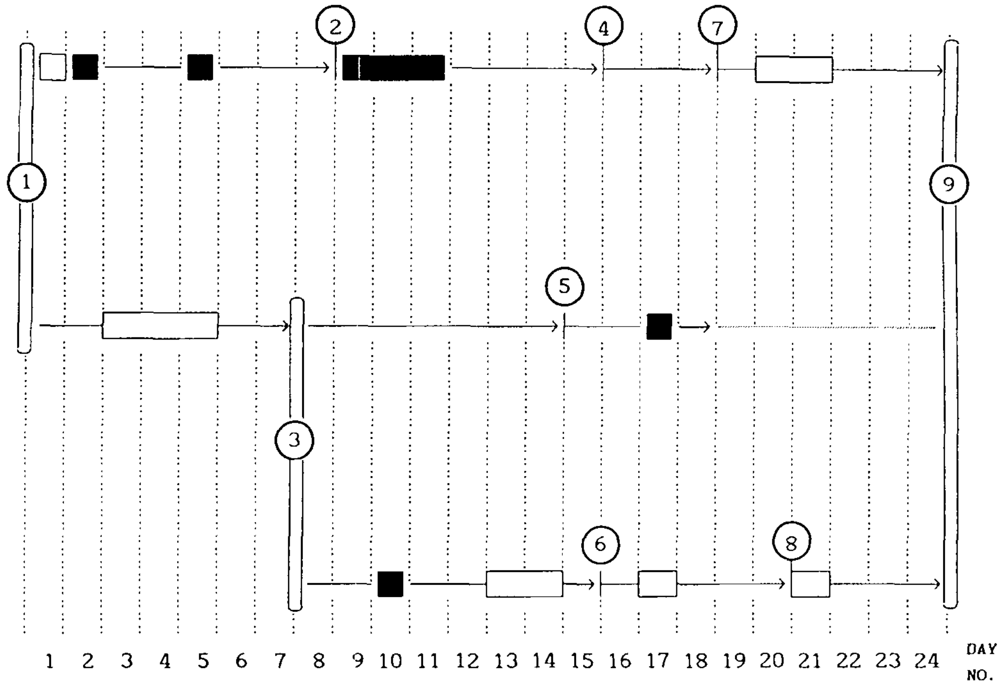

Figure 3 'Adjusted' CPM (key as Fig. 2).

finalized, the amount of delay for which the Employer is liable in terms of both cost and time is found by the difference in time between the actual completion date and the completion date shown on the 'adjusted' CPM. Figure 3 provides an example of an 'adjusted' CPM, and clearly in this case, the Employer is seen to be responsible for 3 days' delay to the whole project with costs; additional extensions of time that are due will therefore be without costs.

Dealing with concurrent delays

Concurrent delays have been described by Rubin *et al.* (1983) as two or more delays that occur at the same time, either of which, had it occurred alone, would have affected the ultimate completion date. In effect, this is another level of complication to the problem of analysing construction delays. Two methods that specifically set out to deal with this situation have been identified in the literature and these will now be described.

First cause defines liability

The philosophy behind this procedure, which is proposed by Hughes (1983), is that once the job is stopped by one cause of delay, it cannot be any more stopped by another delay, unless and until the second delay continues after the first delay has ceased. The argument put forward is that liability must rest with the party responsible for the first delay encountered for the duration of this delay. Subsequent delays that occur during the period of the first delay should not affect liability. This is illustrated by the diagrams shown in Fig. 4. For the scenarios depicted in column 1, (a) to (d), where an initial delay is caused by the Contractor but subsequent delays attributable to both Employer and neither party occur, the argument is as follows:

- 1(a) The initial delay, C, continues beyond the end of both delays of type E and N and thus no resultant claim is justified.
- 1(b) Delay of type N continues beyond the end of the initial delay, C, causing a possible extension of time.
- 1(c) The second delay, E, continues beyond the end of the initial delay, C, causing a possible extension of time with costs; delay of type N continues beyond the end of the second delay causing a possible extension of time.
- 1(d) The second delay, N, continues beyond the end of the initial delay, C, causing a possible extension of time; delay of type E continues beyond the end of the second delay causing a possible extension of time with costs.

