COVER SHEET

Ng, S.T. and Skitmore, R.M. and Deng, M.Z.M. and Nadeem, A (2004) Improving Existing Delay Analysis Techniques for the Establishment of Delay Liabilities. *Construction Innovation* 4(1):pp. 3-17.

Improving Existing Delay Analysis Techniques for the Establishment of Delay Liabilities

S. Thomas Ng[1], Martin Skitmore[2], Abid Nadeem[3] and Michael Z.M. Deng[3]

[1] *Department of Building, University of Newcastle, University Drive, Callaghan, NSW 2308, Australia*
[2] *School of Construction Management and Property, Queensland University of Technology, GPO Box 2434, Brisbane, QLD 4001, Australia*
[3] *Department of Building and Construction, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong*

21 August 2003

Improving Existing Delay Analysis Techniques for the Establishment of Delay Liabilities

Abstract
Delay analysis and schedule compression are normally treated as separate, independent, aspects of the study of delays and their effects on the completion of construction projects. This paper examines the feasibility of integrating the delay analysis and schedule compression functions into a broad-scoped two-stage process. The main issue is shown to be the kind of delay analysis required for each stage of the process and seven existing techniques are illustrated for use in conjunction with schedule compression. Some necessary modifications to these techniques are identified together with a typology for categorising each technique.

Keywords: Construction delays, delay analysis, delay typology, planning and scheduling

INTRODUCTION

Construction projects are subject to the uncertainties of weather, soil conditions, availability of labour, material and plant, disputes, etc. These uncertainties, by their very nature, frequently cause delays in project programmes, resulting in unanticipated extra costs being incurred by both contractors and clients. For contractors, these take the form of liquidated or actual damages, extended labour, material and equipment costs, extended head and field office overheads, and inefficiency costs. For clients, they include loss of profit, revenue, opportunity costs, legal and consulting costs (Trauner, 1990). The research to date (Lewis and Atherley, 1996; Akintoye and Skitmore, 1991) suggests that the costs caused by delays are highly significant. Clearly then, it is in the interests of all parties that delays, or their effects, are reduced. Even quite small advances in the recovery of delayed schedule are likely to have a significant impact on the financial returns of those involved.

The usual remedial effort for delay is to accelerate the remaining activities of the project by employing additional resources or alternative construction methods. Inevitably, this involves extra costs. It is therefore necessary for the client and the contractor to establish each party's extent of legal responsibility for the occurred delays, and hence the amount of delay to be recovered. If the delays are caused by factors expressly stipulated in the contract conditions, however, an extension of time may be granted. When the delay is of a contributory nature, it is necessary to identify the delay liabilities of each party. However, in practice, some contractors accelerate the project without considering who is the responsible party for the delays (Bramble and Callahan, 1992). It is suggested, therefore, that delay analysis should be conducted by the client and the contractor before any schedule compression is ordered.

Delay analysis is a process to determine the respective delay liabilities of the client and the contractor. Current research in construction delay analysis is contained in two broad categories. The first comprises studies aimed at identifying the nature and causes of delays from their composition and importance. These include Majid and McCaffer's (1998) work on the identification of the factors influencing the delays ranking of their significance in delay prevention strategies; Lewis and Atherley's (1996) examination of the time and cost implications of delays; and Ogunlana *et al*'s (1996) consideration of the relationship between delay factors and the economic growth developing countries. The second category comprises studies aimed at analysing the effects of delays on project completion time (Scott, 1993). These concentrate on developing the schedule of the project for use in preparing delay claims (Alkass *et al*, 1996, Bordoli and Baldwin, 1998; Yogeswaran *et al*, 1998) and apportioning delays in a fair way between different parties (Arditi and Patel, 1989; Chehayeb *et al*, 1995)

Existing techniques for delay analysis, however, having been developed and used to settle delay claims *after* project completion, may not be totally suitable for schedule compression since delay liabilities need to be determined during the progress of the project. This paper examines the suitability of current delay analysis techniques for establishing delay liabilities in schedule compression and the likely changes and considerations needed to enable the delay liabilities to be established impartially.

DELAY TYPES

According to Kraiem and Diekmann's (1987) delay types can be classified into compensatory delays (CD), non-excusable delays (NED), and excusable delays (ED). CD refers to any delays caused by clients (or their representatives), while NED represents delays caused by contractors (or their representatives). Any other delays are referred as ED. This delay type classification is adopted throughout this paper.

A schedule recovery effort is considered to be fair if the client and contractor agree on the types of delays for which they are responsible and accommodate them throughout the contract terms (Alkass *et al*, 1996; Reams 1990). Determining the delay type is a difficult task due to problems in assigning the responsibility of delays to a party. Delays are mostly interdependent and autocorrelated (Majid and McCaffer, 1998) necessitating the consideration of the impact of previous delays on following delays. A previous NED may cause the following ED to render as a NED.

The overall delay caused by one party may not be equal to the sum of the individual delays of that party. Although the delays caused by each party in an individual activity can be identified, it is necessary to establish the interactions and overall effects on the project (Kraiem and Diekmann, 1987). Table 1 summarises the major considerations in schedule compression.

