Delay Analysis in Construction Contracts

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P. J. Keane & A. F. Caletka

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Preface

Construction delay claims are a common occurrence in projects. When they arise they need to be evaluated quickly and managed efficiently. However, the whole topic of delay and the various analytical techniques available is one which provokes much debate and controversy due to the seemingly complex and sometimes conflicting guidance provided on these techniques. The purpose of this book is to serve as a practical guide to the process of delay evaluation and includes an in-depth review of the primary delay analysis methodologies available.

The chapters flow logically from an overview of construction programmes in Chapter 2 through to the identification and analysis of delays in Chapters 3 and 4. Due to the complexity of construction contracts and the varying levels of familiarity with programmes or delay analysis, problematic issues arise from time to time when preparing or reviewing claims for additional time. The more common problematic issues are reviewed in Chapter 5 followed by a commentary on some recommended presentation approaches and a case study in Chapter 6.

The views we express are based on combined experience of over fifty years working on a wide range of projects and dealing with programming and delay issues. In practice, most projects are delivered within acceptable time and cost parameters. However, when there is disagreement over the responsibility for unacceptable delays to project completion, major disputes can arise due to the failure to manage the impact of change, and claims for additional time, in a timely or effective manner during the course of the project. In these situations there is a requirement for reliable analysis and assessment of the delay impact which addresses qualitative, quantitative and entitlement perspectives to facilitate an agreement. Much of course turns on the selection and implementation of the most appropriate delay analysis technique. Currently there is little by way of formal instruction in the understanding and application of these techniques with many practitioners being self taught. Accordingly, one main purpose of this book is to assist those construction professionals responsible for assessing delays by way of explaining some of the underlying assumptions and difficulties that may be faced when using some of the more popular and widely used delay analysis techniques.

As we were trained and practised mainly in the UK and US construction industries respectively, we have sought to identify and include in this book best practice guidance from these countries. In addition, our experience gained on major civil engineering, building and infrastructure projects around the world provided us with a broad perspective of the nature of delay analysis in practice, which in turn, we have reflected in the approaches and recommendations included in this text.

Delay analysis, which involves both the study and investigation of historic events, also entails assessing which of those events actually affected the completion of a project. This function is fundamental to the success of traditional construction management activity when potential delays must be identified and managed to prevent or reduce their impact on the project's duration and out-turn cost. When carried out forensically, the process takes on a higher significance due to the accumulation of legal and consulting fees, interest on capital and other related costs as well as diversion of key management and operational staff. While forensic delay analysis may take on a higher relevance in the legal forum, it is important for construction and project management staff to familiarise themselves with the prevailing trends with regard to the use of critical path method (CPM) programming and project management software as well as recent case law relevant to delay claims and the recovery of time related damages. This should assist when attempting to settle negotiations over the impact of change, and unforeseen events, at the earliest opportunity.

Delay analysis is practised internationally, across multinational jurisdictions. We have refrained from including extensive commentary on case law or legal doctrines relevant to compensation for time related costs. With regard to project management and delay analysis terminology, we have tended, for consistency, to follow traditional UK terminology. For example, although 'scheduling' is the common term used in US CPM network analysis, the term scheduling traditionally has a different meaning in the UK. Although the term 'scheduling' is being used more widely for CPM applications in the UK, we have elected to use the terms 'planning' or 'programming' for consistency with prevailing UK guidance, texts, terminology and case law.

It is important to note that forensic delay analysis, like many technical fields requiring analysis, is a combination of science and art and requires many subjective decisions and assumptions by the analyst along the way. The methods described in this book do not represent every possible application of the techniques described nor does the book attempt to address every available technique. The appropriate method, and the appropriate application of that method, will depend largely on the circumstances and facts relevant to the case or project at hand. For example, deducing an as-built critical path cannot be computed using computer based CPM software alone and requires a diligent and objective analysis of the body of information available to the analyst. Any method of delay analysis used should be transparent, forward looking and, most importantly, consistent with and based on, a reliable body of factual evidence.

We are indebted to friends and colleagues in the fields of construction and law who through discussion, argument and general banter have contributed in the preparation of this work. We are also grateful to Julia Burden and her team at Wiley-Blackwell for their encouragement and guidance. Finally, last but not least, we thank our families who have patiently endured our absence and supported us most during the writing of this book.

John Keane
Tony Caletka

Chapter 1
Introduction

1.1 General

Construction represents a tenth of the UK Gross Domestic Product (GDP). Construction is a unique industry due to it being a fast moving, complex and dynamic process which depends on the successful coordination of multiple discrete business entities – including professionals, tradesmen, manufacturers, trade unions, investors, local authorities, specialist trade contractors, etc. to ensure the delivery of a project on time, within budget and of the required quality. This coordination is dependent upon the application of sound planning, programming and project controls, allied to the implementation of tried and tested management techniques. Much of this work is carried out using increasingly sophisticated computer applications that are continually advancing by offering more and more capabilities to the end user.

A survey[1] carried out amongst UK contractors just over a decade ago found that 49% of contractors did not use computers on construction site locations. Now not only are computers commonplace, but also the use of specialist planning software is common as is computer-aided delay analysis.

Risk is an inherent feature of construction and it is well known that 'no construction project is risk free. Risk can be managed, minimised, shared, transferred, or accepted. It cannot be ignored.[2]' If it is accepted that risk is inherent in construction, then it must also be accepted that delays are also inherent in the process and should therefore be anticipated and managed and treated in a similar fashion as risk. When delays are experienced, this is not necessarily an indication that the process or management team is breaking down. Delays are often simply the result of an event which must be managed by a systematic process so as to anticipate the impact of that event on the programme, and to minimise the risk of further delay. Systematic management of delay during the course of the project also ensures that the cause of that delay is identified, and documented, at the earliest opportunity. When there is a requirement to identify the cause and effect of delay to establish entitlement to additional time or money, the results of any relevant analysis should be capable of being presented in a clear and unambiguous way.

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[1] P.J. Keane, 1994. *Survey on Computer Usage in Construction Claims Management*.

[2] Sir Michael Latham, 1994.

The most significant unanticipated cost in most construction projects is the financial impact associated with delay and disruption to the works. Assessing the impact of delay and disruption, and establishing a direct causal link from a delay event to effect, liability and the resulting damages, can be difficult and complex. Contractors and subcontractors require these skills for successful evaluation and presentation of time delay claims; the employer's professional team require similar skills and techniques when analysing and evaluating extension of time entitlements under a construction contract. Where these delay issues are not resolved by the contract administrator and contractor in the normal commercial way, then such issues are often left to be decided by third parties in arbitration or adjudication, before dispute review boards or, ultimately, in litigation. All these steps along the dispute resolution hierarchy have different timetables and expectations regarding the evidence required to demonstrate cause and effect. In selecting the most appropriate technique to suit the project, the relevant facts, the timetable, the nature and number of delay events, as well as size of the potential dispute to ensure proportionality is maintained, must all be considered.

1.1.1 Purpose of this book

The purpose of this book is to provide a practical guide to the process of delay analysis for programmers and delay analysts, and to inform non-programmers of the nuances of delay analysis techniques available, the assumptions which underlie the precise calculations of a quantitative delay analysis, to level the playing field for non-programmers and experts alike. This entails an in-depth review of the primary methods of delay analysis in use today, along with some familiar secondary methods. The timing and purpose of delay analysis is also discussed together with a review of the fundamentals of critical path method (CPM) programming. The 'project control cycle' is also described in detail. Contemporaneous programming evidence, flawed or not, will usually be preferred to retrospectively created programme data, so the emphasis should be on establishing and maintaining an accurate and effective CPM programme throughout the performance of the works.

This book is intended for project and construction management practitioners, contract and legal advisors, and programming consultants alike, who not only seek an understanding of the principles, techniques and methodologies involved in the process of delay analysis, but also want to understand the techniques and underlying processes in some detail. Such individuals include those employed by project owners (employers), contractors/subcontractors, legal experts and consultants who often find the need to manage extension of time or delay claims.

The techniques discussed in the book can be used on projects under all forms of construction contract, both domestic and international. Disputes involving delay entitlement and quantification which have to be resolved by the intervention of a third party trier of fact, are a frequent occurrence in the construction industry. Over the years, judicial decisions on several key aspects of delay dispute have been handed down by the courts, which have assisted, to some extent, in shaping the way in which delay analysis is undertaken in certain aspects. However, while the implications of these decisions clearly have a great bearing on the work of a delay analyst, it must be remembered that most, if not all, decisions regarding delay analysis are made not necessarily on the method of analysis, but rather on the underlying facts presented and relied upon.

The courts are only presented with delay issues after the event, and therefore decisions handed down mainly provide guidance on retrospective delay analysis techniques which demand, and rely upon, a high level of accuracy and detail with regard to the as-built programme. Notwithstanding the influence of the courts on the process of developing claims for delay and disruption, in order to accord with the ethos of this book, and the actual circumstances and facts many construction professionals find themselves managing, the authors have restricted the use of case law references to a minimum; for instance, where a principle has clearly been established and is commonly referred to in delay claims. Where cases have been referred to this has not been restricted to English case law but also includes a small number of significant US cases which are relevant to topics addressed. The US courts have accepted the concept of CPM programming and computer generated delay analysis submissions since the early 1970s. The English courts appear to lean in the direction of ‘common sense’, whereby the method of analysis is secondary, whether CPM programming techniques were relied upon or not.

It is important that a delay analyst should not become blinkered or be constrained by past judicial decisions in devising and applying delay analysis techniques prospectively in a live project environment. If a delay analyst adopts an unorthodox approach which is acceptable by both parties and resolves a time entitlement claim, then that is to be commended. In the same vein it is important not to get too hung up on ‘named’ approaches; this is largely another spin-off from judicial involvement in the development of delay analysis. Such named approaches include ‘time impact analysis’, ‘as-planned versus as-built’ and ‘collapsed as-built’. These names really only start to have any significance when used as expert evidence to provide a general indication of the approach being adopted by the delay analyst. Even so, there has been little guidance, until recently, as to how each method should be carried out. The primary named methods are often misused in court proceedings, arbitrations and adjudications.

Court decisions and arbitral awards sometimes indicate either a lack of willingness to come to grips with the issues and terminology or a difficulty in fully grasping the intricacies of sophisticated delay analyses. This is entirely understandable as judges are not usually presented with easy issues. The complexity of even the simplest of construction processes often proves to be extremely difficult to convey. Also courts, along with parties’ legal advisers, are not always assisted by delay analysts who misdescribe or misapply these techniques and opposing experts who do not take one another's approach 'head on'. When two opposing party appointed experts refuse to engage the other's method of analysis, this leaves a void where agreed programming evidence should be. These cases often conclude by the tribunal making an assessment based on the facts.

In summary, it is somewhat arbitrary to 'badge' and thereby restrict a piece of analysis, and while reference is made in this book to the primary delay analysis approaches, the authors urge caution in becoming too prescriptive because even these primary methods have secondary derivatives and many variations as to how they can be carried out. Also for this reason the authors have restricted the use of case law references to a minimum, to allow the site-based practitioner to make informed judgement calls when developing a delay claim rather than simply discounting one method of delay analysis over another, based on his or her understanding of the latest judicial decision mentioning a method of delay analysis being applied by either party.

This book discusses delay analysis techniques and approaches, with their appropriateness under given circumstances, and demonstrates how a combined, or hybrid, approach can be applied, complete with worked examples and case studies. Delay analysis is becoming an increasingly complex activity and there is continual debate and commentary on the primary approaches available. This book brings together the main techniques available in comprehensive primary and secondary categories. The particular techniques described in this book have been successfully tried and tested by the authors in both the commercial environment and in dispute resolution proceedings: adjudication, arbitration, dispute review boards and litigation. This book will serve as a resource guide for those practitioners, advisors, clients or contractors preparing or responding to construction delay claims.

1.1.2 Guidance

Two major guides have been produced on both sides of the Atlantic to assist those dealing with time extension claims and delay analysis. The first was the Society of Construction Law's Delay and Disruption Protocol, published by the Society in October 2002[3] (SCL Protocol). The stated aim of the SCL Protocol is to provide useful guidance on some of the common issues that arise on construction contracts, where one party wishes to recover from another an extension of time and/or compensation for the additional time spent and the resources used to complete the project. The second more recent guide was published by the Association for the Advancement of Cost Engineering International (AACEI) in the form of its 'Recommended Practice No. 29R-03

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[3] The SCL protocol can be downloaded from www.eotprotocol.com.

Forensic Schedule Analysis[4]' (RP-FSA). This document, issued on 1 July 2007 was officially launched on 15 July 2007. The RP-FSA is primarily focused on the terminology and the application of forensic analysis and is a much more technical document than the SCL Protocol, although it does not address as broad a spectrum as the Protocol. The stated purpose of the RP-FSA is to provide a unifying technical reference for the forensic application of CPM scheduling and to reduce the degree of subjectivity involved in the current 'state of the art' concept while the state of the art in the US differs from the state of the art in England. Both of these documents are discussed and contrasted in Chapter 4.

1.1.3 Construction planning and programming

Most construction projects will benefit from CPM programming. Only the most basic of projects can and should be planned and managed intuitively. The rest require systematic planning and control. Over the past 30 years planning and programming have been fundamental building blocks in any project management and control system and, in some organisations, are given equal weight and importance as the budget and cost management.

CPM is the planning technique most commonly used in the construction industry today, and is based on the same critical path analysis principles established in the 1950s. In Chapter 2 the principles of construction planning and programming are explained. These techniques are fundamental in enabling a project to be successfully managed. CPM programming is a tried and tested method and is today essentially unchanged from the earliest applications almost 50 years ago. The chapter describes the essential elements of a successful project through the planning and programming phase and identifies the pre-construction tasks which are not only prerequisites to effectively planning a project but conversely in the case of insufficient pre-construction planning can result in programmes being developed which contain inherent delays.

The stages and lifecycle of a construction project are described in detail. The project planning stage is the most important to the development of an effective baseline programme. During the planning stage, the project definition is established. Executing a successful project requires a significant pre-construction effort which questions the underlying assumptions and business case for the project. During this stage the professional team considers such issues as whether a project is feasible and buildable, whether any new or novel method of construction will be required, and whether there are technical, geographical, time and/or financial constraints which would prevent the success of the project.

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[4] Association for the Advancement of Cost Engineering International – Recommended Practice No. 29R-03 *Forensic Schedule Analysis*.

The chapter also discusses the process of preparing a construction programme, the creation of a work breakdown structure, and the fundamentals of CPM programming.

A significant aspect of delay analysis is the interrogation of records upon which reliance will be placed in analysis output. Accordingly, the need for good records and the various categories of required record keeping are explained. Finally, there is a cautionary note on predatory programming practices which should be avoided, along with advice as to how to detect and defend against each.

1.2 Construction delays

1.2.1 Identifying delays

The identification and assessment of delay entitlement can be difficult and time consuming. When any degree of complexity is introduced to the mix it can become particularly difficult for project staff who are over-worked while dealing with site issues and other project pressures, and who may be untrained in forensic analysis or programming skills. This often manifests itself as a poor strike rate in achieving extensions of time entitlements by contractors, or, when the employer's team lacks these skills and awareness, a record of granting excessive extensions of time to contractors. To be successful, a time extension claim should adequately establish causation and liability and assist in demonstrating the extent of time-related damages or disruption costs experienced as a direct result of the delay events relied upon. The purpose of delay analysis is to satisfy the causation requirement in such a way that it can be used to assess the resulting damages.

Establishing a basis for identifying delay is the first topic dealt with in Chapter 3, which also deals with the construction phase of a project that is generally where the bulk of a project budget is dedicated. The construction phase is also the phase in which design delays, or lack of sufficient preconstruction planning, will often culminate into critical delays to completion, as measured by delays to site activities.

Delays may be categorised as excusable, non-excusable, compensable and non-compensable. When demonstrating that a delay is both excusable and compensable, the delay must be shown to be critical, by reference to a reliable critical path analysis. The tests which must be satisfied for a delay to be considered excusable and compensable are described and discussed in Chapter 3.

The carrying out of a successful delay analysis requires the preparation of a reliable as-planned programme and an accurate as-built programme. The effectiveness of delay analysis techniques can be greatly increased when it can be demonstrated that the as-planned programme was reasonable. Further discussion on as-planned programmes is also to be found in Chapter 2. The as-planned or baseline programme is useful contemporaneous evidence of a contractor's original intentions, and should serve as the starting point when identifying delays. Unfortunately there are many ways in which as-planned and progress programmes can be manipulated. Chapter 3 highlights checks that should be made to validate the reliability of such a programme before it should be used for any method of delay analysis.

One of the main objectives of delay analysis is the establishment of a factual matrix and a chronology of the events which actually delayed the work's completion date. One important use of this data is to assist in the preparation and/or validation of an as-built programme. In the ideal situation, an as-built programme will have been prepared and maintained during the course of the works. The data required to periodically maintain and update a project programme can also be relied upon when forensically constructing an as-built programme. The primary sources of raw data required for the compilation of an as-built programme are discussed in Chapter 3, together with a cautionary note about the use of lazy scheduling practices, such as the overuse of constraints, negative lags, and 'auto update' functions which can be found in commercially available planning software.

The process of identifying delay events is a fundamental aspect of delay analysis and can be undertaken in two primary ways: either an 'effect-based' approach or a 'cause-based' one. Both of these are explained in Chapter 3, along with a discussion on contractor and employer risk events.