Similar arguments are used for the scenarios depicted in columns 2 and 3, where type E and type N delays occur first, respectively. Hughes points out that this exposition refers only to individual periods of delay considered separately. He states that a diagram must be built up for the whole period of the project to show the interaction of causes so that costs arising from them may

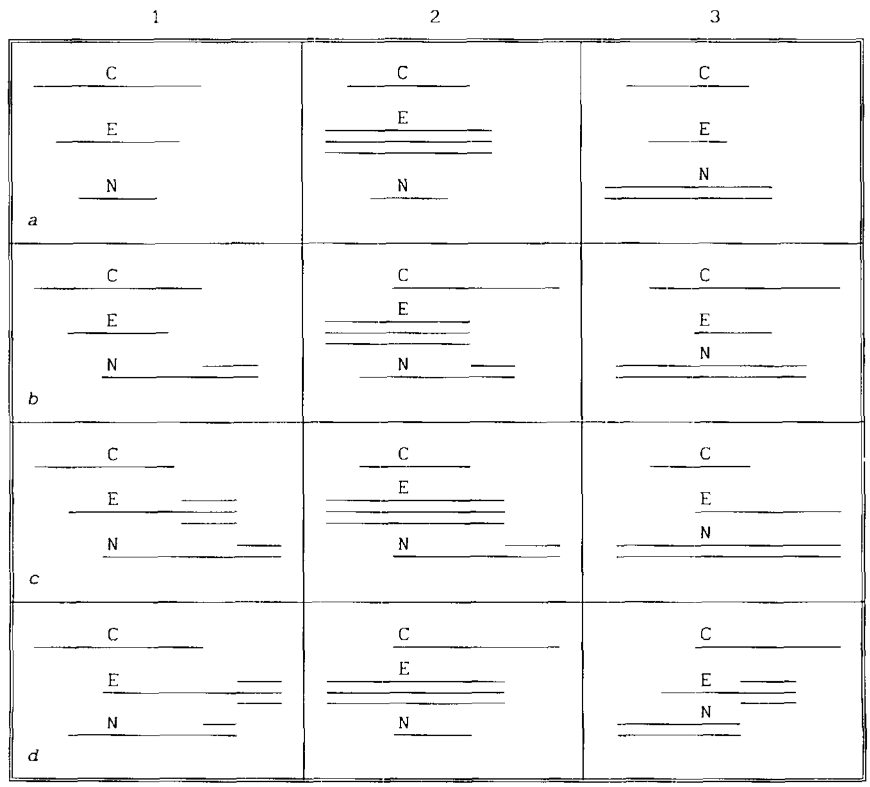

Figure 4 First cause defines liability. Letters indicate delays which are responsibility of Contractor (C), Employer (E) or neither party (N). Possible extensions of time only shown by ═══; possible extensions of time with costs shown by ≡≡≡. Figure taken from Hughes (1983).

be properly allocated. Extension of time considerations, it is stated, will apply only to those delays on the critical path (or a path made critical as a result of delays).

Whether this approach is seen to have merit, and it must be accepted that it is in general quite out of step with the other methods to be discussed, it does at least help to illustrate part of the complexity with which we are attempting to deal. More detailed comments will be found later in the paper.

Date assessment of concurrence

The procedure adopted with this approach to delay analysis is described by Kraiem and Diekmann (1987). It relies on legal interpretations of the remedy for the compound effect of any combination of delays due to different causes. These remedies that stem from precedent set in the USA are summarized in Table 2.

The remedies available when concurrent delays are due to the Contractor and to the Employer are called by Kraiem and Diekmann the 'easy rule' and the 'fair rule' ((i) and (ii) respectively in Table 2).

The method, then, is to assess for each day of the project whether more than one delay has occurred on parallel critical paths through the network and, if so, to determine the combined effect for all such days in line with the remedies discussed. Having completed that exercise, the adjusted schedule may then be determined using the standard CPM approach described earlier. Figure 5 represents the 'as-built' CPM for the network discussed earlier and is the same as Fig. 2, except that this time the 'concurrent' delays have been identified and recognized as types 1 and 2. That being the case, and assuming that the 'easy rule' is to be employed such that the effect of both concurrent delay types 1 and 2 is the right to an extension of time, it can be seen that the schedule adjusted to remove type E delays will give a project time of 27 days. Here, the Employer's responsibility is for no days delay to the whole project with costs, although there will clearly be an entitlement to an extension of time without costs.