< Table 1 >

ANALYSIS OF DELAYS

The analysis of construction delays is carried out by comparing the 'as-planned', 'as-built' and 'adjusted' schedules. An 'As-planned' schedule is the initial approved schedule submitted by the contractor for the project. An 'As-built' schedule is usually prepared when the project is finished and contains all the disruptions (e.g. delays) that have occurred in the project. However, for the purpose of schedule compression, the 'as-built' schedule is the most current schedule available. The 'adjusted' schedule is obtained by modifying the 'as-planned' or 'as-built' schedule according to the methodology dictated by the chosen delay analysis technique.

Various delay analysis techniques have been proposed (Lee, 1983; Kraiem and Diekmann, 1987; Reams, 1989, 1990; Wickwire *et al*, 1991; Alkass *et al*, 1995; Leary and Bramble, 1998; Chehayeb *et al*, 1995). These include (1) global impact, (2) net impact, (3) 'but for' or collapsing, (4) apportionment delay, (5) snapshot, (6) isolated delay and (7) time impact type techniques. The detailed discussion on each of these techniques can be found in Alkass *et al.* (1996) and Chehayeb *et al* (1995). However, for the reader's convenience, a step by step description of the mechanics of each technique is provided in (Appendix 1). The main purpose of describing the original use of these techniques is to provide a reference for comparison with the results obtained from the suggested modifications for these techniques (as done later in the paper).

CASE STUDY

Bubshait and Cunningham (1998) argue that no one delay analysis technique suits every situation. The amount of delay attributable to the client and the contractor depends on the delay analysis technique employed. It is necessary, therefore, to identify which technique is more appropriate for the schedule compression process. A hypothetical project as described in Kraiem and Diekmann (1987) was adopted in this study. The hypothetical project consists of ten activities. The duration of the activities along with their precedence relationships is shown in Table 2.

< Table 2 >

The 'as-planned' duration of the project is 23 days. During the course of construction, delays occurred in various activities and the delays identified are shown in Table 3. The delays affect the planned completion date of the project. The duration of the project after considering the delays is 41 days.

< Table 3 >

This scenario was applied to the seven delay analysis techniques as identified, and the results are illustrated in Table 4. As Table 4 shows, the global impact, net impact, snapshot and time impact techniques do not distinguish between delay types. These techniques provide only the total amount of delay in the project and do not apportion delays between the contractor and the client.

< Table 4 >

In addition, concurrent delays and real time CPM are two additional factors that need to be considered for reliable results of delay analysis (Alkass *et al*, 1996). Global impact and time impact techniques exclude the consideration of the effects of concurrent delays in the analysis. Similarly, global impact, net impact, 'but for' techniques and the apportionment delay method exclude the consideration of real time CPM analysis.

The 'but for' and isolated delay type techniques show comparatively more delays caused by the client than the contractor. For the apportionment delay method, the delays caused by the contractor and the client are in the form of NED and CD. The relative amounts of delay caused by the contractor with respect to the client in the apportionment delay method is different from that in 'but for' and isolated delay type techniques. The relatively greater amount of client delays resulting from the 'but for' and isolated delay type techniques is due to their assumption that the client is willing to be responsible for the excusable part of the delays. This assumption may be true in some circumstances. However, for schedule compression, this assumption does not provide a justifiable delay liability of each party. In 'but for' and isolated delay type techniques, only NED is considered for contractor delays. For consistency, in the calculations of client delays, the analysis should consider only CD, but actually the effect of ED is also included in the analysis. Due to this inconsistency, the justified delay liability for each party for schedule compression cannot be determined.

IMPROVEMENT OF DELAY ANALYSIS TECHNIQUES

Examination of current delay analysis techniques indicates these techniques to be deficient for remedial schedule compression purposes. Certain improvements are required to make them suitable for use in schedule compression. Two improvements are proposed: (1) to incorporate the scrutiny of delay types, and (2) to apply ED so that these will not affect the calculated client and contractor delays but still maintain the basic mechanism of each technique. Delay type scrutiny is the basic requirement for determining client and contractor delays. Insofar as ED is concerned, it seems reasonable to assume that neither the client nor the contractor should be held responsible for ED. This assumption is consistent with the definition of ED. The effect of ED in delay analysis techniques should be used to update the schedule but not to include their effect in the delays recorded for either the contractor or the client.

In using the global impact technique, ED can be ignored, as all the delays are simply added together. The ‘net impact’, ‘but for’ and apportionment delay methods do not support real time CPM analysis, as these techniques update the schedule only once in the analysis. With the ‘net impact’ technique, the ED is not required to be included in the ‘adjusted’ schedule as it will incorrectly be added into the client or contractor delays. The implicit mechanism of the ‘but for’ technique means that the effects of ED are cancelled when the adjusted schedule duration is subtracted from the ‘as-built’ schedule. The apportionment delay method, on the other hand, already has a mechanism for apportioning delays into CD, NED and ED and therefore no special treatment is required. With the snapshot, isolated delay type and time impact techniques, it is necessary to include an ‘updating only effect’ of ED as these techniques support real time CPM analysis and require the schedule to be updated several times between the limits of ‘as-planned’ and ‘as-built’ schedules. The ‘updating only effect’ of ED means that the project delays caused by ED should not be recorded for the contractor and client caused delays - these delays should only be used for updating the schedule. It is also noted that the isolated delay type technique is derived from the snapshot technique by introducing delay type scrutiny into the analysis, making the snapshot method essentially redundant in the schedule compression context. The snapshot technique is therefore excluded from further analysis. The modifications needed for all the delay analysis techniques are summarised in Table 5.