While this book is principally concerned with delay analysis, it is inevitable that the issue of disruption will have to be dealt with to some extent. Chapter 3 is confined to a general overview of disruption, particularly its interface with delay analysis. In the construction industry, delay and disruption are two terms that are often used in the same breath. This is understandable as delay and disruption often result from the same events. However, disruption, unlike delay, always has a direct consequence on financial loss. The main differences between delay and disruption are discussed, together with a review of the many causes of disruption, and factors that affect productivity. An example of calculating disruption is illustrated.

If there is no agreed model or method for quantifying the effects of disruption factors in advance, the establishment of the magnitude of the disruption or loss incurred will likely require the preparation of expert evidence. Accordingly a number of approaches have been developed which include, the measured mile, measured productivity method, work sampling, modified total cost approach, and site sampling (time and motion studies). These are discussed along with brief practical examples which are provided to assist in demonstrating the process of each type of analysis.

1.2.2 Analysing construction delays

The effect of delay and disruption can be identified and assessed using several dissimilar techniques. There is much discussion about the various approaches to delay analysis along with explanations as to why it should not be surprising when two opposing programming experts can apply the same technique and produce widely varying and inconsistent conclusions. Delay analysis techniques are known by many generic titles and each method can be applied in several ways. The most widely known methods of delay analysis are subject to frequent misuse; but the name applied to a technique is not as important as the application of the chosen method. All commonly applied forensic delay analysis techniques generally fit within one of the following primary categories: impacted as-planned, collapsed as-built, as-planned versus as-built, and time impact analysis.

The 'windows' method is also described in detail, using several of the primary methods listed above. The term 'windows' simply refers to the period of time being analysed. When key milestones are relied on, the same approach is sometimes referred to as 'watershed' analysis. Each of these primary delay analysis techniques has secondary derivative methods of application, which may be used in prospective or retrospective settings. All of these named techniques are fully explained in Chapter 4, which also not only explains how to carry out and present several secondary derivative methods, but also contrasts the strengths and weaknesses of each method and considers the underlying assumptions the analyst must make when using any of these techniques. The four primary methods of delay analysis are also reviewed in detail in Chapter 4, complete with a step-by-step guide to their usage and an indication of some secondary approaches which can be derived from each of these primary approaches.

The chapter also explores the use of CPM and total float management techniques relative to delay analysis. CPM programming is essential when attempting to identify which activities are either critical or non-critical. The CPM programme is therefore the key to demonstrating those events which actually contributed to the critical delay to completion and those which may be deemed merely concurrent 'events'. The concept of 'pacing' is also explained in detail. In the US courts the use of CPM programmes to demonstrate delay has been a requirement for some years, to the point where delay analysis in US courts almost exclusively rely on delay analyses which used CPM methods of proving entitlement.

There are many names used in the construction industry for the 'time impact analysis' (TIA) approach, probably because there are as many ways to apply the technique. A summary of the perceived strengths and weaknesses of the TIA technique are summarised in Chapter 4, along with many of the variations and options available to the analyst when carrying out this technique.

The 'collapsed as-built' (CAB) approach is a modelling technique which is traditionally carried out on a single-base programme, e.g. the as-built programme. The other side of the spectrum of the basic methods of analysis include as-built based analytical techniques which do not rely on calculated CPM models. In its simplest form, an as-built versus as-planned analysis compares the planned duration with the actual duration of a project and asserts the difference as being both excusable and compensable. These are referred to as 'Observational' in the AACEI RP-FSA.

On projects where the effects of acceleration (or attempted acceleration) or early completion programmes are at issue, it advisable to apply both a deterministic technique and an analytical technique, which is explained in Chapter 4. This provides a tribunal with a range of opinions, based on different assumptions.

The contemporaneous windows analysis is a technique which relies on the analysis of contemporaneous progress information and is considered to be dynamic because it considers the dynamic nature of the critical path. The as-built critical path of a programme shifts from time to time for many reasons as explained in Chapter 4.

A similar method to the contemporaneous windows analysis is the 'month-to-month update' analysis, whereby the progress achieved in one month, is superimposed on a previous month's programme update. This is a method which discretely determines the loss/gain experienced due to both progress achieved/not achieved, and programming revisions made by the contractor. This is a form of 'what if' analysis, which identifies and isolates delays caused purely by progress, from delays (or gains) which resulted from changed logic, constraints or durations. This method of analysis is very effective when a contractor is seeking to demonstrate acceleration and needs to demonstrate what the 'likely' effect of a delay event would have been, as opposed to the 'actual' effect. The case study in Chapter 6 applies this technique in a worked example.

Determining which technique is the most appropriate to use under given circumstances is a subjective decision, guided by experience, the available information, and other relevant factors. Even when agreement is reached between the parties, often the application of the same 'technique' varies to such an extent that neither party is willing to accept the other's conclusions. These issues have been addressed in both the SCL Protocol and the RP-FSA. Chapter 4 provides detail of the SCL Protocol and the 21 core principles. The approach to event analysis and delay quantification must be both systematic and pragmatic. Notwithstanding the importance of this activity, it is also essential to keep a sense of balance with regard to what is a proportionate cost to benefit ratio and to avoid overly complex analyses. These may be accurate, or precise, but may not be intuitive, at the risk of conflicting with a tribunal's view of 'common sense'. While courts have judicial latitude, contractors and contract administrators cannot be seen to base extensions of time on impressionistic assessments. The methods set out in Chapter 4 will assist parties in arriving at an approach that is pragmatic, systematic, and appropriate for the circumstances of their project.

1.2.3 Delay claim life cycle

Each and every delay claim has its own life cycle. The various stages may be summarised as follows:

- Baseline programme is established
- Project commences
- Deviation from baseline programme is identified (or projected)
- Delay occurrence/discovery
- Delay analysis
- Delay claim submission and presentation
- Delay claim response
- Negotiations (and award of appropriate extension of time)
- Revised baseline programme is established and agreed
- Dispute resolution procedures (if award is not agreed)
- Delay claim resolution

Delay claims are a very effective way to spend money and divert management resource from running a business. Resolution by way of a mutually acceptable extension of time should be sought at the earliest opportunity to avoid the dispute stepping up to the next, more formal process. There are many pitfalls on the path to a successful delay claim resolution as well as steps that can be taken to improve the outcome; for example, the agreeing of delay impacts contemporaneously (i.e. as they arise during the course of the project works) rather than adopting a 'wait and see' approach. Chapter 5 considers a number of problematic issues which arise in connection with both programming and delay analysis. These include problematic issues related to the ownership of float in construction programmes, concurrency, programme submission and approvals, acceleration, disruption and mitigation of delay.

Effective communication of sophisticated delay analysis requires quality in the presentation. There are many ways to present similar facts with different conclusions. The benefits of visual aids with worked examples are explained in Chapter 6, together with methods of graphical presentation that are described and critiqued. In addition, a number of worked examples are included and case studies explained.

1.3 Burning issues in delay analysis

Chapter 5 discusses a number of problematic issues which have arisen in connection with both programming and delay analysis. These include:

- issues related to the ownership of float in construction programmes;
- concurrency;
- programme approvals;
- mitigation;
- acceleration;
- pacing;
- contractors' entitlement to early completion; and
- the assessment of disruption damages.

Float is an integral part of CPM programming and delay analysis. The concept of float, which has given rise to much debate, is introduced in Chapter 2 and further explained in Chapter 4. In Chapter 5, float is discussed in detail, relative to its usage, measurement and ownership. Float loss can reduces a contractor's contingency time cushion and increases the probability of critical delay to the project. Even where it doesn't result in critical delay, float loss can cause financial loss to discrete task related resources. Chapter 5 discusses float loss measurement and also ways in which both employers and contractors can seek to influence a programme, and ways in which planners can manipulate float using various float suppression techniques. An issue of much debate for many years is 'who owns the float in a construction programme?'; the implication being that the owner of the float has exclusive use of it. Chapter 5 reviews the various viewpoints on this matter.

Another common problematic issue which arises in the delay analysis is that of dealing with, and defining, concurrent events and concurrent delay. The uncertainty as to how concurrent delay should be managed or defined continues to cause difficulty to contract administrators, in particular in their task of assessing extensions of time and compensation events during the course of a project.

These issues impact both on the level of extension of time that might or might not be granted, and also on the amount of compensation, for example loss and/or expense, that might be due. Chapter 5 reviews definitions of concurrency, and considers alternative approaches for dealing with concurrent delay, including: 'first-in-line', the dominant cause approach, and the apportionment approach. When concurrent culpable delays are identified by the employer, contractors often argue that it was simply 'pacing the work.' This concept is discussed, including how it might apply equally to the employer's professional team as well as to contractors.

Another area of potential difficulty is that of programme approvals and onerous specifications. Many of the major building and civil engineering forms of contract require the contractor to prepare and submit a construction programme. The content and standard of construction programming data that employers have required to be submitted by contractors in the past has varied quite considerably. However, in more recent times, with the advances in computer generated output and a growing awareness of the nature of construction planning, employers have been requesting ever increasing detailed and sophisticated programmes from contractors. In the US, particularly on government forms of contract, it is a more common practice to require quite detailed and sophisticated programme requirements. These issues together with approval or acceptance of construction programmes are discussed in Chapter 5.

The final issues reviewed under this chapter are those of delay mitigation, acceleration and contractors' rights to early completion. The latter topic is when a contractor submits a programme which indicates an intention to finish a project earlier than the agreed contract completion date.

1.4 Presentation and case study

Effective communication of sophisticated delay analysis requires quality and sufficient level of detail in the presentation. It has been established that people usually understand and retain information at a much higher rate when it is presented to them visually. Studies in the US have shown that jurors, for example, retain as little as 10% to 20% of the material presented to them orally yet retain as much as 65% to 80% of material presented to them visually or with visual supplements. The effect of using high-impact, demonstrative evidence assists greatly in the success of a case which includes complex technical issues. There are many ways to present similar facts with different conclusions. The benefits of visual aids with worked examples are explained in Chapter 6 together with methods of graphical presentation which are described and critiqued.

In addition in Chapter 6, various methods of delay analysis are demonstrated using a case study, largely based on actual assignments. The information available on the case study project is listed and the method of identifying the as-built critical path is described in detail. The purpose of this chapter is to show how these methods of delay analysis may be carried out. It is important to note that the methodology demonstrated in this case study is not the only method, nor the only variant on the method demonstrated, for carrying out this type of delay analysis.

Chapter 2
Construction Programmes

2.1 Introduction

2.1.1 Planning, programming and project controls

In this chapter the principles of construction planning and programming are explained with a review of the merits of the main planning techniques currently in use in the industry. All but the smallest of projects require systematic planning, particularly due to the nature of construction projects. These are often one-off productions, on a site where few if any production facilities exist, with an array of trade contractors marshalled together and to be coordinated with material, plant and services providers. Each project effectively brings the factory to the job and each is different; from the location, to the design, to the participants. Each project requires customised, systematic coordination to avoid delays and cost over-runs.

Planning as a systematic function is a principle cornerstone of effective construction management. In the past, construction planning was something of a Cinderella activity, not entirely recognised as an important discipline in its own right. This all changed with the development of economically available personal computing power in the mid 1980s. Prior to this, construction planning was a time consuming and limited manual process, often most recognisable in the form of bar charts (or Gantt charts) posted like wallpaper in site conference rooms. Due to the effort required to edit, update or re-plan the works manually, these often remained posted, yellowed and faded, without an updated programme or as-built record of progress in sight.

It is difficult to envisage a project involving design, engineering, procurement, and/or construction which would not benefit from some form of critical path method programming or scheduling. Whilst few relatively simple projects may still be planned and managed intuitively, the rest require systematic planning and control. Construction planning and programming have come to the foreground of project management and control systems. In some organisations construction planning effort is treated on par with the financial elements of the project control cycle. Historically, planning was considered to be primarily a supporting activity, usually most relevant in the tender phase of a project. Little attention was paid to the project planner (if there was a dedicated planner) and the programmes, updated or not, were referred to very little (if at all) during the remaining life cycle of a project.

It is widely accepted among design and construction professionals that critical path analysis is the most appropriate tool for the management of complex construction projects and is at the heart of any functional project control system. The most commonly used planning technique based on critical path analysis principles is the critical path method or CPM. Many derivatives of the CPM approach have been developed, and it is still an evolving standard with some advances made in software and management theories, such as the application of the theory of constraints (TOC), the critical chain method (CCM), the use of probabilistic branching, the enhanced precedence diagramming method (EPDM) and Last Planner programming techniques. All of these derivative applications have their foundation in the basic principals of CPM which were developed some 50 years ago.

This chapter describes the tools required to enable a project to be successfully planned, programmed and controlled using CPM philosophies. These are tried and tested methods that have worked for the past 50 years and are today essentially unchanged from the earliest applications. The advancement in the development of computer hardware and processing speeds, together with the availability of low cost, easy, user-friendly software, have encouraged the widespread adoption of CPM based project control systems. These systems track and correlate cost and resource information with the planned and actual progress of work. Control systems and critical path programming, when developed hand-in-hand, assist project executives to decide what progress information is important to decision making during the course of a project. Where required they also assist courts in allocating damages to parties involved in construction related litigation.

Other forms of planning are also reviewed, from the traditional and still widely used bar chart to the more specialist applications such as line of balance charts and mass haul diagrams. The project control cycle (PCC) entails the entire effort involved in creating, monitoring and managing change to both the cost and time elements of a project. The main functions which make up the PCC include planning, programming and control, as follows:

- **Planning:** define project, determine scope, set overall duration, budget, contingencies, identify risks and overall project goals.
- **Project programming or scheduling:** identify individual tasks, assign resources and budgets to each, create a baseline which determines the earliest and latest allowable start and finish times for each activity, the available float to each activity, and the critical path through the project.
- **Project control:** update project programme, monitor progress against the baseline for both cost and schedule performance, measure and manage the effects of progress, delays or changes (re-assigning resources and re-scheduling tasks as required to maintain progress).

The nuances between the terms ‘planning’, ‘programming’, and ‘controlling’ a project are clear once the process of project management and the stages of a project’s life cycle are clearly defined. Project management is not simply the process of managing a project on site but much more. In a code of practice produced by the Chartered Institute of Building[1] the project management function is defined as:

> 'the overall planning, coordination and control of a project from inception to completion aimed at meeting a Client's requirements in order to produce a functionally and financially viable project that will be completed on time within authorised cost and to the required quality standards.'

Project managers require a skill-set gained through education, training, experience and, where relevant, professional certification. In addition, a maturity of expertise is required to lead a team by guidance, mentoring and, most of all, by example. These skills ensure that a rational, systematic process of decision making is established to achieve the delivery of a defined project on time, within budget and to the specification or defined use intended. Each stage of a project requires the commitment and dedication of the professional team as all parties are essential to the successful outcome of a construction project.

The tasks described as 'planning', 'programming' and 'control' should not be confused with the traditional project life-cycle stages, as follows:

- Concept
- Feasibility
- Realisation
- Operation
- Termination

The task of planning a project takes place during the conception and feasibility phases, while programming and control are undertaken during the realisation phase. Realisation typically includes several individual phases, including design, procurement, construction, commissioning and hand-over. Factors for a successful project usually include an effective and well coordinated effort during the concept and feasibility phases which in turn result in realistic estimates, contingencies and time scales for completing all of the above phases. Likewise, projects that fail can often be linked to a failure to understand potential risks during the concept and feasibility phases, when the contractor is creating its baseline estimates and programmes.

2.1.2 Elements of a successful project

Simply put, for a project to be capable of being managed, it must have a beginning, a middle and an end. If there are no clearly defined aspirations, along with a clear definition of the project and completion criteria, uncertainty will

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[1] *Code of Practice for Project Management for Construction and Development*, 2nd Edition (ISBN 0-582-27680-2).

prevail and the likelihood of arriving at an intended completion date on time will be reduced.

For a project to be capable of being planned, programmed and controlled, it must have the following elements:

- a clear definition of project;
- an appropriate staff level and experience;
- a pre-estimate of cost and time;
- identified risk contingencies (cost and time);
- each phase broken into manageable tasks;
- a formal change procedure established; and
- clear completion criteria agreed.

It is essential that all these elements are addressed prior to, or during, the planning stage, which is described in the following section.

2.2 Planning and programming

Before the planning process can commence, various pre-planning tasks should be carried out. These comprise setting the goals, objectives, constraints and aspirations which will define failure or success upon completion. Establishing a project owner or employer's requirements and testing the business case for a desired project are all part of the 'pre-planning' phase. Any changes made to the project definition, once these goals are set and communicated through the employer's requirements or contract documents, are disproportionately more expensive than changes made during the planning and programming phase. The pre-planning tasks which are prerequisites to effectively planning a project include:

- defining the purpose and goal of the project;
- defining all project stakeholders and their competing aspirations;
- identifying funding sources;
- identifying means for project delivery;
- establishing conceptual estimates and cost/benefit analyses;
- establishing conceptual summary programmes (milestones);
- defining risks and go/no-go criteria;
- selection of site;
- definition of professional team roles;
- development of schematic and preliminary design;
- preparation of contract documentation (including drawings and specifications);
- preparation of project management plan; and
- definition of project scope, milestones, duration and budget.

These tasks are not often coordinated and programmed to the same extent that construction tasks are but they are just as important, if not more so, to the successful outcome of the project. When project management principles are used to manage the above tasks pre-construction services are more efficient and transparent. A properly managed pre-construction phase can substantially reduce the risk of any unforeseen or unallocated scope emerging which was not clearly assigned to a work package or a member of the employer's professional team.