Table 2 Remedies for concurrent delays

Concurrent delay types	Remedy
1. Any delay concurrent with a type N delay	Extension of time only
2. Concurrent delays type E and C	(i) Extension of time OR (ii) Apportionment of liability

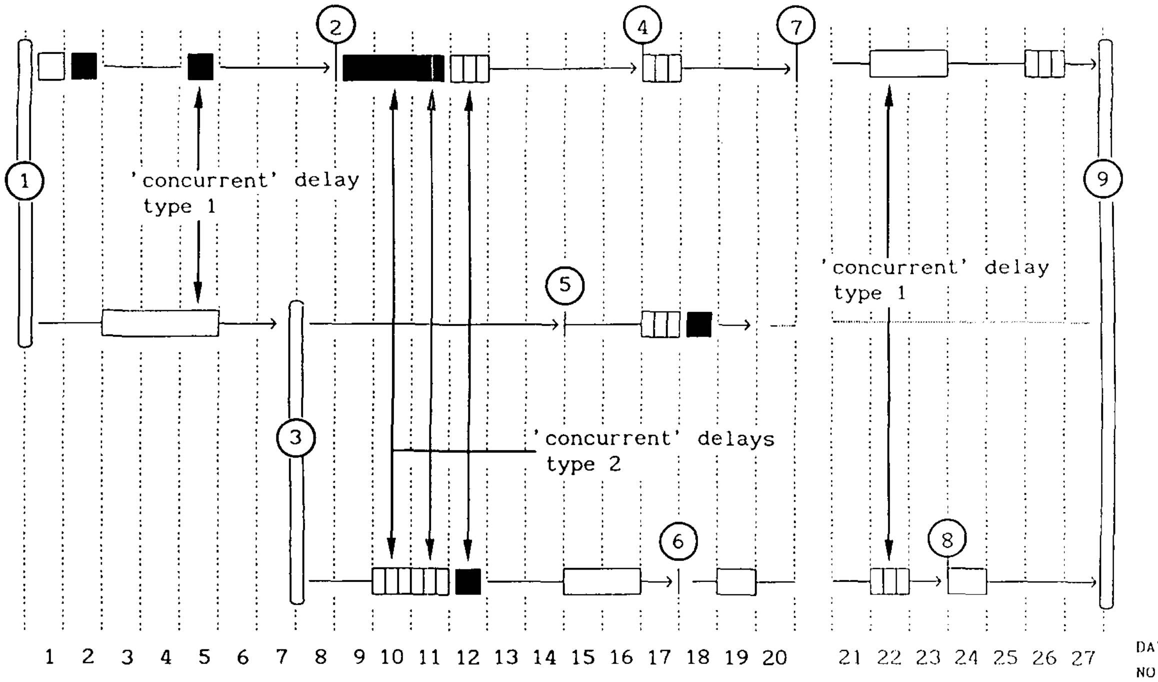

Figure 5 'As-built' CPM indicating 'concurrent' delays (key as Fig. 2)

To conclude this section, it should be pointed out that within the definition of concurrent delays so far offered, the basic approach to analysing delay claims using CPM does deal with some concurrent delay claim situations. In the example given (Fig. 2), the as-built CPM did contain 5 days' concurrent delay exactly as the diagram used for the date assessment of concurrence method. However, because of the different approaches adopted in analysing this problem, a different result is obtained.

To manage delay claims sensibly, the procedures adopted must be capable of dealing with the complexity of the network situation and also with any problems that arise concerning concurrent delays. They must also recognize the nature of delays and be able to deal with real-life events in a way that does not defy common sense. The systems already described will now be considered in this way, after which the various types of delay will be considered individually.

Discussion of the procedures

First cause defines liability

As has previously been intimated, the methods of dealing with delays in the UK appear to be less well advanced than those in the USA and it is also true that there is little in the way of legal precedent in the UK concerning how these matters should be resolved. That being the case, it is perhaps easier to understand how different this approach is from others being considered in the USA. The method clearly attempts simply to deal with the situation where a variety of delays occurring at different times, but with some degree of overlap, delay a single critical activity as shown in Fig. 6a, and the solution offered relies solely on which delay occurred first.