< Table 5 >

COMPARISON AND DISCUSSION

The results of applying the various techniques to the chosen hypothetical project of 23 days planned and 41 days actual duration are summarised in Table 6 (see Appendix 2 for detailed calculations).

< Table 6 >

This shows the estimated contractor and client delays to be quite similar except when using the global impact and net impact techniques. This is due largely to the uniform treatment of ED for each technique. The results of the ‘but for’ and isolated delay type techniques in their original form as shown in Table 4 are quite different from these. Including the suggested treatment of ED in the analysis has reduced the client-caused delays, making the results more consistent with each other. The numerical closeness of the results of the ‘but for’, apportionment delay, isolated delay and time impact techniques cannot, however, be generalised to all projects as the results depend on the duration and relationships of the delaying activities that contribute to the change in critical path.

The delays in an activity may, or may not, cause delays in the succeeding activities or the completion date of the project. If a delay occurs in a non-critical activity then, as long as the delay is less than the free float of the activity, the remaining schedule will not be affected. If the delay is between the free and total float of the activity, the completion date of the project will not be affected. However, the succeeding activities will delay in their start times. Delays in critical activities will cause delay in the start of succeeding activities, as well as the completion date of the project. If, at any analysis stage, CD and NED occur in non-critical activities, their overall effect on the project delay cannot be recorded or reduced according to the available float. Delays in the critical activities are obviously more important. However, the critical path may change when disruptions in the form of delays in the project occur. Therefore, the criticality or non-criticality of a delay is not fixed during the delay analysis. This means that it is not always possible for similar pattern of results to be obtained for client and contractor caused delays.

The reliability of the delay analysis technique depends on the factors considered by the technique. It is clearly incorrect to assess the reliability of techniques by comparing the magnitude of their results. In this paper we have described the delay analysis techniques in what we believe to be an increasing order of reliability, with the global impact technique being the least reliable and the time impact technique being the most reliable. Alkass *et al.* (1996) has grouped global impact and net impact techniques into what they term "simplistic" techniques, with 'but for', snapshot and time impact techniques being regarded as at an increased level of sophistication. Here, we propose a somewhat similar classification to be "rough", "simplistic" and "sophisticated" based on the information, and information processing, needs of each technique (Table 7).

Table 7

By this typology, the global impact technique is said to provide rough results of contractor and client delays without taking into account any of the essential factors of concurrent delays and CPM logic. The net impact, 'but for' and apportionment delay methods are termed simplistic techniques as all of these techniques take into account concurrent delays and are based on CPM. As mentioned earlier, the net impact technique does not take into account ED; the 'but for' technique inherently cancels out as the ED; and the apportionment delay method relies on the concepts of net impact and 'but for' techniques, using the extended capability of these techniques to include ED and interpolate between net their results. However, these techniques disregard real time CPM analysis and the related updating effect of ED. Isolated delay type technique and the time impact techniques, however, are classed as sophisticated techniques as both take into account real time CPM analysis, the updating effect of ED and concurrent delay effects. The time impact technique updates the schedule based on individual activities in preference to the isolated delay type technique approach of packaging many activities in a snapshot. The analysis cycles in the time impact technique are, therefore, increased, which is likely to increase the accuracy of the analysis.

The choice of technique to use depends on the amount of information, time and resources available for the analysis. When there is no schedule but information concerning individual delays is available, the 'global impact' technique is the only choice. All the other techniques require detailed information concerning the delays and the use of CPM based schedules. Although the information needs are same for simplistic and sophisticated techniques, the information processing capability of the sophisticated techniques is clearly greater than that of the simplistic techniques. Sophisticated techniques require more time and resources to use than the simplistic techniques and therefore the choice between the sophisticated and simplistic techniques depends on the resources available for the analysis. In most cases, however, simplistic techniques are used in practice (Bramble and Callahan, 1992).

It is emphasised that the results obtained by using the delay analysis techniques need to be interpreted in the schedule compression perspective. Two situations are briefly described here. First, if the contract requires all the delays to be recovered, the contractor is entitled to compensation for client-caused delays. Second, if there is no contractual obligation to recover delays, the delay analysis results can help the client in making schedule compression decisions. If contractor-caused delays are estimated to be more than client-caused delays, the client is entitled to ask the contractor to accelerate the remaining activities. The amount of acceleration will be equal to the delay caused by the contractor less the delays caused by the client. The contractor will not be entitled to be reimbursed the extra costs incurred by the acceleration effort. Conversely, if the delays caused by the client are more than the delays caused by the contractor, the contractor is entitled to seek compensation for the delays caused by the client less the delays caused by the contractor. In this case, if the client requests the contractor to accelerate, the contractor is entitled to receive the extra costs incurred in accelerating the remaining activities in addition to cost of the difference between the client-caused and the contractor-caused delays.