While traditional delay analysis approaches tend to focus on the design and construction phase, delays and inefficiencies can often result due to circumstances which occur long before the first drawing is produced. Although these early factors are more difficult to identify as delay 'events', typical factors which can result in programmes containing inherent delays before the first delay event culminates on-site include:

- poor project definition;
- use of an inappropriate form of contract;
- inappropriate contract packaging strategy;
- ambiguities present in specifications, contract drawings, bills, employer's requirements;
- the appointment of inexperienced managers and supervisors;
- insufficient budget allowances or contingencies (e.g. cost and time) for unforeseen events and design development;
- poor plant selection;
- failure to communicate plans/intentions to local authorities;
- ineffective site logistics planning; and/or
- incorrect assumptions regarding neighbouring sites, land-owners or other interested stakeholders.

Any of these risks can add unnecessary hurdles while contributing to a breakdown in project execution. Examples of the above factors can be identified, but pin-pointing the impact of each, or any combination of one or more, often proves difficult.

2.2.1 Project planning

The project planning stage is the most important aspect of defining and executing a successful project. In order to adequately plan the work, the input and coordination of the employer's professional team is necessary. In addition planning often also requires the input of specialist trade contractors who must be engaged early in the planning stage to assist in the completion of design elements or specification of products, materials and any novel means (or methods) of construction which are being considered by the professional team. Commercial decisions and financial commitments have to be made by the employer and the professional team at the earliest stages of a project's formation. At the conclusion of the planning stage, it should be possible to answer the following questions:

- Is the project feasible, technically and financially?
- Is the project commercially and financially acceptable to investors or project owners?
- Are risks adequately defined and allocated in the contract documents?

The task of planning a project is undertaken during the realisation period and is dependent on timely and accurate information from the employer's professional team.

When initially preparing a construction programme a balance has to be struck to achieve a workable level of detail. For example, while the temptation might be to plan in minute detail at the outset, this quantity of information would be likely to create an unmanageable and confusing plan. Equally a programme deficient of detail also creates an impractical management tool.

Since the advent and subsequent development of readily available desktop computing and 'user-friendly' project planning software, the issue of 'too much' detail and information is less of a problem, provided that such information has been properly linked, coded, and filtered. For example, the reporting requirements during the course of a project will vary for each participant. The employer (client) will usually require the contractor to simply headline overall progress and forecast completion results. However, each section foreman will require very detailed information on a weekly, bi-weekly or even daily basis to assist in coordinating the work-force.

Clearly an effective programme must also be capable of measuring the impact of changes throughout the course of the works. Methods for managing the impact of change will be explored below and further in Chapter 4.

2.2.2 Work breakdown structure

As an extension of the planning task, the process of preparing a construction programme firstly requires the creation of a work breakdown structure (WBS). The WBS defines every element of the completed project, and cross refers these elements to their respective task. The WBS is presented in a hierarchical breakdown.

The hierarchy of the WBS is described as levels. These levels allow for the summary reporting of cost and programme status and require both the cost and programme to be capable of being cross referenced (coded) to a WBS element consistently to allow for accurate and timely reporting and monitoring.

Level 1 of a WBS traditionally encompasses the entire project. Level 2 could represent each system, stage (design, construction, testing), or product being procured. The number of further levels is determined by the size and complexity of the project or programme. At the lowest WBS level, a definable task and cost item should be defined so that the WBS, cost plan/budget and programme are consistently structured.

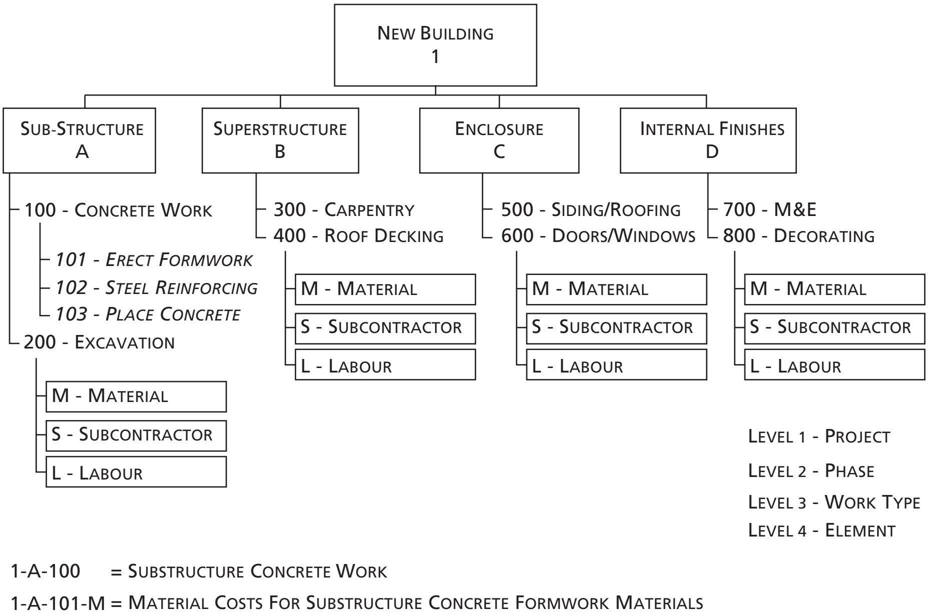

Figure 2.1 Example of a work breakdown structure.

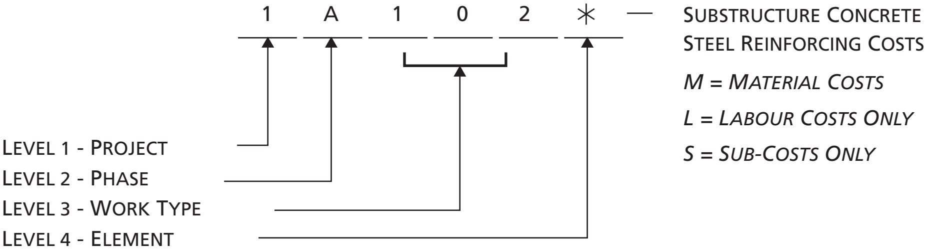

Figure 2.2 Typical work breakdown structure coding definitions.

A sample WBS for a typical building project is presented in Figure 2.1.

In this example, the WBS code for the material costs for substructure concrete form-work, and its associated budget and programming tasks, can be isolated for all items coded to 1-A-101-M. A typical coding structure for a WBS system can be defined as represented in Figure 2.2.

Effective WBS definitions allow a project's document control, filing and retrieval systems to be organised, cross-referenced and structured to be consistent with the WBS codes. WBS coding is something of an art form and can be system based, cost-item based, task-based, process-based, or product based, depending on the industry and tasks defining the project. Deciding the level of detail in a WBS requires a degree of sensitivity to a professional team's ability to manage the works. For example, a WBS which is too shallow (i.e. too few levels) will be ineffective in isolating cost over-runs or deviations from budgeted values. A WBS which is too deep (too many levels) will be too sensitive; will be more labour intensive to manage and populate during each updating cycle; and will require micro-management of individual tasks. An effective WBS assists in developing baseline cost and time estimates and is important in ensuring an efficient project controls cycle.

Creating a baseline programme is an iterative task involving construction professionals (e.g. engineers, architects and quantity surveyors) and the input of specialist trades. An *aide-mémoire* of the tasks involved is set out in Figure 2.3.

Tasks in the preparation of a Baseline Programme

1. De-scope the project into work packages to ensure that:
    - all elements of the BOQ are accounted for;
    - all elements on structural drawings, architectural plans and elevations are accounted for;
    - all elements and constraints defined in specifications, contract documents, planning conditions and tender documents are accounted for; and
    - all elements are defined as 'tasks' or date constraints (with a duration, quantity of measurable work content or deliverable).
2. Define the work breakdown structure.
3. Allocate each activity to both the activity code structure and the lowest WBS level (e.g. location, level, phase, trade, system, task, etc.).
4. Identify required construction sequences 'hard logic' (i.e. the natural sequence of identified tasks or sequence dictated by the design, absent any outside influences, constraints or imposed milestones). With the exception of start milestones or finish milestones, each task should have at least one successor, and one predecessor to assist in determining when the work needs to be carried out. For each task a planner may simply ask:
    - Is this a start milestone?
    - Is this a finish milestone?

Figure 2.3 Checklist for creation of a baseline programme.

- Which tasks must precede this task?
- Which tasks must follow this task?
- Which tasks must take place at the same time as this task?

5. Identify preferential sequences and constraints 'soft logic' (i.e. sequences imposed on the project by resource constraints, plant selection, imposed constraints or imposed intermediate milestones). For each task a planner may simply ask:
    - Is this task resource constrained?
    - Is this task dependent on large plant (e.g. primary crane, earthmover)?
    - Is this task dependent on access to adjacent property?
    - Is this task dependent on agreements with third parties (rail, road or river authority, neighbours for overhead crane swings)?
    - Is this task dependent on the supply of goods or equipment by other parties?
6. Identify required procurement durations for long lead items to prioritise design tasks.
7. Identify tasks for required contractual allowances: employer review of drawings, inspections, testing, approval and commissioning periods.
8. Estimate durations for each defined task using tender quantities, expected crew-size and historical outputs for similar work.
9. Define working calendars (e.g. 40 hours/week, 50 hours/week, holidays, etc.).

Figure 2.3 *Continued*

The most fundamental steps in the above process are defining the logic and dependencies between the tasks, and defining the duration of the tasks.

The construction industry has lagged behind in implementing any real advances in managing construction programmes or schedules. The time available to develop a tender programme or baseline programme is often inadequate, and they are prepared by in-house planners who are stretched over several projects. The SCL Protocol (discussed in Chapter 4) has undoubtedly increased awareness of these issues, and prompted debates which have benefited employers and contractors alike. It is, however, unlikely that a sea-change in the management of construction programmes will take place until employers include more defined programming specifications in contract documents, and contract administrators enforce the requirements in those specifications.

2.3 CPM programming techniques – the fundamentals

A CPM based programme should be a dynamic, forward-looking and transparent tool. A well prepared CPM programme which is robust and sensitive to change allows for the timely identification of any deviations. This in turn reduces or eliminates delays to completion. It is the programme's ability to react and predict the likely effects of changed circumstances which give CPM programmes such value. The CPM programme is the key tool for predicting the impact of change in a structured, logical and systematic process. For example a CPM programme allows the project manager to perform 'what if' scenarios to assist in making decisions when considering the potential outcomes of upgrading or enhancing the base-design.

The level of awareness of programming factors and consideration of these issues has grown exponentially in recent years, as have the programming requirements in construction contracts and the need for a cause–effect nexus for demonstrating the impact of events during the course of the works. This is helped in part by publications such as the SCL Protocol and the US published RP-FSA No. 29R-03, which have provided guidance while prompting industry-wide debates regarding contentious programming issues.

Before discussing approaches to monitor and control the project programme, it is essential to understand the basics of critical path programming and diagramming techniques. The following sections describe the fundamentals of CPM programming, along with the process of creating or validating a baseline. The CPM enables a planner to:

- determine the shortest time in which a project can be completed;
- identify the tasks which determine the shortest path to completion (and, by definition, are on the 'critical path'); and
- identify how much delay, or slippage, can occur to activities which are not on the critical path before they become critical. (The amount of allowable slippage is called 'float' or 'slack' time.)

CPM programming is a mathematical model based primarily on two variables: activity durations and activity relationships. Reducing subjectivity and risk in the determination of either of these variables in an as-planned programme (APP) makes the APP more objective and less susceptible to criticism for failing to sufficiently account for all the work content in the contract.

2.3.1 Activity durations

Estimating activity durations requires experience, judgement and knowledge of the means and methods intended to carry out the works; in effect, activity durations are subjective in nature. Factors which influence the estimate of durations include:

- the quantity of work represented by the task;
- the number of resources assigned to the task;
- the number of hours worked per day/shift;
- the height or depth of work face;
- the working conditions, safety requirements;
- the logistics or access to work face;
- plant selection (e.g. turning radius, cycle times);
- weather patterns (e.g. wave patterns, high tide restrictions); and
- minimum 'wait' periods (e.g. concrete cure, drying, approvals).

There are other factors that influence the outputs assumed in determining task durations but there is no substitute for having experience and a track record in the same type of construction. Ideally that experience would be supported by past performance on previous projects constructed under similar circumstances. To arrive at a task duration, the total labour-hours required to complete a task must first be determined. The crew size working on that task must then be estimated to determine the 'available labour' so the duration can be estimated using the following simple equation:

$$\text{Task duration (days)} = \frac{\text{Required labour (hours)}}{\text{Available labour (hours/day)}}$$

Establishing the task duration from estimated quantities, assumed labour outputs, and assumed labour availability involves many assumptions. The champions of the CPM clearly understood the risks and uncertainty involved in stating precise durations against tasks. The project evaluation and review technique (PERT) is a probabilistic technique developed specifically to address these uncertainties and to estimate a 'most likely' project duration. PERT (discussed later in this chapter) is particularly effective on projects involving new methods of construction where there is little historic data available to assist in minimising the risks involved in estimating durations. PERT allows planners to estimate three potential durations for each activity (most likely, optimistic and pessimistic). Each of the potential durations is then assigned a probability of occurring, which in turn provides a planner with a range of possible project durations, rather than a single precise (and potentially inaccurate) completion date.

When preparing a construction, design or commissioning programme, it is important to remember that activity durations are the result of considered approximations at best, and wild guesses at worst. Plans and intentions change from time to time. Estimating durations is a task which should involve many disciplines so that the programme can benefit from the experience of the project team.

The success of the critical path method of programming depends on accurate task durations. Each person will estimate the time they believe it will take them to perform a task. If they are pessimistic by nature, that person will add an allowance to their estimate, based on personal experience performing or managing similar tasks. This will ensure that task durations are not systematically over-run. However, each person estimates different allowances. Traditional CPM programmes are based on 'deterministic' processes, because they only allow for one fixed planned duration for each task. The mathematical process of the forward and backward pass determines the start and finish date of each task and ultimately the duration of the project.

On the other hand stochastic, or random, processes deal with many possible outcomes of the same project by exploring different probabilities and likelihoods of the duration of each activity and, ultimately, how the project might evolve over time. Stochastic processes result in completion date probability distributions (how often each completion date is calculated) based on a random selection of the likelihoods and probabilities based on risk durations defined by the project team. Once the baseline is set, the process assists the project management team by identifying which outcomes are more probable than others. These stochastic systems recognise the uncertainty involved in estimating task durations and logical relationships and that the baseline as-planned programme represents just one possible outcome. Experience and intuition will allow the probabilities to establish which project durations, and activity paths are more likely to be critical than others. These stochastic processes have a place in research and development of programmes for processes with little historic empirical data, but are likely to have little relevance in forensic delay analysis.

When programmes are created by an individual with little experience of the particular type of work being planned, there is a risk that the durations will reflect this inexperience. Planners should ask many questions of the project participants and gather as much information as necessary before publishing a programme for construction or bidding purposes. The more information available to the project controls team regarding task duration, assumptions, resources requirements, cost allocation and scope the more effective they can be in managing change and the impact of unforeseen events affecting schedule performance.

2.3.2 Activity relationships

The second variable, 'activity relationships', is made up of either 'hard' logic (natural construction sequence) or 'soft' logic (preferential construction sequence). Assumptions made in the planning stage regarding the sequence

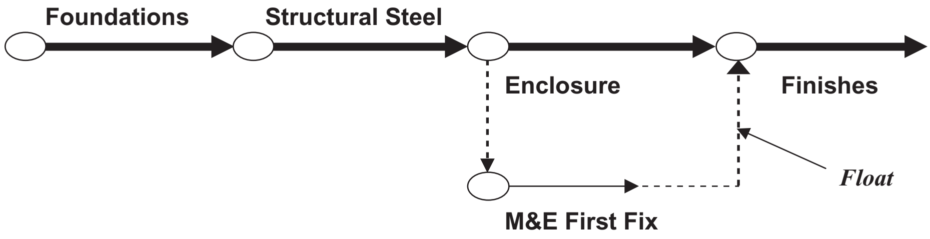

Figure 2.4 Activity-on-arrow technique diagram.

in which the work will be carried out, for example estimating task durations, require input from the project team and should be clearly recorded for future reference. While a contractor may change the programme's originally intended logic from time to time, inherent logic errors in the baseline programme are usually not discovered until they manifest into actual delay on site. Correcting inherent logical flaws is costly both in terms of time and money. When these corrections add time to the critical path, this critical delay is considered a contractor risk event, and under virtually all forms of contract will not provide entitlement to additional time.

CPM is a mathematical as well as graphical technique for determining the length of a project. It is a technique which also identifies the activities and constraints on the critical path. The two methods of developing logical relationships in CPM are: arrow diagramming method (ADM) and precedence diagramming method (PDM).

ADM is also referred to as 'activity-on-arrow' (AOA) or the 'I-J' method of logic diagramming, as illustrated in Figure 2.4.

Before the advent of powerful personal computers and colour graphics, AOA planning was the primary tool for developing CPM activity logic. The critical path was denoted by a bold (heavier) line weight. All relationships in an AOA network were 'finish to start', as defined by a unique number assigned to each node. Interpreting CPM schedules with I-J node designations was intuitive, and the logic and critical path were easy to ascertain. I-J node diagramming is an art form that is now consigned to the history books and, while some call for a return to I-J node diagramming software, a proposal supported by the authors, it is no longer a practice in use in today's construction industry. Indeed none of the major project management software packages support AOA network diagramming today.