The justice of this way of doing things must surely be questioned, when apparently it would appear that the right to what could be a substantial claim may rest on the fact that one cause of delay began (say) a matter of hours

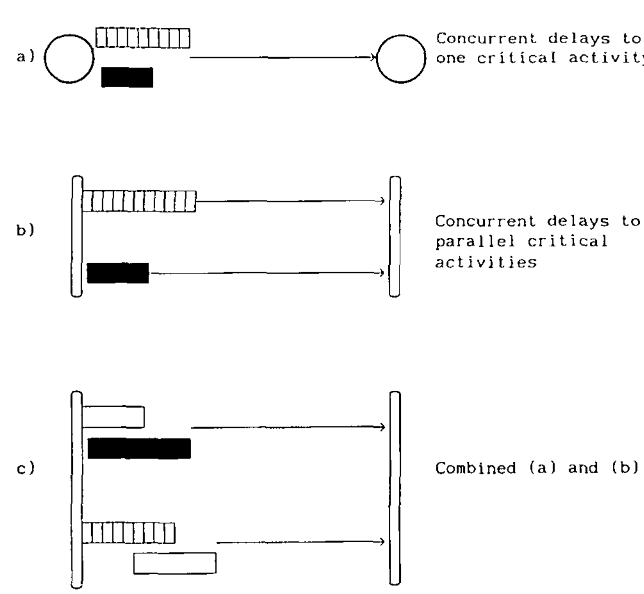

Figure 6 Types of concurrent delay (key as Fig. 2).

before another such cause of delay. There are also likely to be problems with the practicability of this approach, in that it does not help to provide a solution when causes of delay start at the same time – a common situation at the beginning of contracts. That having been said, however, there is perhaps some assistance in understanding the general problems of concurrent delays proffered perhaps inadvertently by this approach. A number of instances can easily be imagined where once one delay has occurred to an activity, any subsequent delays attributable to other parties will not become apparent until the first delay has come to an end. For example, a Contractor who is being prevented from starting an activity due to a particular part of the site not being available (type E delay), is unlikely to own up to the fact that he could not have started anyway (say) because he had not given sufficient notice to the suppliers of some essential materials required for that activity. The suggestion that stems from this argument is that some of the concurrent delay situations which can be envisaged by different combinations of the symbols adopted to represent delays and activity progress may seldom, if ever, occur in practice. Such situations may appear as a series of delays attributable to different parties with little or no overlap, much as the resultant solution given by this approach.

Date assessment of concurrence

This system is probably best seen as an additional stage added to the general procedure for dealing with delay claims. Having arrived at the 'as-built' CPM for the project, the extra operation is to seek out and modify any concurrent delays that are found on parallel critical paths. This completed, the adjusted CPM is then determined in the normal way. The justification for this approach is presumably that it has been accepted that concurrent delays should be dealt with in a particular way, and yet a number of difficulties can be envisaged in the carrying through of this procedure, and in the justice of solutions obtained. These will now be considered:

1. To be able to apply this modification to concurrent delays, we need to be certain when the relevant delays took place. This may be difficult to define or it may be that it is determined by chance, as the following examples indicate:
   (a) If a Contractor takes longer to carry out an activity than he originally planned, does this necessarily constitute a Contractor-responsible delay, and if so, when can it be deemed to have taken place?
   (b) When additional work is added to an activity on the instruction of the Engineer and this work causes a delay, it may be important whether the Contractor did the extra work at the beginning, at the end or throughout the main activity.
2. Concurrent delays are only to be modified if they occur on parallel 'critical' paths, and it is made clear that any non-critical path need not be considered because it did not participate in the delaying of the project. The question arises of whether it will ever be possible to know definitely that two paths through the network were of the same length. At the planning stage of CPM use, when activity durations are given as whole numbers of days, weeks or months, it is easy to determine parallel critical paths, but in 'real life' when each working day has 8 h and each hour has 60 min, just how close do the durations of two paths through the network need to be before they can both be considered as critical? In the situation where the payment of large sums of money may rest on the answer to this question, the negotiations would no doubt be protracted.
3. A blanket adoption of this procedure would appear likely to produce results that owe more to chance than they do to any semblance of justice. The situation can be imagined where, if parallel critical paths can be identified, one of these could contain only delays for which the Contractor was responsible, meaning that he could not have completed the contract any sooner, and yet 'concurrent' delays on a parallel critical path may give an extension of time and defray the option of deducting liquidated damages. On the other hand, as occurred in the example given, concurrency of delays may have the effect of reducing the Contractor's rights to an extension of time with costs in an instance where he could have completed earlier but for the Employer-caused delays.

These difficulties seem to cast serious doubt on the value of this approach. Undoubtedly concurrent delays are an issue when they affect a single activity, but to look for concurrency on parallel critical paths may be stretching any legal precedent rather too far. As stated previously, there is little in the way of precedent on these matters in the UK, but a quotation from Abrahamson (1980) may indicate how such matters are generally viewed:

> The thorny problem of concurrent delays has already been mentioned. Decided cases about similar but not identical issues in different settings are not very helpful. The general rule would seem to be on principle that if the employer's actions do not actually delay the Contractor because, for example, he was not in any case ready for drawings held back, or the Contractor cannot prove which of several causes for

only one of which the employer was responsible was the operative cause of the delay and his losses, having failed to discharge the burden of proving loss due to the action of the employer the Contractor is not entitled to recover compensation from him.