CONCLUSIONS

Construction project delays are very common. When delays occur on a project, the need to recover the delays arises in order to minimise the costs due to delays. This paper describes the application of a variety of delay analysis techniques in schedule compression. It was found that the seven main delay analysis techniques in current use, under their original forms and assumptions, are unlikely to provide the necessary level of feedback reliability for recovering delays. To remedy this situation it was found necessary to incorporate some means of delay type scrutiny, ED updating, and treatment of concurrent delays. Once suitable modified, the techniques were then applied to an existing case study. The lessons learned from this enabled a ranking and typology to be also proposed for the techniques. This comprises categories termed “rough”, “simple” and “sophisticated” depending on the information needs and processing capabilities of the technique.

Whilst it is clear that the methods described in this paper are of potential value in the treatment and management of project delays, it is noted that the basic assumptions contained in the methods (i.e. strict adherence to the legal minimum provided in the contract, excluding considerations of maintaining good working relationships, team spirit, moral and ethical stances, etc.) mean that immediate practical implementation may be limited. Perhaps the most important aspect of the work is to bring some transparency into the somewhat neglected aspect of uncertainties surrounding the planning process, providing a better understanding of the issues involved and, hopefully, a basis for negotiation and improved interdisciplinary relations.

ACKNOWLEDGEMENTS

The authors are grateful to acknowledge the financial support provided by the Strategic Research Grant of City University of Hong Kong.

REFERENCES

Akintoye, A.S. and Skitmore, R.M. (1991) Profitability of UK construction contractors, *Construction Management and Economics* **9** 311-25.

Alkass, S., Mazerolle, M., Tribaldos, E. and Harris, F. (1995) Computer aided construction delay analysis and claims preparation. *Construction Management and Economics*, **13**, 335-352.

Alkass, S., Mazerolle M. and Harris, F. (1996) Construction delay analysis techniques. *Construction Management and Economics*, **14**, 375-394.

Arditi, D. and Patel, B.K. (1989) Impact analysis of client-directed acceleration. *Journal of Construction Engineering and Management*, **115**(1), 144-157.

Bordoli, D.V. and Baldwin, A.N. (1998) A methodology for assessing construction project delays, *Construction Management and Economics*, **16**, 327-337.

Bramble, B.B. and Callahan, M.T. (1992) *Construction Delay Claims*, John Wiley & Sons, Inc.

Bubshait, A.A. and Cunningham, M.J. (1998). Comparison of delay analysis methodologies. *Journal of Construction Engineering and Management*, **124**(4), 315-322.

Chehayeb, N.N., Dozzi P.S. and AbouRizk, S. (1995) Apportionment delay method: is there only one solution?, *Proceedings of Construction Congress*, San Diego, California, Oct, pp. 217-224.

Kraiem, Z.M. and Diekmann, J.E. (1987) Concurrent delays in construction projects. *Journal of Construction Engineering and Management*, **113**(4), 591-602.

Leary, C. and Bramble B. (1988) Schedule analysis models and models and techniques, *Symposium of Project Management Institute,* California, pp. 63-69.
Lee, D.M. (1983) Time impact analysis forensic scheduling. *Proceedings of Liability in Construction Management, Symposium of ASCE Construction Division*, Oct, pp. 43-55.

Lewis, T.M. and Atherley, B.A. (1996) Analysis of construction delays. *Proceedings of International Symposium for the Organisation and Management of Construction: Shaping Theory and Practices*, Vol. 2, pp. 60-71.

Majid, A.M.Z. and McCaffer, R. (1998) Factors of non-excusable delays that influence contractors' performance. *Journal of Management in Engineering*, **14**(3), 42-49.

Ogunlana, S.O., Promkuntong, K. and Jearkjirm, V. (1996) Construction delays in a fast-growing economy: comparing Thailand with other economies. *International Journal of Project Management*, **14**(1), 37-45.

Reams, J.S. (1989) Delay analysis: a systematic approach. *Cost Engineering*, **31**(2), 12-16.

Reams, J.S. (1990) Substantiation and use of the planned schedule in a delay analysis. *Cost Engineering*, **32**(2), 12-16.

Scott, S., (1993), The nature and effects of construction delays, *Construction Management and Economics*, **11,** 358-369.

Trauner, T.J. (1990*) Construction Delays: Documenting Causes, Winning Claims, Recovering Costs*, R.S. Means.

Wickwire, J.M., Driscoll, T.J. and Hurlbut, S.B. (1991) *Construction Scheduling: Preparation Liability, and Claims,* John Wiley and Sons, New York.

Yogeswaran, K., Kumaraswamy, M.M. and Miller, Douglas (1998) Claims for extension of time in civil engineering projects, *Construction Management and Economics,* **16**, 283-293.

Project Phase	**Major Task**	**Input data**	**Expected Output**
Implementation	Delay type scrutiny	Schedule activities database	Determination of compensatory, excusable and non-excusable delays
	Delay analysis	Scrutinised delays. As-planned and as-built schedules. Delay analysis technique.	Adjusted schedule and delay amount entitlement to the owner and the contractor.