The PDM, perfected in the early 1960s, uses the same basic mathematical model to determine the critical path. However, more variables have been added to the equation due to the flexibility of placing the event (activity) on the 'node' rather than the 'arrow'. In PDM programming, each 'node' is an activity, and arrows represent logical relationships between the activities. This method is also referred to as the activity on node (AON) diagramming technique. Rather than depicting the activity along the length of an arrow (as with

<table>
<tr><td>ACT</td><td>OD</td><td>RD</td><td>PCT</td></tr>
<tr><td colspan="4">DESCRIPTION</td></tr>
<tr><td colspan="2">ES</td><td colspan="2">EF</td></tr>
<tr><td colspan="2">LS</td><td colspan="2">LF</td></tr>
<tr><td>TF</td><td>FF</td><td colspan="2">CAL</td></tr>
</table>

Figure 2.5 Activity box.

the AOA technique), the activities are represented as 'boxes' with the information for each activity represented at each node, where relationship arrows commence and terminate. A typical activity box configuration is illustrated in Figure 2.5.

When using PDM diagramming, the tasks (or nodes) are illustrated large enough to include key task information, normally including the following data:

- **'ACT':** activity ID – a unique task reference number.
- **'OD' and 'RD':** activity duration – original and remaining duration.
- **'ES', 'EF', 'LS' and 'LF':** event dates – early start, early finish, late start, late finish. These are further defined as follows:
  - early start (ES): earliest date that a task can commence, based on preceding logic and duration of events;
  - early finish (EF): earliest date that a task can complete, based on its early start date and its own duration;
  - late start (LS): latest date on which the task can commence, without causing delay to the completion date (based on its own duration, and the duration and logic for all of the tasks which follow this task);
  - late finish (LF): latest date on which the task can complete, without causing delay to the completion date (based on the duration and logic for all of the tasks which follow this task).
- **'PCT':** percent complete.
- **'TF':** total float – the amount of time between the early start and early finish for each task (the amount of time the early start can 'slip' without causing delay to the project). Activities with zero total float are on the critical path.
- **'FF':** free float – the amount of time that an activity can be delayed without delaying any of its successor activities. When an activity has zero total float, its free float will also be zero. When an activity and its predecessor have the same amount of total float, its free float will be zero;
- **'CAL':** working-day calendar designation (e.g. 5 day week, 7 day week, 24 hour day).

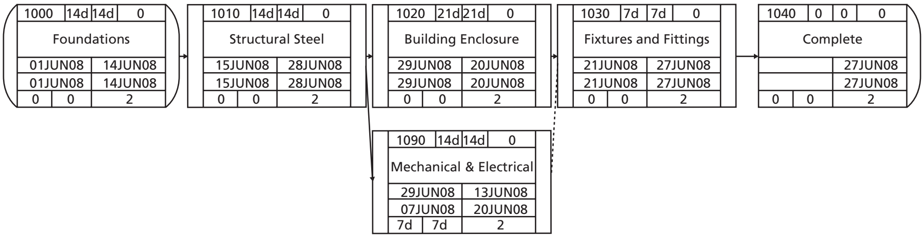

Figure 2.6 Precedence diagram method.

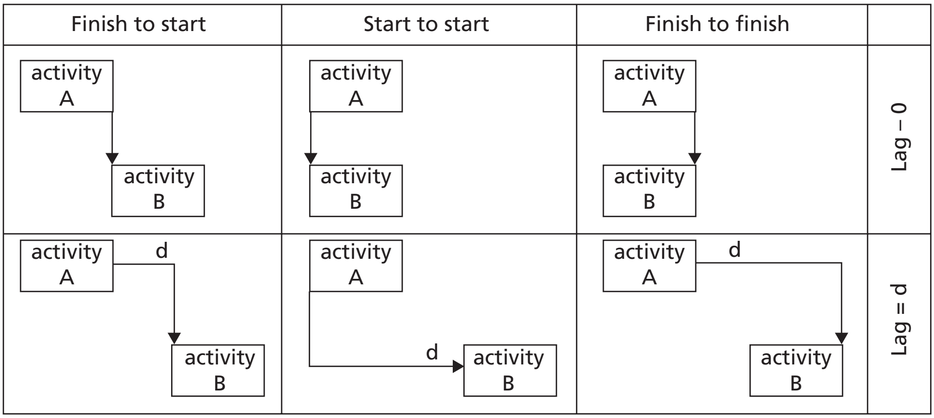

Figure 2.7 Logical relationships.

The same network as represented by the AOA technique in Figure 2.4 is shown in Figure 2.6 using the PDM and using the above activity box as a template.

In the PDM method of diagramming logical relationships there is more flexibility available to the planner to model the dependencies between activities. It is this flexibility which reduces the intuitive nature of determining the critical path and calculating the amount of float available to each task. Understanding these relationships is essential when using any of the commercially available CPM software applications. The available logical relationships as illustrated in the SCL Protocol are shown in Figure 2.7.

The logical relationships depicted in Figure 2.7 are explained as follows:

- **finish-to-start** – Task B cannot start until Task A has finished
- **finish-to-start with lag** – Task B cannot start until 'd' days have elapsed after Task A has finished
- **start-to-start** – Task B cannot start until Task A has started
- **finish-to-finish with lag** – Task B cannot finish until 'd' days have elapsed after Task A has finished.

The ‘d’ periods represented above are referred to as ‘lags’. The value of the lag ‘d’, can be positive (e.g. 5 days) or negative (e.g. –5 days). The latter are also termed negative lags. Programming software today allows planners to utilise ‘negative lags’, but there are few scenarios where negative lags are appropriate in a forward-looking, transparent process of project management. Accordingly it is recommended that the use of negative lags is avoided.

A primary purpose of using the CPM approach is to determine the total float value for each task. When the early start date is the same as the late start date for a task, total float equals zero, and that activity is deemed to be ‘critical’. When the early start date is later than the late start date for a task, that task is behind schedule (i.e. total float is negative). If an activity has already commenced (i.e. it has an ‘actual start date’) the same logic described above holds true for the early finish date and the late finish date. Therefore, if the early finish date is the same as the late finish date for a task, total float equals zero, and that activity is deemed to be ‘critical’. Float is a relative value and is indicative of which activities are more critical than others. Float is influenced by many factors, including the work-day calendar assigned to a task, date restraints, zero total float constraints and other hidden settings in programming software which influence and alter the calculation of float in updated CPM programmes. (These aspects of float are discussed further in Chapter 5.) Float values, and slippage from month to month, may not relate to day for day losses to the completion date. The longest path, and most critical path, should be analysed each month along with actual absolute slippage to the project completion date, calculated in calendar days. Sample calculations for event times and float values are described in detail below.

The arrow diagramming technique (and I-J node numbering system) is unfortunately no longer supported by modern project management software. Accordingly the use of lags and multiple combinations of the above relationships have made calculating network critical paths by hand more difficult and less intuitive. The working product of the diagramming techniques described is usually depicted as a bar chart, where negative lags and positive lags will not be readily apparent (see Figure 2.8).

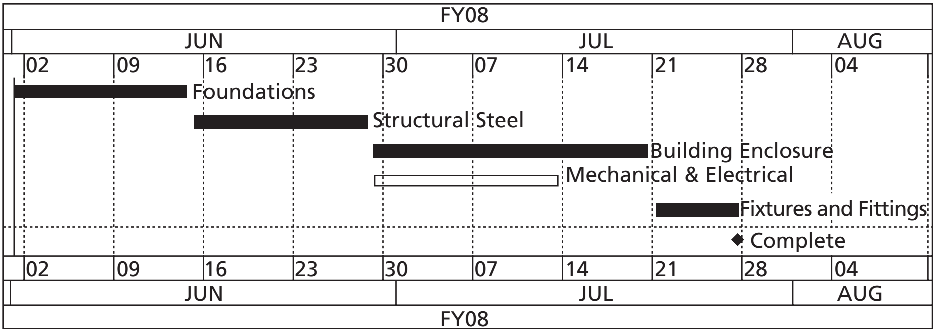

Figure 2.8 Bar chart.

When preparing a baseline, it is recommended that an 'activity data sheet' is created to document relevant assumptions made when establishing the activity duration and logic, including:

- Relevant specifications and drawings
- Assumed quantities
- Duration calculations
- Calendar assignments
- Time risk allowances
- Assumed production/outputs
- Assumed resource allocation
- Assumed cost allocations
- Successor activities
- Applicable completion date, key date or milestones

Any changes to these assumptions can then be logged on the data-sheet as an historic record. When this data is available it is possible to reconcile the as-planned and as-built programmes, and explain deviations in as-built logic, out of sequence work and durations. It is also possible to keep this information in user defined text fields linked to each activity so that alterations, and the reason for any alterations, can be documented contemporaneously.

Baseline task sheets have a secondary value in that they are invaluable to a forensic programming analyst when seeking to understand the cause of duration over-runs along the critical path of a project. They are also a useful reference source when identifying and negotiating time extension requests during the course of a project. These sheets document a number of factors including changes in logic, use of any time risk allowance set aside for individual tasks, changes in durations due to known delays, and any changes to the underlying assumptions used to determine the 'original duration' of the task. These can take any form, from a simple handwritten page in a file, to a relational database, linked to CAD drawings, payment and cost data, and estimating software.

If these sheets are managed in a live project and used as a tool to monitor fluctuations in the work content of a task, cost, resource allocation and deterioration of float along sub-critical paths, a dispute regarding extension of time entitlement is unlikely simply because of the transparency of cause and effect that these sheets would provide.

2.3.3 Event date calculations

Once the tasks and their durations have been identified and the logical relationships between them is established, the time required to achieve project completion (and each task's early and late start and finish date) can be determined by simple mathematical calculations.

As described above, the event times associated with each task are: early start (ES), early finish (EF), late start (LS), and late finish (LF).These are established through what is referred to as the ‘forward pass’ and ‘backward pass’. The forward pass through the network determines the ES and EF for each task, along with the networks completion date (shortest path to completion). Based on the calculated completion date, the backward pass through the network then determines each task’s LS and LF event time. For consistency, these calculations are based on one of two approaches, depending on the software settings:

- Option 1 – each task commences in the morning (00:00 Midnight) of the respective start date (ES or LS) and completes at the end of the day (23:59 p.m.) for each respective finish date (EF or LF). Using this option, EF = ES + D – 1.
- Option 2 – each task commences in the evening (e.g. 5:01 p.m.) of the previous work day and finishes in the evening (e.g. 5:00 p.m.) of the following work day. Using this option EF = ES + D.

When software uses Option 1 for calculating event times a task with one day duration will start and finish on the same calendar day. When Option 2 is applied, the same task will start on one calendar day, and finish on the next. So long as the above approaches are applied consistently, the event times will be correct and the overall project duration will be the same. A planner should be able to calculate the early and late dates for tasks manually; and the personal computer is simply an extension to allow the calculation of hundreds or thousands of tasks much more quickly. If the planner is not familiar with manual event time calculations he will not be able to identify inconsistencies, flaws or mistakes in the logic, which may result in inherent flaws in the as-planned programme.

The programmer responsible for the management of the CPM programme should be well versed in how early and late event times are calculated. Calculating event times for an as-planned programme is straightforward. However, most commercially available planning software allows programmers to update the baseline at frequent intervals and document differences (deviations) from the planned programme. This requires the use of personal computers to perform these tasks effectively and quickly. The use of personal computers also allows the programmer to perform numerous ‘what if’ calculations quickly and efficiently to determine the likely impact of an event, or to evaluate whether a potential variation or change order will have a negative effect on a contractor’s ability to achieve a planned or revised completion date.

The ultimate purpose of a CPM programme is to determine event dates, and float values for each task on the programme. Total float is the most common float value referred to, but there are actually four types of float a project planner should be familiar with when analysing CPM programmes. These are:

- Total float – the amount of time by which a task may be delayed or lengthened without impacting upon the calculated earliest finish of the project completion date [ES – LS, or EF – LF].
- Free float – the amount of time which a task may be delayed or lengthened without impacting upon the early start date of any of its successor activities.
- Independent float – the amount of time which a task may be lengthened or delayed without impacting upon the early start date of any of its successors nor impacting the latest start time of any of its predecessors.
- Interfering float – the amount of time that, if expended, would decrease the float available to its successors.

Each of these ‘float times’ are clearly related and basically indicate how much flexibility, or contingency, each task has. In all cases, total float will always equal or exceed free float, while independent float will always be less than or equal to free float. Further detailed definitions, together with problems arising in connection with float are contained in Chapter 5. The PDM diagram in Figure 2.9 will be used to demonstrate how to perform both forward and backward pass calculations and, ultimately, determine the critical path. This is a simple network representing the scope of a concrete package involving the excavation and placement of concrete for perimeter footings and grade beams. The same network activity box configuration will be used as presented in the previous section for PDM diagrams (Figure 2.5) and, as provided below, the network in Figure 2.9, the early start, early finish, late start, late finish, total float and free float have not yet been determined. All of the relationships are dashed lines, indicating that none of them are ‘driving’ at the moment. Driving relationships are those which determine the start of the successor activity. These are important in tracing the critical path when a critical activity has more than one successor.

2.3.4 Forward pass

Early start dates are determined from the ‘forward pass.’ This is the pass which works its way from beginning to end, ‘forward’ through the programme. For consistency the forward pass must comply with the following rules:

- Day 0 is the earliest start date for the first task;
- the EF of a task is equal to the ES of that activity plus its own duration;
- the ES of any succeeding activity is the EF of the predecessor activity plus one calendar day;
- when an activity has more than one predecessor, the ES of that successor activity is equal to the largest EF date of all of its predecessors;

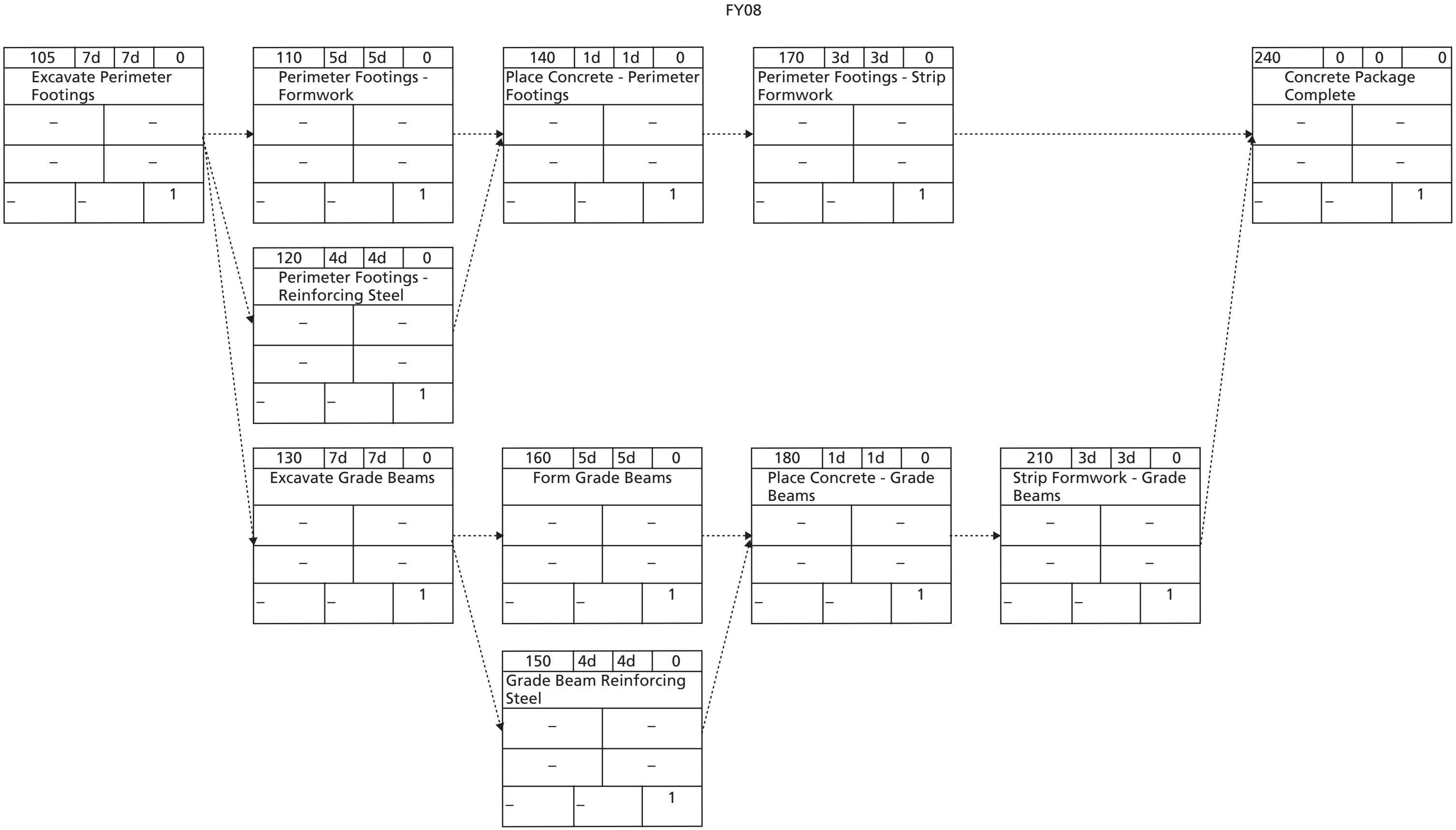

Figure 2.9 PDM diagram.

- the LF of a predecessor activity (as determined by the backward pass) is equal to the smaller of the LS for all of its successor activities minus 1 calendar day; and
- TF is equal to either LF – LS, or EF – EF.