Such a viewpoint clearly bodes ill for the chances of a Contractor being given an extension of time when he is delayed by his own failings, concurrent delays or not. An important point to be made here is that it is noticeable that this view is much more closely allied to the procedure described in the general approach to dealing with delay claims than to the one being currently discussed.

Adjusted CPM schedules

There is a powerful logic at the root of this approach to delay analysis, which is difficult to fault. The justice dispensed by a system that attempts to determine the time a Contractor would have taken to complete a contract in the absence of Employer-responsible delays, and then attempts to give additional time with costs for any extra time he had to remain on site as a result of those delays, seems most reasonable. From the literature, it is clear that the procedure is not considered susceptible to mechanization and it is generally accepted that there will always need to be associated with this approach, a discussion and thorough back-up in the form of detailed site records.

As previously noted, concurrent delays are not typically mentioned in this approach, and yet concurrent delays on parallel critical paths (Fig. 6b) can clearly be handled. What is not covered by this method, however, is an ability to deal with the problem of concurrent delays to a single critical activity as shown in Fig. 6a. We can also easily imagine an instance where this is compounded by the same situation on a parallel critical path (Fig. 6c). It seems, then, that the issue of concurrent delays cannot be totally avoided by this procedure and that a system of dealing with the problem depicted by Figs 6a and 6c needs to be combined into the overall approach. It may be that this is an area where legal precedent would be helpful. In the absence of that, solutions for such situations could be prescribed in the contract documents.

Discussion: The nature of delays

In the analyses conducted so far, the only classification of delay type adopted has been by responsibility, namely types E, C and N. It has also been assumed that the actual dates when such delays took place could be readily and uniquely determined. Whilst considering the particular problems of concurrent delay, however, some of these assumptions have been brought into question. In this section, the intention is to highlight the areas of uncertainty recognized and attempt to make recommendations as to how these difficulties may be overcome. If the methods of delay claims analysis require data on delays in a form that cannot be provided, it may be necessary to amend those procedures to enable the handling of data that can be produced.

Much of the difficulty seems to arise from the need to tie down each delay to particular dates so that the CPM approach can be adopted. It will be seen that some delays will take place on specific dates, irrespective of which activities are under way. Some delays will take place at particular points in the completion of an activity and some delays may be capable of leeway in when they have their effect. Each of the previously recognized delay types will now be considered in turn in an attempt to identify any specific anomalies or discrepancies.

Contractor-responsible delays

So far, typical examples of this type of delay have been considered to be such matters as inadequate supervision and technical support, late agreements with subcontractors/suppliers and insufficient labour/plant. From factual networks used as examples in the literature, only Rubin *et al.* (1983) identify any Contractor-responsible delays. These are late start, repairs to the works and delay by the Contractor in producing a drawing. The question arises of whether any unhindered activity duration that is longer than the duration quoted on the original contract programme should be considered as containing Contractor-responsible delays.

If we recognize the contractual arrangement that exists on construction sites, then it must be clear that the Contractor will not wish to appear to have any responsibility for delaying the works. This might well diminish his claim for loss as a result of other delays where time or preferably time and costs may be laid at the Employer's door. With this in mind, it is considered that it may be quite difficult to pinpoint delays for which the Contractor is responsible. Thus the problem of dealing with them in concurrent delay situations may be a minor one. When the Contractor has clearly used inadequate materials or produced work below the standard required by the specification, and must make amends by replacing or repairing, there will be little doubt that the delay caused is the Contractor's responsibility. Such a delay would be readily fixed as to the date of occurrence and duration. In other circumstances, as it is the Contractor who decides what activities will be shown on the contract programme, he is unlikely to show any activities that he need not show. An example of such an activity would be his production of falsework drawings, where there is a real possibility of late achievement.

Concerning late starts of activities being identified as type C delays: in the situation where only one or two activities were being undertaken on the site, such inactivity might well be noticed and commented on by the Engineer. On a moderately large contract, however, the confusion of activities under way, only roughly following the expected sequence of work, may well hide the fact that an activity is not starting that might be started. Anyway, the Contractor may simply say he has his own reasons for not pursuing a particular activity at a particular time and consider such matters to be none of the Engineer's business. Provided the records show that there was no work and yet no delay, any subsequent analysis should not be affected.