Table 1 Major considerations in schedule compression

Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Precedent activities	-	-	1	2	2	3	4	5	6	8
Duration (days)	7	5	7	9	6	4	3	9	5	3

Table 2 Activities in the hypothetical project

Activity	1	2	3	4	5	6	7	8	9	10	Total
Excusable (ED)	1	3	-	-	5	-	-	1	2	2	14
Non-excusable (NED)	3	1	3	-	1	-	1	-	3	-	12
Compensatory (CD)	-	1	2	-	3	2	1	1	2	-	12

Table 3 Delayed activities identified

Technique	Total delay (days)	Contractor's delay (days)	Owner's delay (days)	Others (days)
Global impact	38	*	*	
Net impact	18	*	*	
'But for'	*	2	9	
Apportionment delay		5.5 (NED)	5.5 (CD)	7 (ED)
Snapshot	18	*	*	
Isolated delay type	*	6	16	
Time impact	30	*	*	

* Not determined

Table 4 Delays calculated by different delay analysis techniques

Technique	Delay type scrutiny	ED updating effect
Global impact	Included	Not supported - ignored
Net impact	Included	Not supported - ignored
‘But for’	Not needed	Not supported - ignored
Apportionment delay	Not needed	Not supported - ignored
Isolated delay type	Not needed	Included
Time impact	Included	Included

Table 5 Modifications needed to the original delay analysis techniques

Technique	Contractor delays (days)	Client delays (days)
Global impact	12	12
Net impact	9	6
‘But for’	2	5
Apportionment delay	5.5	5.5
Isolated delay type	6	5
Time impact	4	5

Table 6 Overall results of using different delay analysis techniques

Classification	Information Needs	Information Processing	Techniques
Rough	Individual delays	No schedule	Global impact
Simplistic	Individual delays, CPM based scheduling,	Single schedule updating	Net impact ‘But for’ Apportionment delay
Sophisticated	Individual delays, CPM based scheduling,	Multiple schedule updating	Isolated delay type Time impact

Table 7 Classification of delay analysis techniques

APPENDIX 1: CURRENT DELAY ANALYSIS TECHNIQUES

Technique Description	Outcome
Global impact technique 1. Adds all the individual CD, NED and ED of the project irrespective of concurrency.	Total project delay
Net impact technique 1. Subtracts 'as-planned' schedule durations from 'as-built' schedule durations.	Total project delays
'But for' or collapsing technique 1. Obtains the 'adjusted' schedule for contractor caused delays by imposing CD and ED in 'as-planned' schedules. 2. Obtains the 'adjusted' schedule for client caused delays by including NED in 'as-planned' schedules. 3. Subtracts the duration of each 'adjusted' schedule from the 'as-built' schedule duration to find the contractor and client caused delays.	Delays caused by the contractor and the client
Apportionment delay technique 1. Updates the 'as-planned' schedule each time by including CD, NED and ED individually. 2. Subtracts the 'as-planned' schedule duration from each of the updated schedule durations to provide delays corresponding to CD, NED and ED. 3. Updates the 'as-built' schedule each time by excluding CD, NED and ED individually. 4. Subtracts each of the updated schedule durations from the 'as-built' schedule durations to provide delays corresponding to CD, NED and ED. 5. Adds the corresponding CD, NED and ED (from #2 and #4 above) to find the total individual CD, NED and ED. 6. Adds all the calculated CD NED and ED together to find the total calculated delay. 7. Finds the actual delay in the project by subtracting 'as-planned' schedule durations from 'as-built' schedule durations. 8. Apportions the total individual delays corresponding to CD, NED and ED (from #5 above) in the ratio of actual project delay (#7 above) to total calculated delay (#6 above).	Delays in the project due to CD, NED and ED

Snapshot technique 1. Divides the 'as-built' schedule duration into a number of consecutive time periods or snapshots. 2. Updates the 'as-planned' schedule by imposing all delays occurring in each snapshot and in succession. 3. Records the delay caused by each update in the 'as-planned' schedule duration. 4. Adds all the recorded delays.	Total project delay
Isolated delay type technique 1. Similar to snapshot technique. In step 2 above for snapshot technique, delay types are scrutinised into CD, NED and ED instead of considering all the delays together. 2. For contractor caused delays, NED are imposed to update the 'as-planned' schedule and the delays are recorded. Excusable delays (ED) are imposed to update the schedule but no delay is recorded due to their imposition. 3. For client caused delays, CD and ED are imposed to update 'as-planned' schedule and the delays are recorded.	Delays caused by the contractor and the client
Time impact technique 1. Updates the 'as-planned' schedule by imposing each delaying activity in succession and disregarding any concurrency of delaying activities. 2. Records the delay caused by each update in the 'as-planned' schedule duration. **3.** Adds all the recorded delays	Total project delays

APPENDIX 2: DETAILED CALCULATIONS OF EACH DELAY ANALYSIS TECHNIQUE CONSIDERING THE PROPOSED IMPROVEMENTS

Global impact technique

The delay duration is calculated by the simple addition of individual delays. From Table 3, the total NED and CD are 12 days each. The delay caused by the contractor is the total NED, which is 12 days and the delay caused by the client is the total CD, which is also 12 days.