Starting with the first activity in the programme, its early start time is equal to the start date or (T = 0 days). The same activity's early finish date is equal to its early start plus its original duration, less one day. To illustrate this, the first activity (Act 105) on the above programme in Figure 2.9 will be used, along with its successors (Activities 110, 120, and 130). The example project is assumed to commence on 1 June 2008. This date will be used to calculate the early and late event times for the activities in the network. A seven day calendar is assumed for ease in illustrating the manual calculations.

The early start of Activity 105 'Excavate Perimeter Footings' is 01-Jun-08. The early finish date of this activity is equal to its early start plus duration (i.e. 01-Jun-08 + 7 days – 1) which results in an early finish of 07-Jun-08. Each of Activity 105's successors has an early start date of 08-Jun-08 (Activity 105's EF + 1). Then each of the successor activities early finish dates are established using the same formula as for Activity 105. This is illustrated in Figure 2.10.

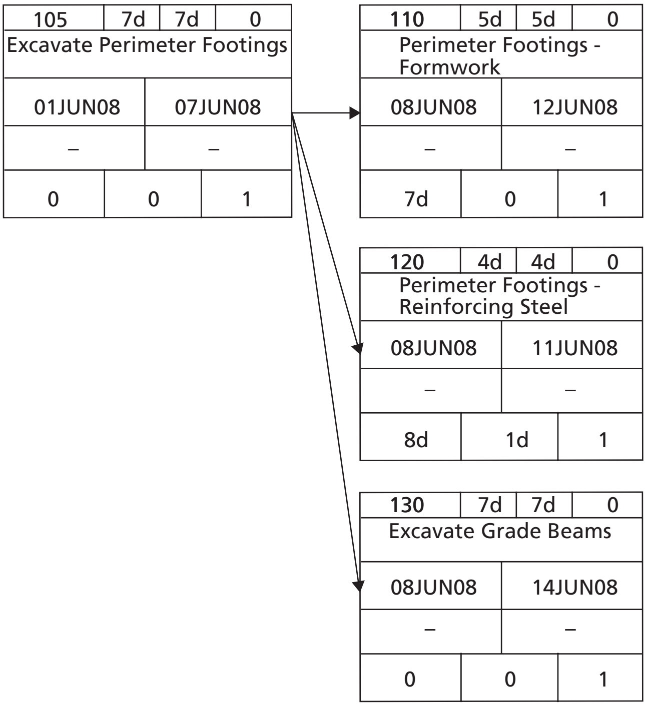

Figure 2.10 Example of a network calculation.

This process continues through the network until every path has been followed. When two competing paths of activities share a successor activity, the path with the latest 'early start date' must prevail. The fully completed forward pass for the above network is represented in Figure 2.11. Driving relationships can now be identified, by the predecessors that determined the early start date of each task on the network.

What happens where an activity has two predecessor tasks? In Figure 2.11 Activity 140, 'Place Concrete – Perimeter Footings' is such an activity. When this occurs, its early start date is derived from the predecessor with the latest early finish completion date, which is Activity 110. The forward pass determines the earliest the project can complete, as well as the earliest each task can start, based on the completion of its latest predecessor activity. The 'earliest' Activity 140, 'Place Concrete – Perimeter Footings' can start is 13 June 2008; the day after Activity 110, 'Perimeter Footings – Formwork' is complete. The diagram in Figure 2.11 is fully populated to assist in understanding the mathematical calculations of the forward pass. We cannot determine the critical path until we complete the 'backward pass'.

2.3.5 Backward pass

The 'backward pass' is a similar exercise to the forward pass. The difference is that on the backward pass, the last activity in the project is the starting point and we work backwards to the first activity. Starting with Activity 240 'Concrete Package Complete' which has an early finish date of 23 June 2008; work backwards, determining the 'latest' each task can complete, without impacting the overall project completion date of 23 June 2008.

Working backwards from Activity 240 we see that it has two predecessors, Activity 170, and Activity 210. Based on the fact that Activity 240 has zero duration, the late finish of both of its predecessors is equal to 23 June 2008. The late start of Activity 170 is equal to its late finish, less its duration, plus 1. This is because the duration is inclusive of the late finish date. Activity 170 therefore has a late start date of 21 June 2008 (23 June 08 – 3 + 1). Activity 210 also has a late start date of 21 June 2008. These calculations are illustrated in Figure 2.12.

To demonstrate the calculation of a predecessor's late finish date for a task, rather than a finish milestone, the predecessor for activity, Activity 180 is also illustrated in Figure 2.12 as a predecessor to Activity 210. The late finish for Activity 180 is 20 June 2008, which is equal to its successor's late start, less one day (applying Option 1 as set out in the previous section). Activity 180's late start date is equal to 20 June 2008, less 1 day duration, plus 1 day, or 20 June 2008. This one day activity starts and finishes on the same day.

See Figure 2.13 for a completed forward and backward pass network diagram.

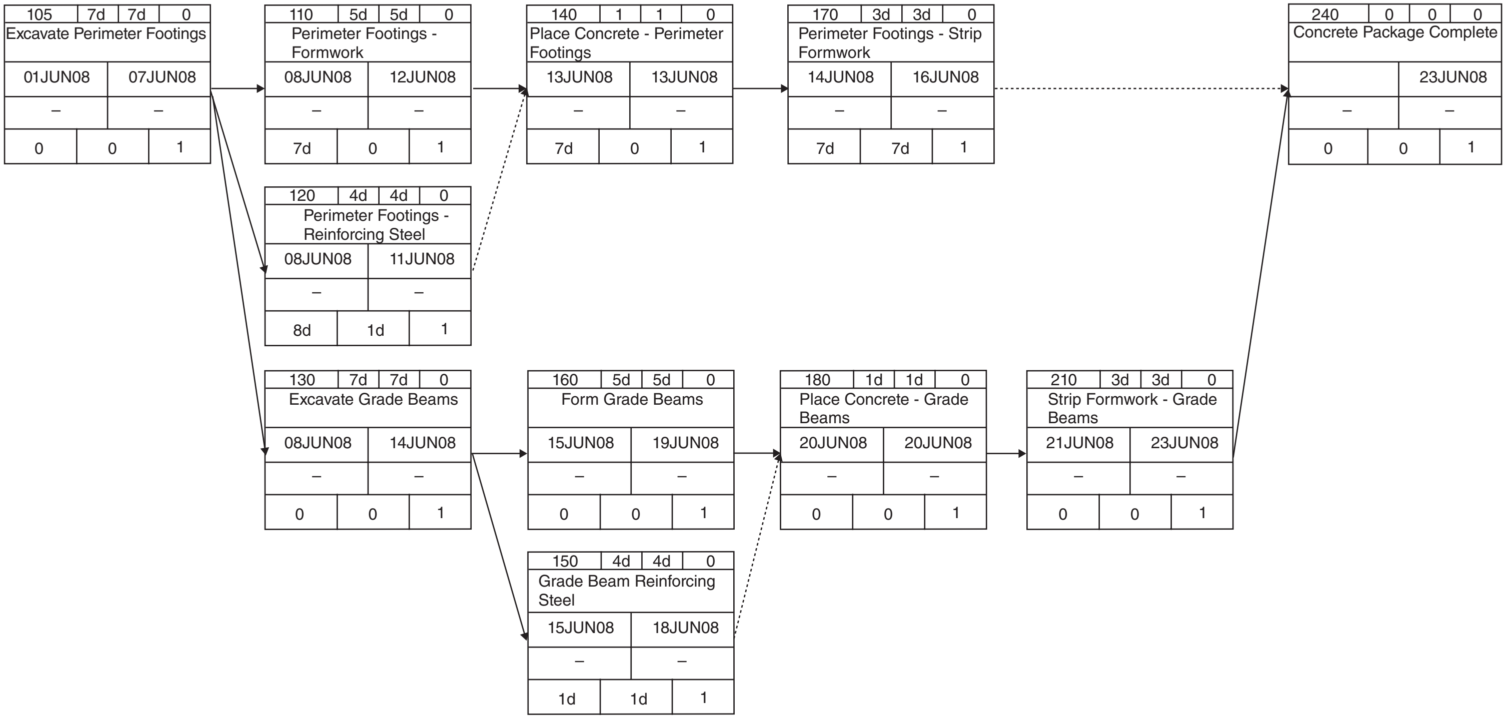

Figure 2.11 Completed forward pass.

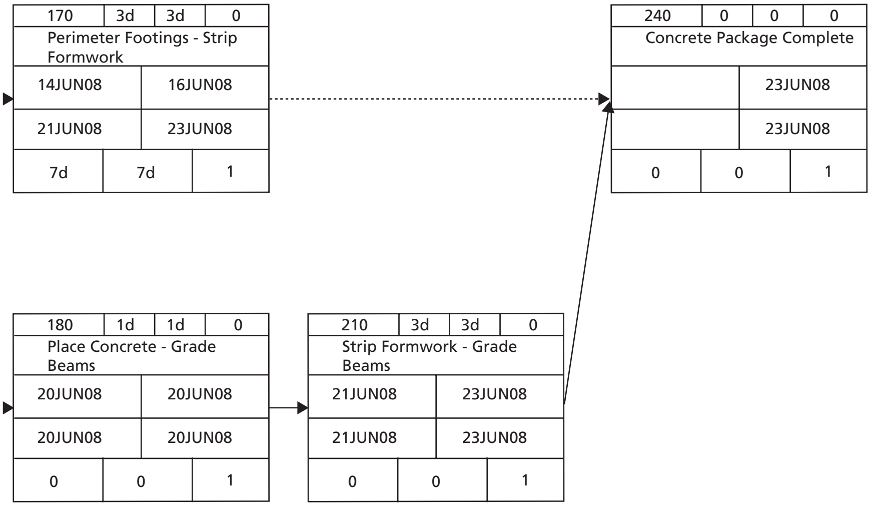

Figure 2.12 Completed backward pass.

2.3.6 Total float

Calculating the early and late event dates are necessary before the critical path can be determined. The critical path is simply those activities with the same late finish and early finish (or late start and early start). These activities cannot slip without causing delay to the completion date. Free float is the relative measure of an activity to its successor's total float. Activity 140 in Figure 2.13 has a total float of 7 days, but a free float of 0 days. This is because if Activity 140 slipped by 1 day, it would decrease the amount of float available to its successor activity, which also has 7 days of total float. All of our sample network activities and event date calculations are listed in Table 2.1, with the critical path indicated in bold font.

Total float (TF) is the amount of time that the start or finish of a task can be delayed without extending the project's overall duration, or delaying the completion of the project's final activity. Total float is equal to the difference between each task's LF and its EF (or its LS and ES). In a baseline programme, or unconstrained updated progressed programme, the total float is equal to zero. These activities are critical and make up the critical path.

2.3.7 Constraints

A final consideration when calculating earliest start and finish dates may be the imposition of a date constraint to certain tasks. These are the tasks which must be constrained for various valid reasons, some of which are listed below:

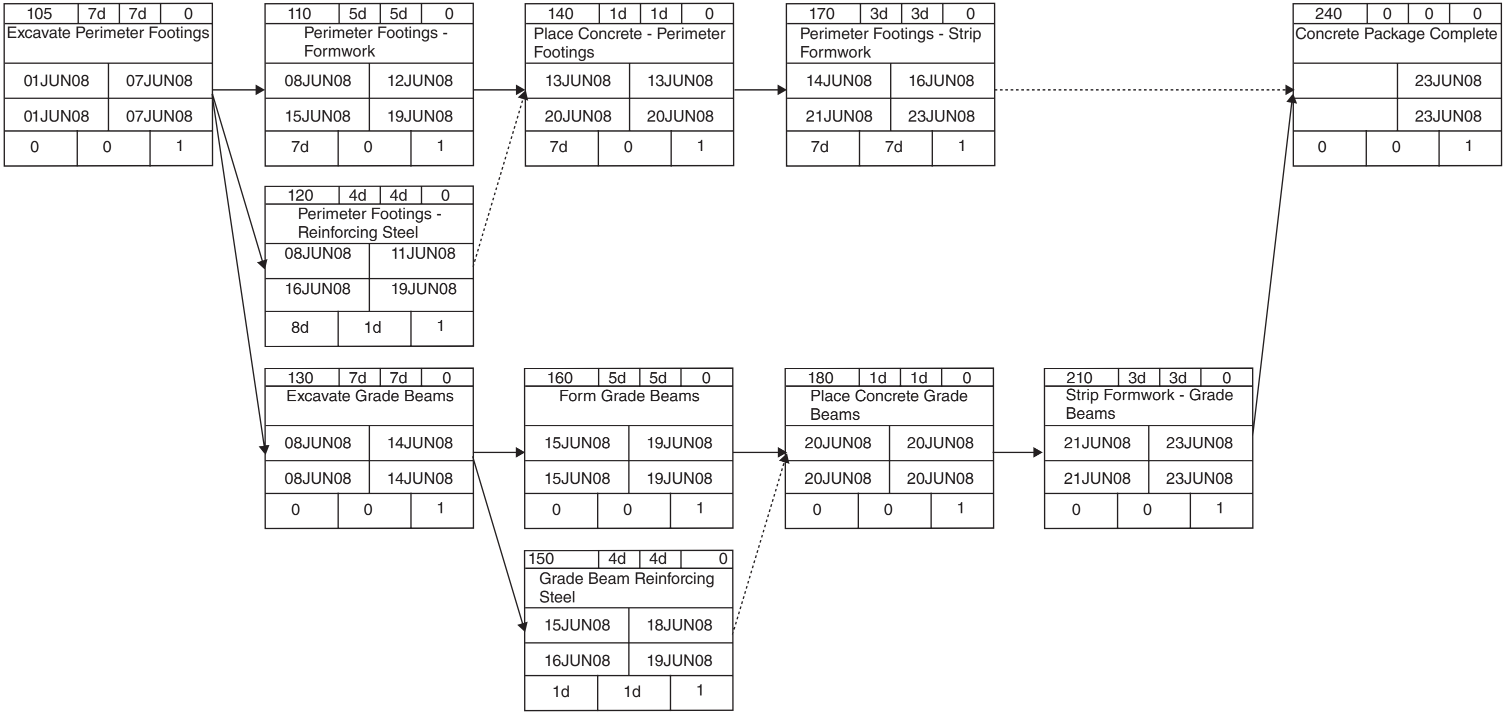

Figure 2.13 Completed forward and backward pass.

Table 2.1 Completed forward and backward pass calculation table.

Act ID	Description	Orig Dur	Early Start	Early Finish	Late Start	Late Finish	Total Float	Free Float
105	**Excavate Perimeter Footings**	**7d**	**1-Jun-08**	**7-Jun-08**	**1-Jun-08**	**7-Jun-08**	**0**	**0**
110	Perimeter Footings – Formwork	5d	8-Jun-08	12-Jun-08	15-Jun-08	19-Jun-08	7d	0
120	Perimeter Footings – Reinforcing Steel	4d	8-Jun-08	11-Jun-08	16-Jun-08	19-Jun-08	8d	1d
130	**Excavate Grade Beams**	**7d**	**8-Jun-08**	**14-Jun-08**	**8-Jun-08**	**14-Jun-08**	**0**	**0**
140	Place Concrete – Perimeter Footings	1d	13-Jun-08	13-Jun-08	20-Jun-08	20-Jun-08	7d	0
170	Perimeter Footings – Strip Formwork	3d	14-Jun-08	16-Jun-08	21-Jun-08	23-Jun-08	7d	7d
150	Grade Beam Reinforcing Steel	4d	15-Jun-08	18-Jun-08	16-Jun-08	19-Jun-08	1d	1d
160	**Form Grade Beams**	**5d**	**15-Jun-08**	**19-Jun-08**	**15-Jun-08**	**19-Jun-08**	**0**	**0**
180	**Place Concrete – Grade Beams**	**1d**	**20-Jun-08**	**20-Jun-08**	**20-Jun-08**	**20-Jun-08**	**0**	**0**
210	**Strip Formwork – Grade Beams**	**3d**	**21-Jun-08**	**23-Jun-08**	**21-Jun-08**	**23-Jun-08**	**0**	**0**
240	**Concrete Package Complete**	**0**		**23-Jun-08**		**23-Jun-08**	**0**	**0**

- to represent interim contractual milestone dates;
- to represent when access to a certain part of the site may be provided;
- to represent when a long lead item is expected from a manufacturer;
- to represent when employer furnished equipment will be available; or
- to represent when staff will be migrating into or out of certain parts of the works.

There are many valued uses of constraints, but they are not a substitute for logical relationships to determine early and late start event times for each task. Over-use of constraints prevents the project network from calculating auditable or sensible critical paths to completion.

There are six primary types of date constraints:

- start-on date;
- start-no-earlier than;
- start-no-later than;
- finish-on date;
- finish-no-earlier-than; and
- finish-no-later-than.

Each of these affects the programme, and task float calculations, differently. The constraint ‘start/finish-no-earlier-than’ affects only the early date (the forward pass) calculations. The constraint ‘start/finish-no-later-than’ only affects the late date calculations (backward pass). The ‘start/finish on’ constraint is a combination of ‘no-earlier-than’ and ‘no-later-than’ constraints and over-rides both the early and late date calculation. These, and other constraints, provide useful functions in programming but their over-use is an indication of ‘lazy logic’ and should not be a substitute for actual network logic to determine early and late event times for activities.

Other forms of constraints allowed by various programming software is set out in Table 2.2.