The question raised earlier, of whether activity durations longer than those shown on the Contractor's initial programme should be thought of as containing Contractor-responsible delays, has not yet been addressed. If we were to consider a 5-week activity on the Contractor's initial programme that actually took 7 weeks to carry out as containing 2 weeks of type C delay, when exactly would we say that the delay had occurred? In fact, the effect of recording 7 weeks for the activity on the factual network has a similar effect to recording 2 weeks of type C delay. The Contractor in this case has approached 2 weeks closer to the time for completion whilst not gaining any advantage that he could use for a claim for extra time or costs. Perhaps then, where no particular reason can be established as creating the delay, it is sufficient simply to record the actual duration without any other comment.

In general, it seems that delays caused by the Contractor may be hard to recognize. Perhaps it is only in those circumstances where the Contractor's responsibility is undeniable that a type C delay needs to be recorded.

Employer-responsible delays

The typical Employer-responsible delays are those caused by changes to the contract documents, failure to provide land or information within a reasonable time and failure to approve the Contractor's method of working expeditiously. This is reflected in the networks in the literature where failure to approve a reinforcement design (Wickwire and Smith, 1974), a design change and a suspension of the works (Rubin *et al.*, 1983) are used as examples of this type of delay. It seems that such delays will typically be painfully evident in their effects on progress and, of course, there should be no attempt to cover up these effects. That is not to say that there may not be considerable discussion between the Contractor and the Employer or his Engineer as to the exact extent of each of their liabilities.

The Employer-responsible delay is probably the one with the most variety and it is easy to imagine the following types:

1. delays that can affect a number of activities and are not specific to any particular one;
2. delays that must occur at a particular point in the completion of a specific activity;
3. delays where some flexibility exists as to when they have their effect.

The first type could result from a suspension order that might affect one activity, a number of activities or all activities depending on what particular aspect of the work had been suspended. An example would be the uncovering of an uncharted gas main in an excavation. This might lead to a need to plan and implement a services diversion that clearly could not have been known about at tender stage. This would typically require that other work in the area would have to be stopped and could not resume until the diversion was complete.

An example of the second type would be failure to approve falsework drawings in time, in which case the Contractor's erection of the temporary works would have to be delayed. This delay could be seen as taking place at the beginning of the erection activity. We can also imagine another situation in which specific additional work was instructed that clearly added to the workload of an existing activity in the contract programme, and that had to be carried out at a particular stage of that activity. For example, an instruction to increase the reinforcement in a reinforced concrete member would usually involve some delay at a particular point in the activity of fixing reinforcement in that member.

It is believed that many instructions to carry out additional work will not involve delays being enforced at a specific time or at a definite stage in the completion of an activity. Some variations will require the Contractor to carry out work that is unlike any other work in the contract. In these circumstances the Contractor will be expected to reschedule to accommodate the new task with minimum disruption. Even where similar work exists in the contract it may not be essential that the extra quantity is carried out at the same time as the similar contract work. If it is implemented during the same period, it may be possible for the instructed task to be performed at any time during that period with no detriment. For these unaffiliated delays, to record them as occurring at a particular time and then to process them along with other more fixed concurrent delays may be unreasonable. It seems that such delays should be annotated to record that they might have taken place at another time.

Delays due to neither party

Under the JCT form of contract (Joint Contracts Tribunal, 1980), these delays are well documented and consist of exceptionally adverse weather conditions, civil commotion, strike or lock-out, local combination of workmen, and force majeure. This last term is used to mean events completely unpredictable by the parties prior to making their agreement and that affect progress. The ICE conditions do not spell out what is to be considered under this heading anything like as clearly as this, referring specifically only to exceptionally adverse weather conditions. There is, however, the opportunity for the Engineer to accept that 'other special circumstances of any kind whatsoever' have delayed the works and to award an extension of time if the Engineer believes that to be deserved. In examples in the literature, it is the strike that has been adopted to represent this type of delay.

Undoubtedly, certain type N delays will arise on specific activities. A local strike on the site might easily result if the bonuses to be earned on a task are seen by the workforce as unfair or if output targets to be achieved in order to earn bonuses are considered unattainable. In many circumstances, though, the delay will take place irrespective of whether a contract exists or not. The weather is totally independent of how many contracts are under way and a national strike of a particular part of the workforce will not generally be directly influenced by a specific contract. It will, however, clearly affect all contracts under way at the time. The fixing of these delays in time should not, on the face of it, cause any special problems as they are not usually susceptible to manipulation. Neither should it be especially difficult to identify quite which activities have been affected. These statements are believed to be true of most of this type of delay, but the problems associated with weather delays are felt to be significantly different.