Net impact technique

The total delay is obtained by subtracting the 'as-planned' schedule duration from the 'adjusted' schedule duration. The 'adjusted' schedule for the contractor-caused delays is obtained by updating the 'as-planned' schedule including the NED. The 'adjusted' schedule duration obtained for the contractor-caused delays is 32 days (Figure A.1). The contractor-caused delay is therefore 9 days (i.e. 32 - 23 days). The 'adjusted' schedule for the client-caused delays is obtained by updating the 'as-planned' schedule including the CD. The adjusted schedule duration obtained for the client caused delays is 29 days (Figure A.2). The client caused delay is therefore 6 days (i.e. 29 - 23 days).

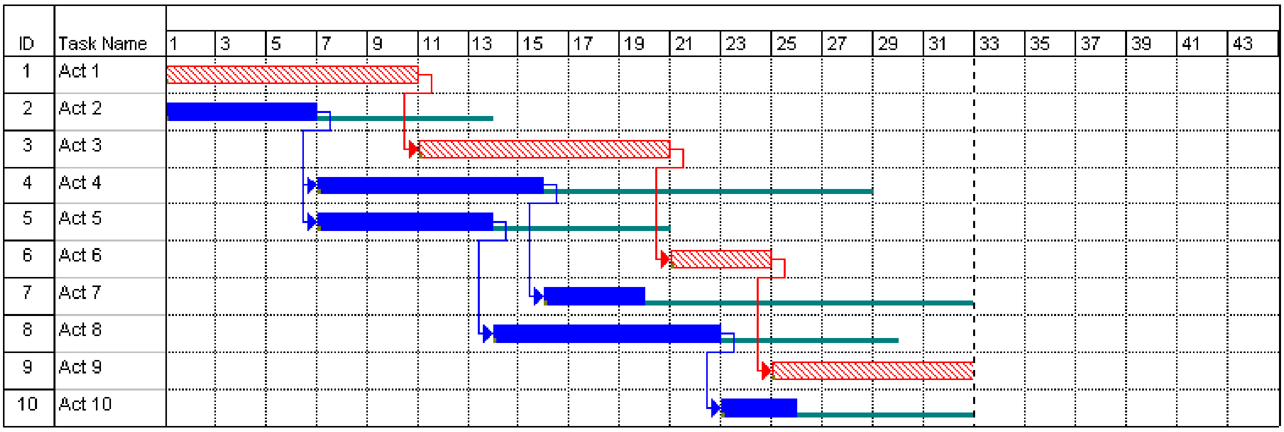

Figure A.1: Net impact technique – 'adjusted' schedule for contractor-caused delays

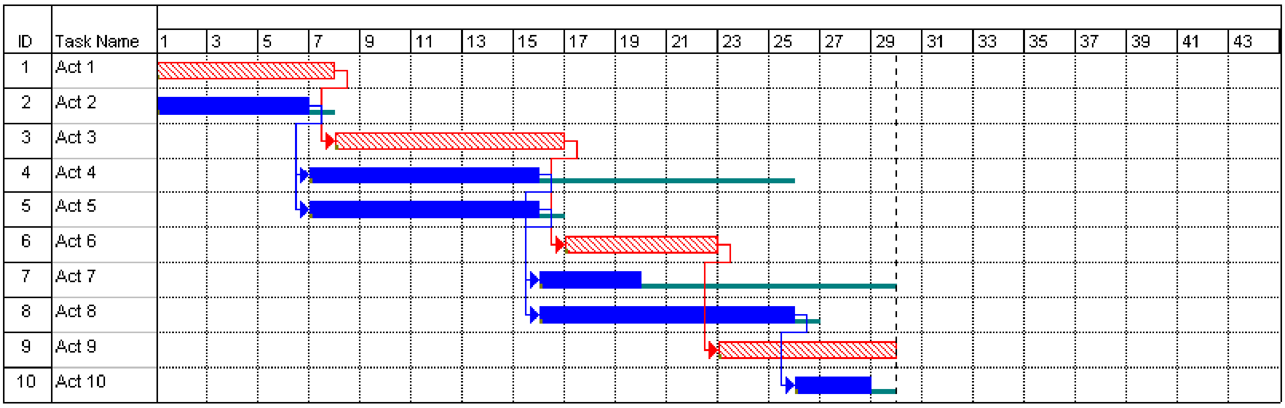

Figure A.2: Net impact technique – 'adjusted' schedule for client-caused delays

'But for' technique

The delay in this case is obtained by subtracting the 'adjusted' schedule duration from the 'as-built' schedule duration. The 'adjusted' schedule for the contractor-caused delays is obtained by updating the ‘as-planned’ schedule including both the CD and ED. The ‘adjusted’ schedule duration obtained for contractor-caused delays is 39 days (Figure A.3). The contractor-caused delay is therefore 2 days (i.e. 41 - 39 days). The ‘adjusted’ schedule for client-caused delays is obtained by updating the ‘as-planned’ schedule including both the NED and ED. The ‘adjusted’ schedule duration obtained for client caused delays is 36 days (Figure A.4). The client-caused delay is therefore 5 days (i.e. 41 - 36 days).