2.4 Baseline validation

2.4.1 Joint Baseline Review

When all of the tasks are assembled, the task sheets are prepared (which document the assumptions behind the duration and logic underlying each task), the critical path identified and a draft programme is ready for review, it is common for a Joint Baseline Review (JBR) workshop to take place. These may be formal or informal meetings involving designers, estimators, engineers, contract administrators, the client, contractors, the project/construction manager and quantity surveying staff. These JBR workshops address any assumptions and constraints which may have been considered by the

Table 2.2 Constraint forms.

Constraint	Usage
Start on	Forces the activity to start on the constraint date
Start on or after	Use this constraint to set the earliest date an activity can begin
Start on or before	Forces the activity to start no later than the constraint date
Finish on	Forces the activity to finish on the constraint date
Finish on or after	Forces the activity to finish no earlier than the constraint date
Finish on or before	Use this constraint to set intermediate completion points in the project
Must be finished by	Use when an overall project deadline must be met
As late as possible	Delays an activity as late as possible without delaying its successors
Mandatory start and finish	Forces early and late dates to be equal to the constraint date
Zero Total Float Constraint	This forces an activity to have the same early dates and late dates, and forces the total float of the activity to be equal to zero. This is the simplest method to sequester available float to an activity.

programming staff. The typical items reviewed at these workshops are listed in Figure 2.14.

2.4.2 Programme approval

Finally, when all of these factors have been considered by the project management team, a draft CPM programme can be circulated for final review by the contractor's in-house staff. This programme should be accompanied by verification that all subcontractors have participated in its development and are fully aware of the statement of intent expressed in the as-planned programme. The final review and input from in-house staff provide a last chance to ensure that the resulting programme is contractually compliant and allows the works to be constructed within the tender sum. This final, internal review will often consider:

- the final means and methods of construction to ensure that method statements for key tasks are in accordance with the final CPM before it is submitted for approval;
- the resulting 'critical path' to ensure that it is logical and consistent with intuition and the experience of the contractor's senior staff;

- Plant selection, e.g. availability, restrictions, sizing/capacity, cranes, bucket-size, and tipper truck cycle time
- Labour composition, e.g. local union requirements, actual crew composition intended, skilled tradesmen availability, resource levelling to avoid discontinuity of work, number of tradesman and subcontractors
- Weather conditions, e.g. known historical weather patterns, high/low tidal flow periods, weather sensitive tasks, delivery restrictions (river crossings/temporary road maintenance)
- Site layout/location, e.g. delivery restrictions or difficulties, skilled labour availability, lay-down, storage and material handling logistics, safety and security logistics, drying sheds, cafeteria and toilet locations, quantity of temporary site office accommodation and parking required on/near site, temporary services
- Supply chain factors – opportunities or risks in the procurement of certain products (structural steel, concrete, timber) or services (specialist designers/consultants)
- Staff migration – when refurbishing or extending hospitals, schools and most government buildings, minimising disruption to any operational areas and moving existing staff to temporary accommodation are fundamental to the perception of the ultimate end user as to how well managed, and well planned, the project is
- Risks and opportunities within each project assumption
- Constraints dictating by when certain activities must commence (start no later than), or dates which they cannot commence before (start no earlier than)
- Constraints dictating by when certain activities must finish (finish no later than), or dates which they cannot finish before (finish no earlier than)
- Constraints dictating when certain activities must commence (start on)
- Preferential (soft logic) and required (hard logic) relationship assumptions

Figure 2.14 Planning factors for consideration at a Joint Baseline Review.

- the programme level of detail and coding to ensure that it is consistent and relevant to the project controls systems, WBS and cost coding structure, and that all tasks have budgeted costs, and resources; and
- each task to ensure that it has a clear 'owner', whether that be a subcontractor or an individual sector manager.

It is often a requirement that the contractor must obtain express buy-in to the programme from major subcontractors or suppliers of primary building elements or specialty equipment. This is important to ensure that each team member understands and is able to comment upon the CPM programme printout from time to time. Representing the tasks, descriptions, coding, calendar assignments and logical relationships in a clear and understandable way is vital. A construction programme should be prepared with discipline and diligence. It should be able to recalculate critical paths, along with revised start and finish dates for each task, and must be able to predict reliable project completion dates from time to time. When major changes to logic, durations or scope are introduced into a programme those changes should be clearly documented and a new 'baseline' should be agreed for all remaining work.

Baselines are not affected by actual progress, only changed intentions for completing the remaining works. Actual progress should be capable of being easily compared to the baseline programme upon which that progress was measured. When a new baseline is agreed, all deviations from the original baseline should be well documented and, under many forms of contract, require the employer's representative or contract administrator's express approval. Approvals of programmes are discussed in more detail in Chapter 5.

This ensures the effort involved in preparing and approving the original baseline is not wasted effort, and that the programme remains a transparent, forward-looking and relevant document which is used to assist in the management of the project, rather than simply reporting progress. Before commencing the update cycle of the baseline for the first time, the baseline needs to be well documented and communicated. The updating cycle is discussed in more detail later in this chapter.

Most forms of contract require a project baseline programme to be submitted prior to commencement, approved by the contract administrator, and to be updated on a regular basis. Many contract forms define the frequency of the updated cycle (usually tied to the payment cycle) and make provisions for a revised 'baseline programme' to be submitted following instructed changes or culpable delays which are likely to have an impact on the projected completion date.

The SCL Protocol provides a 'Model Specification Clause' for the preparation and management of CPM programmes on traditional construction projects. The SCL states:

> 'The following model clause has been drafted to be included in the specification section of a project's tender documents. The requirements are intended to be suitable for large complex projects. However, the principles of the requirements represent good practice and should be applied to smaller projects where practicable. The words in the model clause will need to be reviewed and amended to ensure that the terms and terminology used are consistent with the conditions of contract and/or agreement for the project'[2]

For an actual programming specification clause, used successfully on a £100 m project in the UK in 1997, which was enforced, complied with, and contributed to a project being finished on-time, see Appendix (p. 259). Both this clause and the Model Specification Clause as provided in Appendix B to the SCL Protocol are pragmatic and logical, and would be just as effective today on an NEC3 project over 10 years later.

2.4.3 The project baseline

Once the project programme is prepared and the project needs are estimated, the original programme is saved as a 'baseline' programme. A baseline programme allows the plan to be communicated to all parties. This is referred to in the following chapters as the 'as-planned programme' (APP).

Various methods are available for representing the resulting network and to assist in how the above process results in a useful tool for managing the works.

2.5 Other planning techniques

While the critical path method of programming is the most widely used planning method in the construction industry today, there are a number of other techniques and methodologies available for use in the preparation of construction programmes. A list of some of these planning techniques is contained in Table 2.3.

Table 2.3 Planning tools and techniques.

- Arrow diagrams
- Bar chart, or Gantt charts
- Critical Chain Method (CCPM)
- Cascade diagrams
- Critical Path Analysis (CPA)
- Histograms
- Linear or time-chainage
- Line-of-balance
- Mass haul diagrams
- Milestone charts
- Network analysis
- Precedence diagrams
- Programme Evaluation and Review Technique (PERT)
- Scatter diagrams
- Theory of constraints

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[2] Appendix N of the SCL Protocol which can be downloaded from www.eotprotocol.com.

Most planning techniques represent work operations in terms of time scale. However, the facility exists also to include resources and costs. The addition of resources and costs will increase the scope for management and control, but requires more input and expertise at the planning stage. Other specialist methods of representing time–location or production include 'assembly line balancing' and 'mass haul diagrams'. A number of the more frequently used techniques are discussed briefly below.

2.5.1 PERT – Project Evaluation and Review Technique

PERT is a project management technique which schedules, organises, and coordinates event tasks within a project. PERT was developed by the US Navy in the 1950s to manage the Polaris submarine missile programme. A similar methodology, the CPM, was developed for project management in the private sector at about the same time. Some key features of a PERT network are:

- events must take place in a logical order;
- activities represent the time and the work it takes to get from one event to another;
- no single event can be considered to be finished until all activities leading to the event are completed; and
- no activity may be completed until the event preceding it has been finished.

A PERT programme is also commonly referred to as 'Quantitative Risk Analysis' (QRA) when carrying out one-off risk assessments to determine project contingencies and likelihood of success or failure of large capital expenditures. When applying PERT calculations one applies the same approach as CPM, with the exception that the planner calculates three possible durations for each task, the 'most likely', 'pessimistic', and 'optimistic' durations:

- **Most Likely Time** – the best estimate of the time period in which the activity can be accomplished. (This is the equivalent duration which would be used in traditional CPM calculations.)
- **Optimistic Time** – the minimum time period in which the task can be accomplished, i.e. the time it would take to complete the task if everything proceeded better than expected.
- **Pessimistic Time** – the maximum time period it would take to accomplish the task.

Firstly, a planner should assume the work will be done within the industry norm, for example, with a standard crew size, no overtime and in ideal conditions. This duration is the 'most likely' duration. The planner then makes aggressive and conservative duration assessments, referred to as 'optimistic'

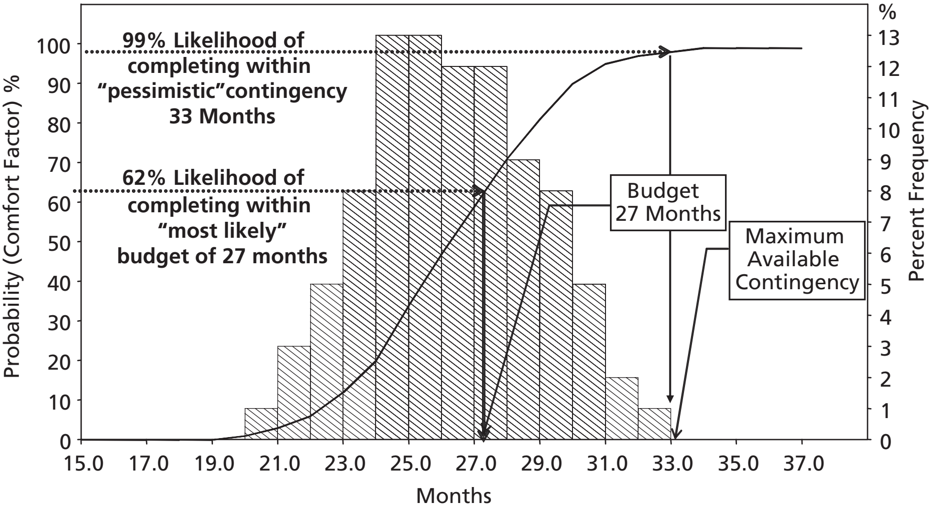


Figure 2.15 Frequency distribution curves.

and 'pessimistic' durations respectively. These three durations form the basis for a 'three point estimate' for each activity, arriving at an optimistic, most likely and pessimistic overall completion.

Due to the inherent uncertainty in calculating (estimating) accurate task durations there are many who believe that probability needs to be added to the equation (i.e. the probability that the task will be carried out in line with its optimistic, pessimistic or most likely durations). The resulting approach using these additional variables is referred to as a 'probabilistic critical path management' technique. When applied in conjunction with PERT or CPM frequency distribution curves it can be utilised to determine the likelihood of a project being completed within a given overall duration. This is illustrated in Figure 2.15.

Cumulative probability and frequency profiles are useful products of quantitative risk analysis using PERT methodology. Depending on the employer's appetite for risk, 62% likelihood of completing on time may not be sufficient and action may be required to increase the likelihood of completing within the available time frame. CPM schedules can facilitate and encourage decision making but decisions must be made by a project team that is fully conversant with the schedule and participated in its creation. Going through the process of developing the tasks, their logical relationships, durations and evaluating the reasonableness of the critical path assists the project management team in using the CPM as a tool for managing the works, rather than using it solely as a retrospective reporting tool. Additionally, managing a project by means of simply monitoring the critical path is insufficient. All of the tasks on a programme are estimates and each one could potentially become critical if the planned duration and float values are exceeded. The project team must be aware of the resources and conditions under which the work was planned to be performed, and the actual condition of the project and availability of resources at the time of performance. Managing these variables, in addition to watching the programme deviations, is the key to ensuring timely completion.

2.5.2 Gantt charts (bar charts)

A Gantt chart is a horizontal bar chart that displays the duration and intended sequence of the tasks represented. Gantt charts have been around since the early 1900s and are frequently used in business to scope projects. The chart is named after its inventor, Henry Laurence Gantt, an American engineer and social scientist. He is also noted for his ‘humanising’ influence on production management and increasing efficiency in the work-force where he emphasised the need for working conditions which had a favourable psychological effect on the workers. The Gantt chart is the most widely used method of illustrating project sequences and plans and is still relevant today.

Gantt charts provide a method for determining the broad sequence and particular actions which need to be taken to achieve a given objective. However, they provide little assistance in calculating early or late event times, and are not able to determine the impact of delays or the critical path through the events. Only with logical relationships between the tasks can these be identified. A Gantt chart with logical relationships is also known as a ‘time scaled logic diagram’. In its basic form the Gantt chart is simply a time phased task diagram (see Figure 2.16).

However, more sophisticated Gantt chart techniques are available, to demonstrate actual progress achieved, and estimated delays to completion (see Figure 2.17).

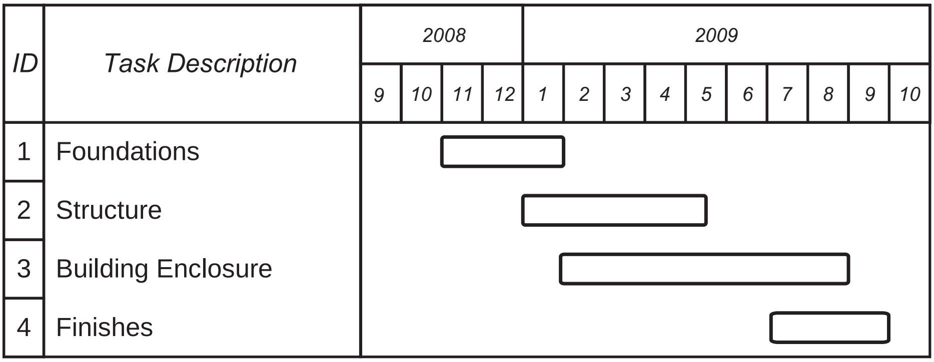


Figure 2.16 Basic Gantt chart.

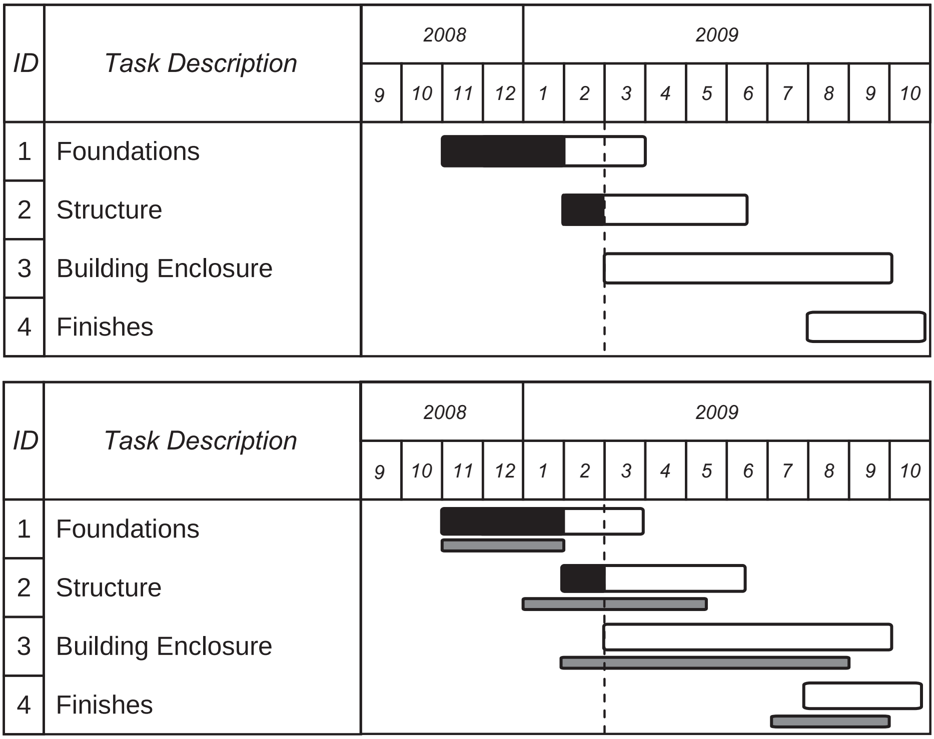


Figure 2.17 Progressed Gantt chart and Gantt chart with target bars.

The problem with (non-CPM) bar charts is that they are incapable of showing logical relationships or demonstrating the impact of changes or delays. They do not indicate which activities are critical from time to time. Unless work proceeds in the exact sequence as-planned, it is difficult to determine overall project status unless proper CPM techniques are applied. Gantt charts are, however, sufficient on projects with few activities which can be managed intuitively.

The Gantt chart is useful in representing task durations as well as start and finish dates. Nevertheless, without the corresponding logic, these fail to allow the planner to determine which activities are critical to completion or predict the impact of a change to events; neither do they measure actual against planned performance other than by simple observational techniques.