Defining exactly which days of a project were lost due to adverse weather conditions should not create too many problems. The difficulties arise when we realize that not all days lost due to weather are accepted as generating a possible extension of time. It is 'exceptional' adverse weather that must be identified for this purpose. The recommendations in the literature are that to assess if the weather has been exceptionally adverse, the Engineer will have to look at the weather for the project as a whole. If the weather in the area concerned is generally better than the project weather, then presumably the Engineer will use his assessment of the average weather to calculate a number of days of delay for the project. No specific procedure has been found as to exactly how to do this, but the following is suggested as a possibility:

1. For the contract under consideration, look at the weather conditions that occurred on the site on days when work did not take place and note them.
2. From the above data, attempt to identify the one weather parameter of wind, rain, temperature etc. that resulted in an inability for work to take place.
3. Search past weather records over a number of years for identical parameters to those that have been found to cause work to stop and make a record of each such day.
4. From the above information calculate an average number of days that could be expected to be lost on construction work per year.
5. Compare actual days lost over the construction period to the average. If there is a marked difference between summer and winter (as might be expected), it may be necessary to attempt to identify average weather over a shorter period than a year. This would lead to a simulation of average weather over the particular months or seasons in which the contract was working.
6. From the comparison of average weather and actual weather experienced during the contract, any assessment of exceptional adverse conditions could be deduced and a number of days' delay calculated.

Such an approach is clearly flawed for the following reasons:

1. It assumes that one parameter alone will always be responsible for work stopping when it may be that a combination of factors, each at a lower level than the individual factors, will sometimes have the same effect.
2. The possibility that certain weather conditions will affect some activities and not others has not been incorporated.

However, it is believed that this approach is as good as, if not better than, the analysis carried out on most sites. At the end of such an analysis, we will be left with either an awareness that the contract weather was no worse than could have been expected or that it was worse, and that an allowance of a number of days' delay can be justified. In the latter event, the problem still exists as to exactly which of the days lost should be considered as exceptional and which to be expected.

Figure 7 demonstrates the difficulty in a simplified representation of the problem. The actual days lost to the project as a whole as a result of weather are shown in section (a), and we can see that in the 100-day project, there were 16 days in which work could not progress. If our assessment of average conditions leads us to believe