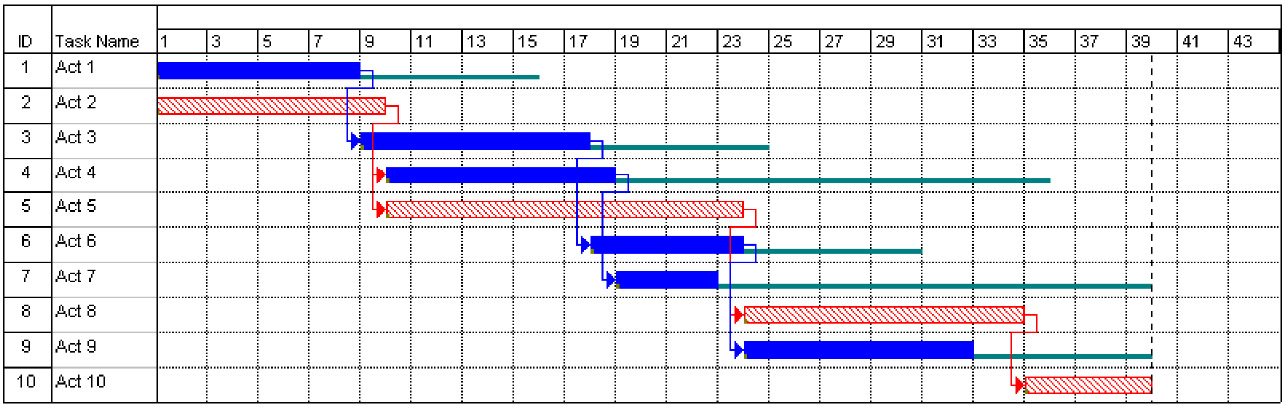

Figure A.3: ‘But for’ technique – ‘adjusted’ schedule for contractor-caused delays

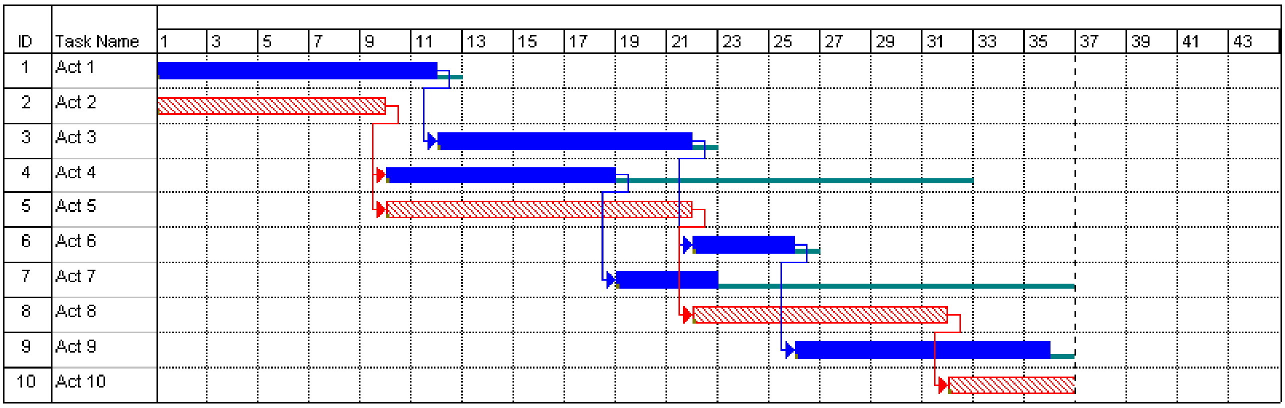

Figure A.4: ‘But for’ technique – adjusted schedule for client-caused delays

Apportionment delay method

Apportionment delay method is a compromise between the results of the net impact and ‘but for’ techniques. The contractor-caused delays were already found to be 9 days and 2 days respectively from net impact and ‘but for’ techniques. These delays correspond to NED. Similarly, the client-caused delays were found to be 6 days and 5 days respectively by applying the net impact and ‘but for’ techniques. These delays correspond to CD. The net impact technique provides 11 days and the ‘but for’ technique provides 3 days of ED (cf.: Figures A.5 and A.6). The total CD, ED and NED are thus 11, 14 and 11 days respectively and their sum is 36 days. The actual delay in the project is 18 days (i.e. 41 - 23 days). The method assumes that the total computed delay (i.e. 36 days) from both the net impact and ‘but for’ techniques is proportional to the actual delay (i.e. 18 days) in the project. This method apportions the actual project delay according to the ratio of the CD, ED and NED to their total. The contractor caused delay is thus 5.5 days (i.e. 11 x (18 ÷ 36 days)). The client-caused delay is also 5.5 days.