2.5.3 Line of balance

The line of balance programming technique is appropriate when a project consists of repetitive tasks which are required to be carried out at numerous locations. These can be undertaken at any location, but in a pre-defined

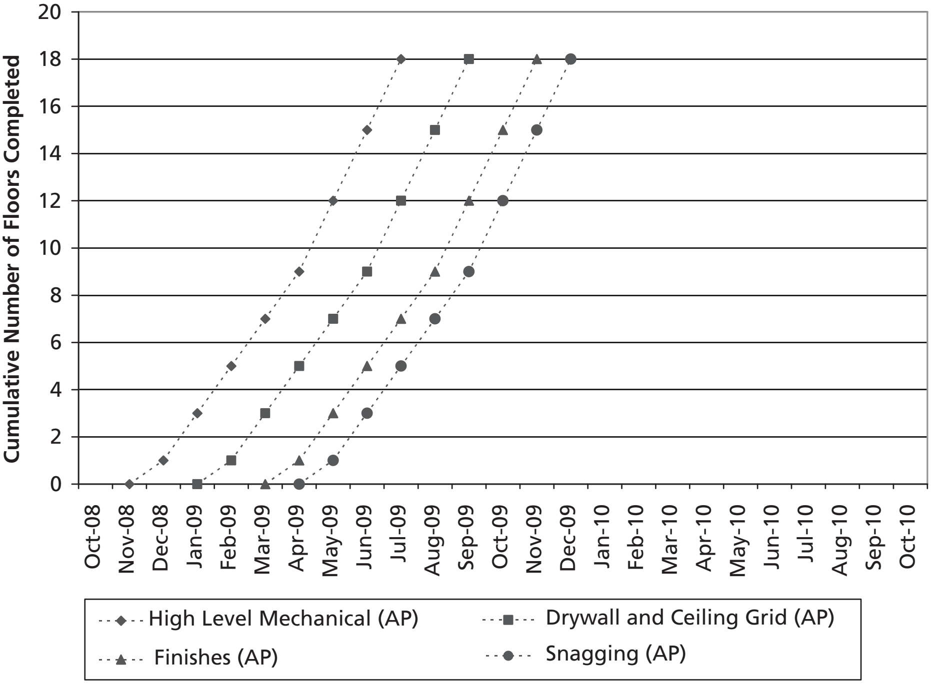


Figure 2.18 Line of balance chart. As-planned – internal trades.

sequence at each location. Line of balance charts are typically used on projects where repetitive, resource constrained sequences can be diagrammed on a cumulative basis, including housing, pipelines, bridges, roads, rail and tunnelling works. When combined with traditional CPM programming techniques, the line of balance chart is easily adaptable to internal finishes, mechanical and electrical installations – anything repetitive and at different locations.

The chart in Figure 2.18 was developed to demonstrate the relationship between sequential tasks in a traditional high-rise building where multiple trades must follow one another floor to floor up (or down) through each subsequent floor for 18 repetitive floors. When the sequence of operations is altered, the work can still be monitored against progressive cumulative completion of floors.

When used to assist forensic delay analysis the line of balance curves are a useful tool for quickly ascertaining which trade was in effect slowing down or causing delay to subsequent trades. For example, see an as-planned versus as-built diagram (Figure 2.19) for the four tasks illustrated above.

The illustration clearly indicates an initial delay to commencement, and then various periods when follow-on trades did not keep pace with their predecessors. A line of balance analysis will not in itself provide adequate proof for determining periods of excusable, inexcusable, compensable or non-compensable delay but, by isolating delays to individual trades, it will be

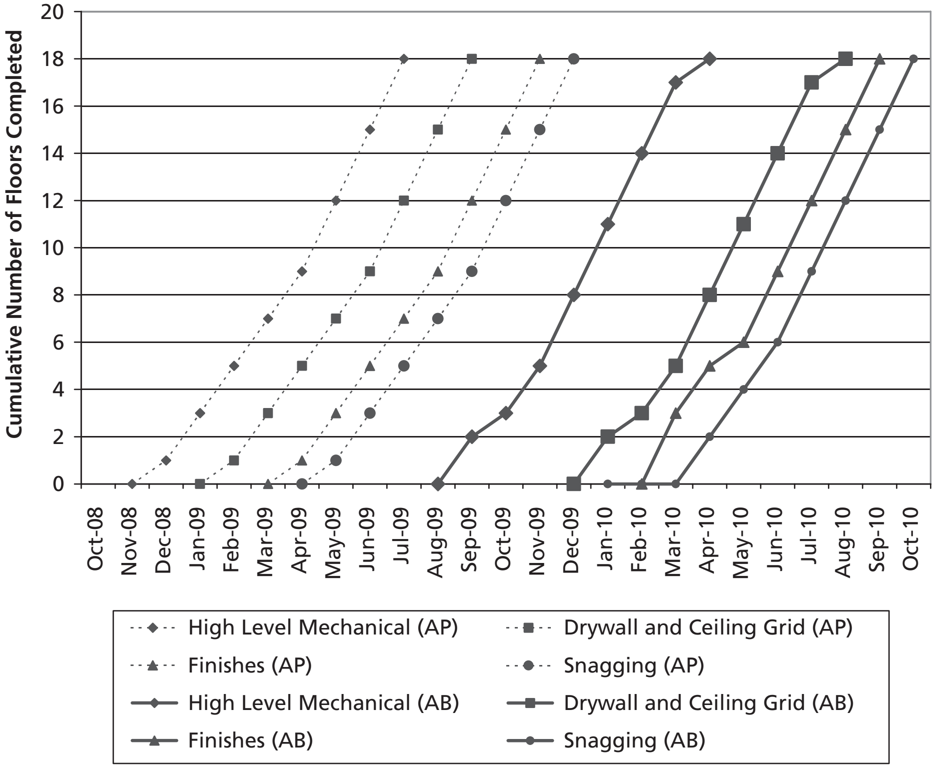


Figure 2.19 Line of balance curves 1. Planned vs actual progress – internal trades.

easier for the analyst to link the facts of the case to the actual progress achieved. In the example in Figure 2.20 we can easily demonstrate the initial delay to the commencement of High Level Mechanical as follows.

This is illustrated as ‘Delay 1’ (Figure 2.20). While there will be discrete delays to each floor which warrant more detailed analysis, this approach allows more significant delays to be identified and analysed. Following the commencement of High Level Mechanical work, it appears from the as-built that its successor, Drywall and Ceilings, did not keep pace with planned progress, when measured relative to the completion of the High Level Mechanical work. The delay to the commencement of Drywall is represented as ‘Delay 2’ illustrated in Figure 2.21.

The graphical technique of representing progress, planned versus actual, in this way will also assist the analyst to concentrate his review of the evidence on the periods and tasks which were causing delays to successors, or not keeping pace with predecessors, at key periods along the project timeline. Line of balance charts are perfectly suited for providing assistance in isolating the driving activities although traditional critical path techniques may still be

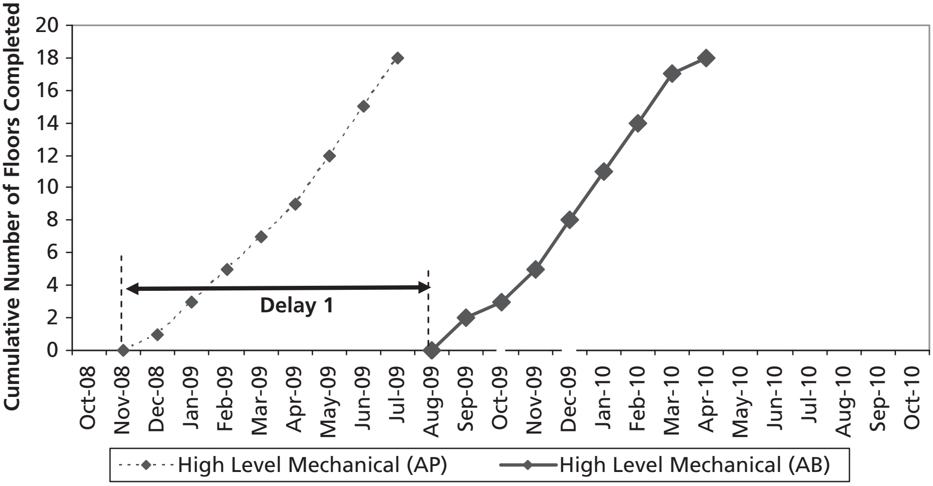


Figure 2.20 Line of balance curves 2. Planned vs actual progress – internal trades.

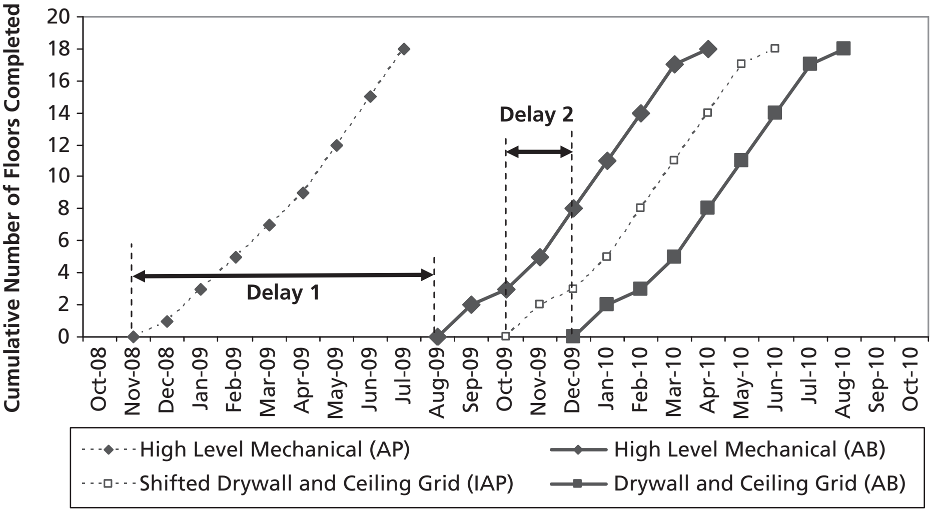


Figure 2.21 Line of balance curves 3. Planned vs actual progress – internal trades.

required when discrete delay events are identified which cannot be isolated or identified using this technique.

2.5.4 Critical chain method/theory of constraints

The critical chain method (CCM) was developed to address the uncertainty involved in estimating task durations. CCM is mainly a product resulting from the application of the theory of constraints (TOC), which is used widely in managing manufacturing processes and attempted occasionally in the traditional construction environment. TOC and CCM focus on identifying bottlenecks in a process or flow and then improving or eliminating these bottlenecks to allow the throughput of the overall system to increase.

In traditional CPM based programming, uncertainty in task durations is managed by including a time-risk allowance (i.e. padding) within task durations, starting work as early as possible; performing as much work as possible concurrently; and focusing on meeting intermediate milestone dates. Some of the problems CCM proponents associate with traditional CPM based programming are:

- Task durations which are based on worst case estimates (to ensure a high probability of task completion) result in waiting until the last possible moment to perform, or complete, a task.
- Starting too many tasks on their early start dates results in multi-tasking. This results in all task durations taking longer to complete, with very few completing by the early finish dates.
- Effort spent in finishing to early finish dates is wasted when it results in discontinuity of work for trade contractors. Early completion of one task rarely offsets delays to other tasks. Late completion will, however, always be passed on to successor tasks.

In CCM, it is argued that uncertainty is managed by:

- using average task duration estimates;
- calculating backwards from the date a project is needed (to ensure work that needs to be done is done only when needed); and
- identifying aggregate time or resource buffers in the project plan – to be managed by the team to protect the project completion date and ensure the ‘key tasks’ are not delayed.

While the CCM management technique varies in many ways from traditional CPM project management techniques (e.g. identification of bottlenecks and elimination of constraints preventing planned start or completion dates), there are similarities. For example the key tasks are those on which the ultimate duration of the project depends, also known as the critical chain, like the critical path. Additionally, buffers are put in place in the same way as float. When these buffers start to deteriorate, intervention is required to restore the buffer, or to ensure the buffer is still sufficient for the delay or event which is interfering with progress.

In addition to these primary diagrammatic techniques of representing networks, there are many other specialist techniques which have been developed for use in the manufacturing, oil and gas exploration industries. For instance, when planning road works, heavy earth moving or mining operations, one would typically consider the application of mass-haul diagrams. When planning a manufacturing process, the assembly line would likely be based on a combination of through-put and line of balance techniques. Oil and gas, R&D and exploration projects, or any project with much uncertainty at the outset, rely more heavily on a combination of probabilistic risk tools and PERT methods of determining the most likely overall project duration.

2.6 Why use CPM planning or scheduling techniques?

There are recognised limitations in relying solely on critical path methodology for risk management and delay avoidance. The CPM provides a quick and rational means of determining the events which are likely to present the greatest risk to project completion. Widespread adoption of CPM techniques and support from project programming software packages has led to a growing understanding and acceptance of critical path as the primary programming technique in the construction industry. PERT, CPM, precedence diagramming and other diagramming methods have been specifically developed for construction, research, development and manufacturing processes. In fact, in some manufacturing environments there is a trend away from 'sequential processing'. The random access capability of relational databases is being exploited in new project network software – new tools which may have applications in the construction industry in the future.

Nonetheless, for now the tried and true form of CPM programming or scheduling has withstood the test of time. Attempts to add bells and whistles, with stochastic and probabilistic programming tools, the application of least-squares non-linear regression to float deterioration and resource levelling, enhanced collaboration and 'web-based' software integration have not called into question, or improved upon, the fundamentals of CPM programming.

CPM programming is the vehicle to transition a vision, plan or network, into a timetable with specific calendar dates governing the beginning and completion of all project events. A properly prepared programme should:

- alert all parties engaged in the project of the required performance time of their functions and responsibilities;
- assist in the efficient use and coordination of productive resources to ensure project completion is achieved on time;
- permit continuous and transparent analysis of the original plan to actual performance, thereby enabling measurement, evaluation of the current project status, and corrective action to rectify any identified deviations; and
- allow various 'what if' scenarios to be analysed from time to time to allow timely and educated decision making by senior management when evaluating the impact, or potential impact, of a change to the project.

2.6.1 Project management

The CPM programming techniques also provide project managers with a tool for assessing the level of resources required on multi-disciplined projects involving multiple prime contractors. A project manager executing a programme has several responsibilities. He must:

- balance multiple and competing requirements for resources within realistic activity and project time constraints;
- execute the work in accordance with an approved CPM network by ensuring adequate resources are available to complete the planned activities in the allotted time-periods; and
- conform to the network or else be able to communicate any planned deviations from that network and justify the reasons for those deviations.

To do this, he must maintain the interdependence between actual site progress and the programming function throughout the life of the project and should resist any attempts to over-ride the planned logic with pure intuition and instinct. This would otherwise relegate the schedule to a retrospective reporting tool and would lay to waste all of the effort in developing and validating the original programming logic. As stated above, any deviations from the stated intentions should be documented, readily auditable, and provided in a transparent manner to the contract administrator before implementation (or approval if necessary). The key tenets involved in maintaining this relationship include:

- allowing the approved programme to determine the sequence and content of the work to be performed until that sequence is altered;
- making adjustments to the schedule (time calculations or network logic) only when it is apparent that the schedule is unable to validate the network by predicting a timely completion date;
- communicating any and all adjustments and, where necessary, seeking approval of these adjustments from time to time; and
- maintaining only one single network that is consistently and openly reported to all interested parties and used for the planning and execution of the work.

2.6.2 As-planned programmes

Attempting to develop a perfectly accurate APP is a mistaken concept. These programmes must be contractually compliant, readily auditable, and must be a true reflection of a contractor’s intentions. If the accuracy of a programme was determined by comparison with the as-built programme for the same project, activity by activity, then not a single programme seen by the authors (with 50 years combined construction industry experience) would be shown to be 'accurate' by any statistical test. Nonetheless, the authors have seen many projects completed on time, even with duration over-runs and sequence changes. However, the APP is the base from which change should be measured, or which can be used to predict the impact of change.

Communicating the final APP to all relevant stakeholders involves the creation of several 'levels' of programme reports. All of these should be derived from the same centrally managed 'Master Project Programme' (MPP) to avoid inconsistencies in reporting. The levels are typically described as follows:

- Level 1 – Executive Summary Level
- Level 2 – Summary Level
- Level 3 – Management Level
- Level 4 – Site Level (Daily)

Level 1, the Executive Summary Level, is represented by the project summary network, which is usually limited to a single page display of the overall project plan, progress and current forecast. It is time-scaled and represents, in a summarised form, the programme for each contractor, or each trade, or each project on a programme or site. These programmes typically include summary bars and summary milestone events (e.g. notice to proceed, planned completion, etc.) as required.

Level 2, the Summary Level, is often referred to as the Master Programme. The Level 2 planning and programming function is performed within the constraints of the Level 1 periods and serves as the basis for updating Level 1 planning documents. Status reports include selected activities which are extracted from the overall Level 2 Master Programme to concisely depict the status, on a Level 2 basis, of the project. These programmes reflect, in a more summarised fashion, the plan shown on a contractor's or subcontractor's site level (Level 3) detailed programme.

Level 3, Management Level, refers to the networks which are the working construction planning documents. These are prepared by prime contractors and specialist trade contractors. Level 3 networks represent the work sequence and programme, in detail sufficient to plan and monitor weekly activities at the contractor working level. These are derived within limits defined by specific programme network activities and are used to confirm and report progress to the Level 2 activities they represent. They should be prepared for each Level 2 activity where the magnitude of the work and/or complexity of the activity require detailed planning and monitoring. It is expected that each contractor will programme tasks correlating to the work breakdown structure (WBS) relevant to the work content of their activities. Level 3 networks can also be described as 'fragnets' and are usually associated with particular disciplines, work areas or trades. However, during the final months of effort, leading to pre-operational/handover events, the scope for using fragnets may be modified to combine the remaining activities of all disciplines relating to a particular system or subsystem.