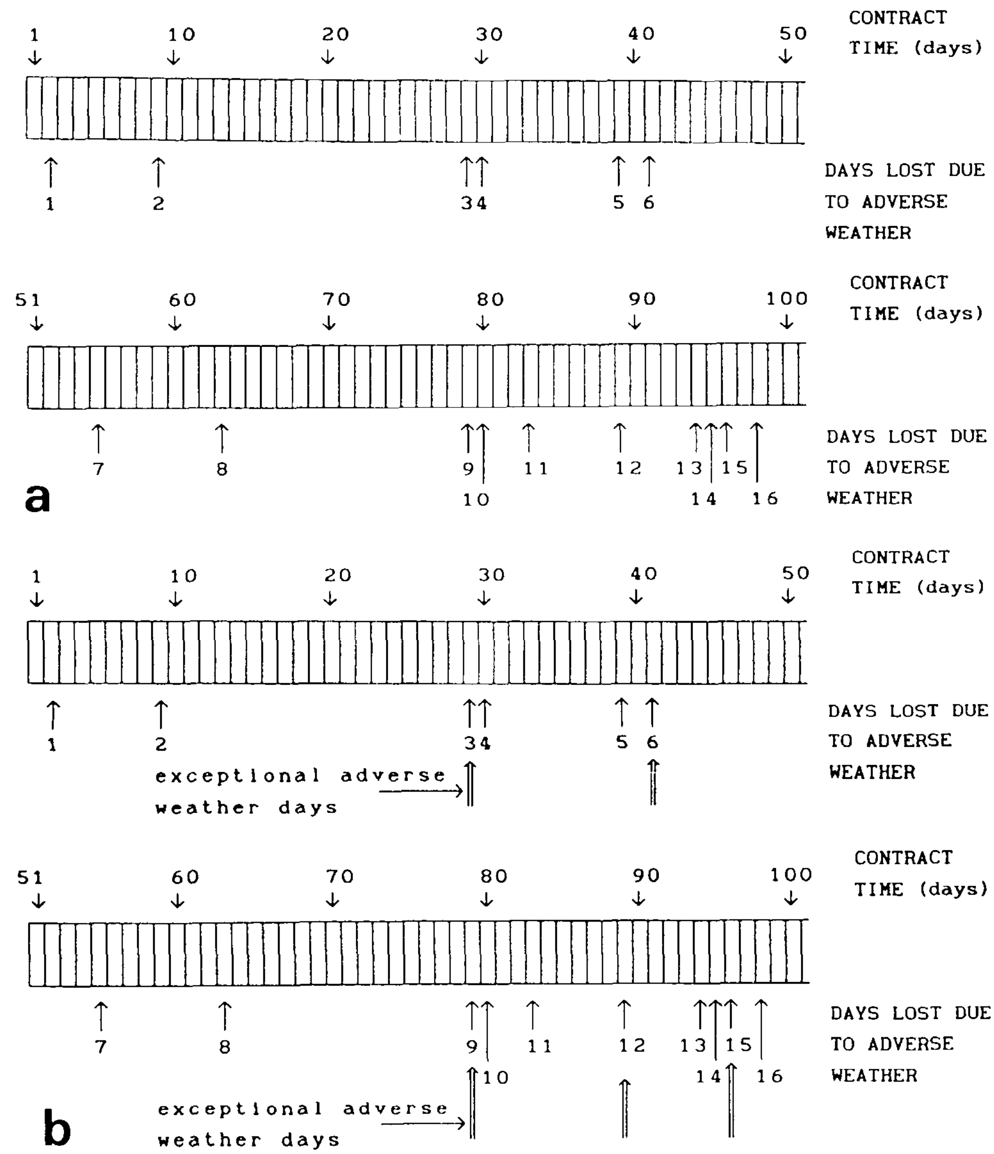

Figure 7 Identifying days lost to adverse weather: (a) days lost to adverse weather; (b) selection of days of exceptional weather

that 11 days lost due to adverse weather could have been expected, then presumably 5 days of exceptional adverse weather will be admitted. In a total cost approach, this information might well be adequate, but when using CPM, we need some method of deciding which 5 of the 16 days should be considered as exceptional. Any method adopted to identify these 5 days must surely be seen as in some respects artificial, in that the particular days pinpointed will depend on the approach that is used. It is suggested that any solution should embody the following principles:

1. The days selected must be actual days when work was in fact stopped on the site.
2. The spread of exceptional delays throughout the contract should follow the general pattern of total days lost due to weather.
3. The method should be standarized and unaffected by the individual contract.

With these principles in mind, it is proposed that the following be adopted. Starting with the first day lost numbered 1 and subsequent days numbered in order as in Fig. 7a, exceptional days are to be selected as occurring every nth day lost, where n is given by:

$$n = \text{INTEGER}\left[\frac{\text{Total days lost}}{\text{Exceptional days}}\right]$$

thus, in the example:

$$n = \text{INTEGER}\left[\frac{16}{5}\right] = \text{INTEGER}\,[3.2] = 3$$

Figure 7b shows the result that stems from this procedure. A quite different result would, of course, have been obtained if exceptional delays had been selected starting from the end of the project and working towards the beginning. However, it has already been accepted that the method of selection must to some extent be a compromise. It is suggested that the recommendation above is a reasonable compromise in the circumstances.

In general, it seems that for delays for which neither party is responsible, the duration of these delays and their impact on the contract should be straightforward. The same cannot be said for delays due to adverse weather, and to incorporate such delays into a CPM-type analysis, a procedure for selection of exceptional delays will need to be adopted.

Conclusions

A number of suggestions have been made in this paper, and these are fully explained in the discussion sections above. The main points are as follows:

1. Concurrent delays, if found on parallel critical paths, can be dealt with by the standard method of assessing delay claims. It is only when two delays both affect a single activity concurrently that any additional guidance is needed. This could be provided by incorporating a clause into the contract documents.
2. In practice, it seems unlikely that it will be possible to identify parallel critical paths. It is difficult to imagine that, when using real numbers for activity durations rather than integers, two paths through a network would be exactly the same length.
3. There may be a choice for when some delays should be considered to have their effect. In some circumstances involving concurrent delays, it may be important that the uncertain timing of these delays is made evident.
4. To identify the days of exceptional adverse weather on a contract, some artificial method of selection must be used. One such method is described in the paper.

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