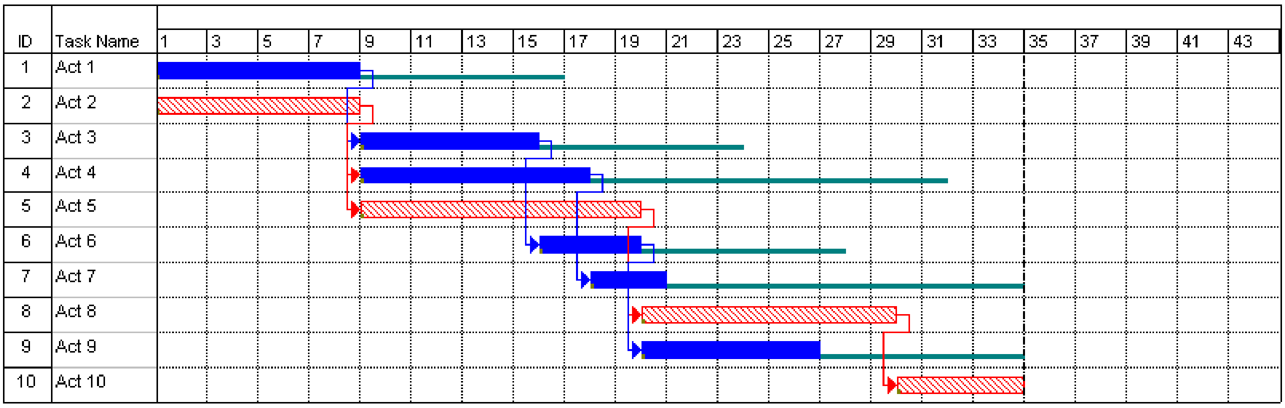

Figure A.5: Net impact technique – 'adjusted' schedule for ED

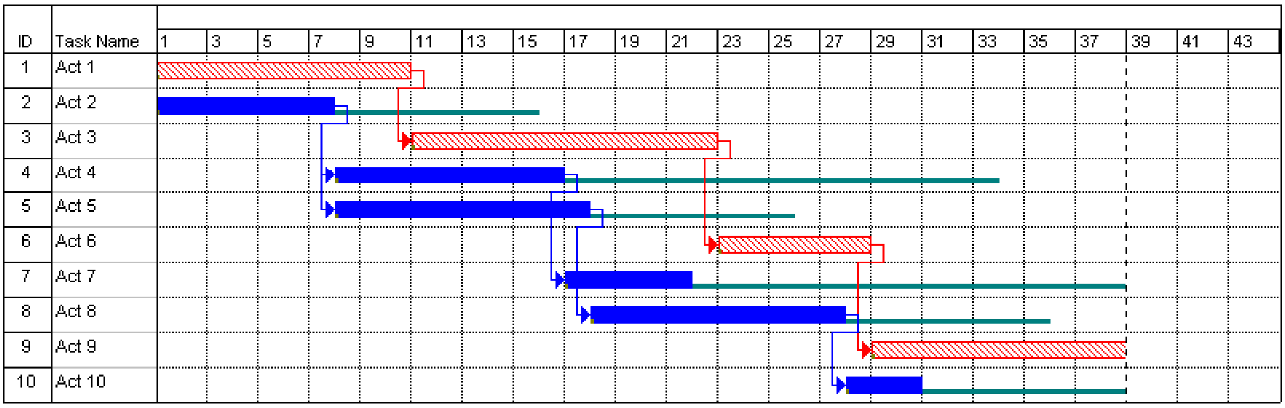

Figure A.6: 'But for' technique – 'adjusted' schedule for ED

Isolated Delay Type Technique

The isolated delay type technique uses the snapshot technique approach, with delay type scrutiny and concurrent delays considered in addition. For the hypothetical project, three snapshots have been chosen (Alkass *et al.*, 1996). These were taken from the starting day to the 11th day, from the 12th day to the 25th day and from the 26th day to the 41st day. For the contractor caused delays, the NED in each snapshot are used for recording the delay in the project and the corresponding ED in the snapshot are used to only update the schedule. Client caused delays are treated similarly by replacing the NED with CD in the analysis for the contractor caused delays. The results of the analyses for the contractor and client caused delays are shown in Tables A.1 and A.2 respectively.

Snapshot No.	**Adjusted duration due to NED (days)**	**Adjusted duration due to increment of ED (days)**	**Contractor-caused delays (days)**
1	26	27	3
2	30	33	3
3	33	36	0
Total			6

Table A.1: Results for contractor-caused delays based on isolated delay type technique

Snapshot No.	Adjusted duration due to CD (days)	Adjusted duration due to increment of ED (days)	Client-caused delays (days)
1	27	35	4
2	35	35	0
3	36	39	1
Total			5

Table A.2: Results for client-caused delays based on isolated delay type techniques

Time impact technique

By taking into account the chronological order of delaying activities and their concurrency, if any, the delay analysis for the contractor-caused and the client-caused delays is performed. NED is used for recording the contractor-caused delays and CD are used for recording the client-caused delays. ED is used for the schedule update only and the delays caused by ED are not recorded. The results are shown in Tables A.3 and A.4.

Activities impacted	Adjusted duration due to NED (days)	Adjusted duration due to increment of ED (days)	Contractor-caused delays (days)
1, 2	26	27	3
4, 5	28	33	1
3	33	33	0
7	33	33	0
6	33	33	0
8	33	34	0
9	34	35	0
10	35	37	0
Total			4

Table A.3: Results of contractor-caused delays based on the time impact technique

Activities impacted	Adjusted duration due to CD (days)	Adjusted duration due to increment of ED (days)	Client-caused delays (days)
1, 2	24	27	1
3	27	27	0
4, 5	30	35	3
6	35	35	0
7	35	35	0
8, 9	36	37	1
10	37	39	0
Total			5

Table A.4: Results of client-caused delays based on the time impact technique