Level 4, Site Level, programmes are the daily progress lists or tick-sheets, which are developed and maintained by each department, section or trade. These include material monitoring reports, expediting reports, logic diagrams for phases or areas in progress, construction punch lists, and testing programmes. These documents provide data and information which is interpreted by the programmer to supplement the three primary levels of programming. They also identify information, material and/or equipment requirements which could restrain the progress of construction activities represented in the Level 2 and 3 programmes.

2.7 Project controls and the project control cycle

Effective project control can only be achieved when cost, schedule, and technical objectives are clearly documented, realistically derived, and actively managed. Project programme development is one of the most important processes in a project's overall plan development. However, a project will generally never follow the plan exactly and even the most well thought out project programmes will inevitably exhibit variances between the planned and actual performance. Therefore, in order to prevent these variances from affecting the planned completion date, continual control and monitoring must be implemented from the outset. The ability to measure current performance status, and also forecast potential problems and manage change at the time it occurs, can mean the difference between the success and failure of a project.

Project control involves the implementation of the plan (construction programme), monitoring progress and measuring performance. A key function of controlling a project involves identifying and instigating corrective measures or modifying the plan as necessary to account for changes or deviations. This is better described as the 'project control cycle' which involves the following stages:

- Establish the plan
- Monitor progress
- Process and analyse information
- Implement corrective action

The 'cycle' can be seen as a repetitive process, based on the updating interval/frequency required for any specific project. The constituent parts of each stage are illustrated in Figure 2.22.

We have discussed the methods of establishing the plan above. Controlling time and controlling money are two interrelated functions. This text is only concerned with the control of time in the project control cycle.

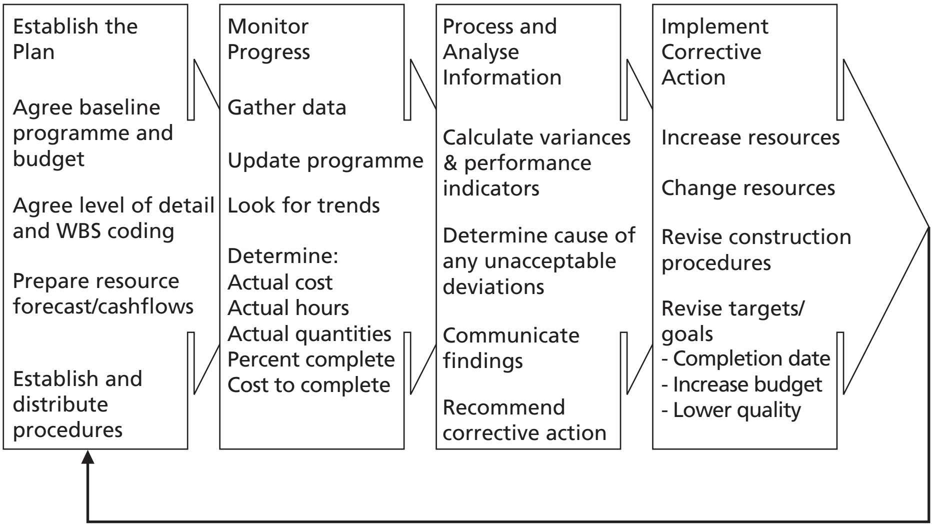


Figure 2.22 Project control cycle.

2.7.1 Progress monitoring

When updating a project, actual progress is recorded for each activity relative to the date of each update (the 'data date'). The data date is the date up to which performance data is measured and the date from which future work is re-programmed. This regular update will include progress on values for:

- dates on which activities started or finished;
- actual percent of work completed within each task;
- actual resources expended on each task; and
- actual cost expended on each task.

This progress is usually measured as a percent complete value, and typically determines the remaining duration (remaining percent multiplied by original duration). Once this data is captured and entered into the programme software, the forward and backward pass calculations are performed. The early and late event calculations determine the float for each activity, and the critical path to completion. There are six basic techniques for measuring the progress of a task in a CPM network as follows:

1. **Unit Measure** – This is based on the percent of units, or quantity, of work completed as at the date of a progress update.
2. **Incremental Milestones** – These are used where incremental progress of a task, or series of tasks, is measured in a linear fashion as milestones are achieved. This can only be used where the milestones provide an acceptably reliable rate of progress to completion.
3. **Start/finish** – This is used where the unit of measure or rate of progress for a task is difficult to measure with certainty. This applies to some major

rigging, alignment or commissioning activities. These are tasks where achieving specified tolerances may occur in a single attempt, or over a series of trials with uncertain durations. When these tasks 'finish' they are deemed 100% complete, but only arbitrary progress is capable of being assessed at intermediate stages.

4. **Observational Assessment** – This is a subjective method, which should only be applied to non-critical tasks or those where measuring actual progress with precision would be extremely time-consuming. This could be true for certain design or drafting functions, finishing trades and de-watering of large areas, or other tasks which require a disproportionate level of effort to determine the discrete progress of an individual task, or where this is simply impossible.
5. **Level of Effort/Cost Ratio** – This method applies to time-related functions which are continuous throughout the life of a project and are not based on production or discrete progress. These include quality assurance and monitoring roles. These are usually determined simply by comparing the actual cost to date to the total forecast cost to completion and are more measures of budget expenditure than actual progress achieved.
6. **Equivalent Units** – This is applicable to sub-tasks, included in a single task, which take place concurrently or over a very long period of time, each with a different unit of measurement. This could include the installation of sub-assemblies of structural steel or composite wall framing, whereby each sub-task is given a weighted value in equivalent units to allow a composite unit of progress to be determined.

Once one of the above techniques has been applied to each task, the percentage of completion and remaining duration for each task can be identified. To determine the overall percent complete for the entire project a method of 'earned value' must be applied. In measuring progress to the entire programme, a simple formula relating the percent complete to the budgeted value of each task is used.

$$\text{Earned Value}\,(\text{task}) = (\text{percent complete}) \times (\text{task budgeted value})$$

$$\text{Percent complete}\,(\text{project wide}) = \frac{\sum \text{Earned value}\,(\text{all tasks})}{\text{Budget value}\,(\text{all tasks})}$$

Earned value is discussed in more detail later in this chapter as it relates to project monitoring and delay analysis.

2.7.2 Process and analyse information – earned value method

The measurement of performance in any project control function is based on earned value. The earned value method is derived from a system used on US Government contracts known as Cost Schedule Control Systems Criteria

(CSCSC). Using this system the project controls team was required to consolidate job cost information into the consistent formats required by the Air Force, Army, Navy, Defence Logistics Agency, Department of Energy and NASA. The most important criteria for the purpose of this chapter are:

- actual cost of work performed (ACWP) – the costs actually incurred to date;
- budgeted cost for work scheduled (BCWS) – the sum of the budgets for the work scheduled to be performed within the time period being analysed;
- budgeted cost for work performed (BCWP) – the sum of the budgeted values for the work which was actually completed in the period being analysed; and
- budget at completion (BAC) – the sum of the budgets for all work included in the WBS.

From these parameters, the health of the project can be readily assessed and corrective action focused on the work which is delayed the most or the budgets which are suffering from cost over-runs. Firstly, the 'estimate at completion' (EAC) is established. This is represented as:

$$\mathrm{EAC} = \mathrm{ACWP} + (\mathrm{BAC} - \mathrm{BCWP})$$

From this, the cost and schedule performance indicators can be determined. These are useful in both delay and disruption analysis. When used effectively, these tools can assist in pin-pointing the cause of cost and time over-runs. The cost performance index (CPI) is a measure of the project's actual cost for the work completed to date, as compared to the budget for the same work in the APP:

$$\text{Cost Performance Index (CPI)} = \mathrm{BCWP}/\mathrm{ACWP}$$

The schedule performance index (SPI) is a measure of the project's actual time incurred for the time allowance included in the APP for the same scope of work:

$$\text{Schedule Performance Index (SPI)} = \mathrm{BCWP}/\mathrm{BCWS}$$

There are many more statistical analyses that can be performed from these, and other, simple parameters. However, these two performance indicators are fundamental to the project control team's understanding of the performance and allow for the identification of early warnings and implementation of corrective measures when the performance indicators indicate that progress is falling behind, or cost is running over-budget.

During the life cycle of a construction project, most contractors routinely predict in some fashion the project's final job costs to determine whether it will be in a profit or loss position at completion. If these predictions are reasonably frequent, accurate and timely, a contractor can often identify job problems, take appropriate action and mitigate or eliminate potential loss while the project is

Table 2.4 Assumed values.

BAC	Budget at completion – £139,000
BCWP	Budgeted cost of work performed to date – £58,500
ACWP	Actual cost of work performed to date – £66,750
ETC	Estimate to complete (to be determined)
EAC	Estimate at completion (to be determined)

Table 2.5 Steps in calculating the EAC.

Step 1	Determine the BCWP. This will require analysis of the work completed to date.
Step 2	Determine the ACWP. This will require analysis of the most recent and current job cost report.
Step 3	Determine 'operating efficiency' (BCWP/ACWP).
Step 4	Determine the ETC. This is calculated by subtracting the BCWP from the BAC. Divide this value by the present rate of efficiency. In formula, it is written as (BAC – BCWP)/(BCWP/ACWP). In our example, that is (£139,000 – £58,500)/(£58,500/£66,750), or (£80,500/0.88), for an ETC value of £91,852.
Step 5	Determine the EAC. This is calculated by adding the cost-to-date (ACWP) of £66,750 to the ETC of £91,477, for an EAC of £158,227. This figure represents that, in consideration of the current rate of efficiency (88%) and the assumption that the efficiency rate will not change for the remaining work, there will be a £19,227 overrun on this element of the work (BAC – EAC).

underway. When combined with in-depth knowledge of the original budget and the actual cost of the work through to the date of inspection, the physical percent completion data leads to the ability to estimate accurately the cost of the remaining work. For illustrative purposes, assume the values set out in Table 2.4 for a single element of work within a total project. The object is to calculate the estimate to, and at, completion (i.e. ETC and EAC).

In order to calculate the EAC, follow the steps outlined in Table 2.5.

It is essential that the development of an ETC and EAC be accomplished in consideration of all the available information. Without careful consideration of these factors, contractors will be unable to predict accurately whether a job is in a profit or loss position until it is completed. Finally, without an accurate EAC, it will be impossible to identify specific problem areas in a timely manner and take the appropriate action at the time to mitigate cost overruns. This information should be provided for all appropriate management levels and for periodic submission to the employer.

In the previous section various methods of measuring work progress were described. These can all be rolled up using earned value to show the overall percent complete to any level of detail, e.g. Level 1 Project, through to Level 4

Table 2.6 Worked example.

BCWS		
Budgeted Cost of Work Scheduled = £55,000,000		(Should be 55% Complete)
ACWP		
Actual Cost of Work Performed = £37,000,000		(37% of Budget Expended)
BCWP		
Budgeted Cost of Work Performed = £45,000,000		(45% Complete)
Schedule Variance		
BCWP – BCWS	£45 m – £55 m	*–£10 m* (*i.e. £10 m behind schedule*)
Schedule Performance Index		
BCWP/BCWS	£45 m/£55 m	*0.82*
Cost Variance		
BCWP – ACWP	£45 m – £37 m	*£8 m* (*i.e. £8 m under budget*)
Schedule Performance Index		
BCWP/ACWP	£45 m/£37 m	*1.22*

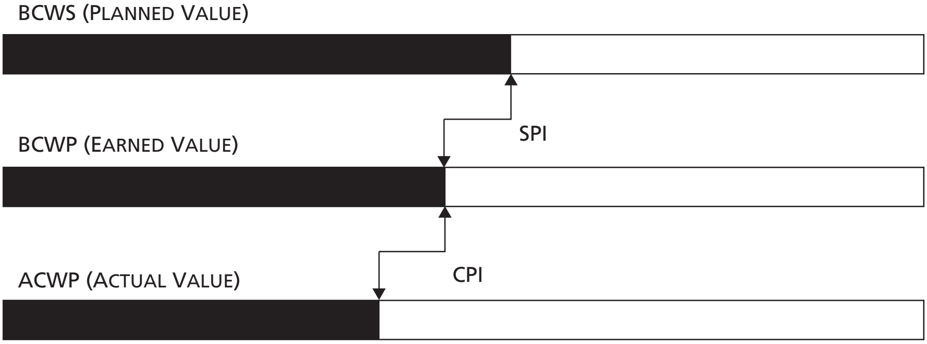
Element (see the WBS example provided earlier in this chapter). The illustration in Table 2.6 provides a worked example which assists in demonstrating the usefulness of this data.

When taken alone, an outflow of £37 m against a planned spend of £45 m at a point in time could be an indicator that the project was going to come in under budget. However, when the schedule performance is taken into account, it is clear that the under spend experienced is also a factor of lack of progress. This situation is exposed with the use of EVA techniques.

2.7.3 The cost and schedule performance curves

One of the most useful formats for quickly presenting a project's cost and programme status is shown in Figure 2.23. This is a three dimensional view of the project status for the data in the sample illustration provided above. The reader can quickly ascertain both cost and schedule variances and approximately how far the project is ahead of or behind schedule.

The projected productivity curve allows the actual productivity plot to be more meaningfully evaluated. As shown in Figure 2.24, a cost performance index of 1.22 indicates that the actual cost of the work completed was achieved 22% under budget. The schedule performance index of 0.82 indicates that the project is 18% behind schedule (1 – 0.82), based purely on the value earned. These trends are usually monitored over the life of the project using illustrations, such as the one in Figure 2.24, so that trends can be identified, and when necessary corrected.



SPI = Schedule Performance Index (BCWP / BCWS) £45/£55m = 0.82
CPI = Cost Performance Index (BCWP / ACWP) £45m/£37m = 1.22

Figure 2.23 Example of cost and programme status.

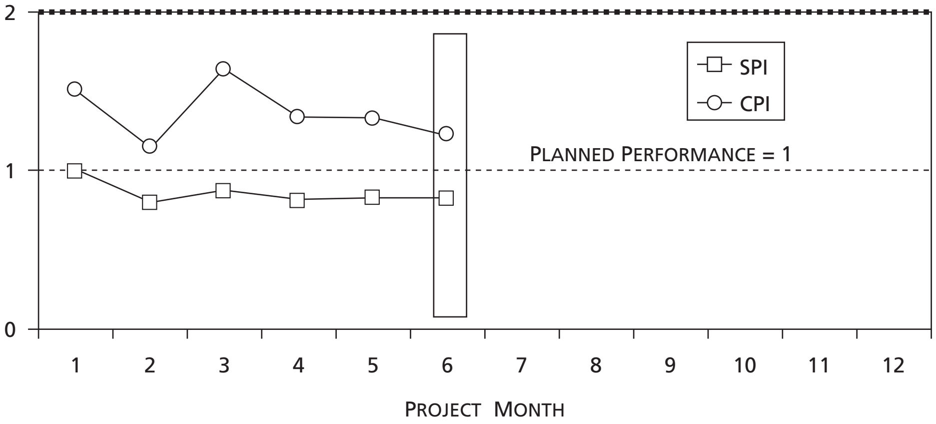


Figure 2.24 Performance index trend lines.

Put simply, the data indicates that the SPI is less than planned, which is unsatisfactory. The CPI is greater than planned, which is satisfactory. If both values were equal to 1.00, the project would be on time and on budget. In this example, the project is behind schedule, but coming in under-budget. Statistics tell us that when the CPI falls below one, it rarely, if ever, returns to 1 or greater. Once the project is over-budget, finding savings to offset that over-run, without compromising quality or scope, is impossible. In the authors' experience, when the SPI falls below 1 it takes additional funding to bring the project in on time, which has a corresponding effect on the CPI. The interaction of these indicators can be used for many statistical calculations.

2.7.4 Time control

The term 'time control' has been introduced to liken the process of setting time-risk budgets for tasks to that of setting and managing financial control.[3]

- **Time Budget** – this is equivalent to the overall project duration, or the time available as defined by project goals or fixed completion constraint;
- **Time Plan** – the division of the time budget into smaller definable and manageable tasks, each with logical predecessor links, a defined duration 'time-risk allowance', and definable start and finish dates;
- **Time-Risk Allowance** – the duration allowed to each definable task included in the 'time plan'. In addition to the time-risk allowances allocated to tasks, a reserve, or time contingency (defined in the critical path analysis as 'float') is usually available for authorised budget transfers from the contingency to tasks which over-run their allowed time-risk allowance. (When activities under-run their time-risk allowance, the available contingency budget similarly increases.)
- **Time Checking** – monitoring closely actual time spent on each activity against the allowance in the time plan, reporting deviations against the time plan and the usage of time-risk allowances.

While not strictly in accordance with critical path analysis methodology, the principles set out in 'time control' effectively lay down a method of managing time budgets in the same way one would manage cost over-runs. They also cover budget transfers, over-runs and under-runs when deviations occur. This contingency management is basically a method by which the 'float' is controlled by authorising, or denying, budget transfers to tasks. When a task uses more time than has been allocated to it in the 'Plan' there are five possible actions:

1. Transfer time-contingency to the time-risk allowance for the offending task to eliminate any deviation from time plan and time budget;
2. Re-sequence remaining activities to absorb the impact/over-run of the potential delay;
3. Shorten the time-risk allowances for remaining activities;
4. Accept a later date for completion (increased time budget); or
5. Enforce damages for delay (contra-charge, liquidated damages etc.).

When 'time-risk allowances' are used and tracked effectively, as recommended above, the duration over-runs and 'float' can be controlled and managed as a usable (depleting or increasing) commodity or resource – just as money is managed.

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[3] Royal Institute of Chartered Surveyors (RICS) *The Procurement Guide*.

2.7.5 Programme updates

Employers, contractors, investors and all relevant stakeholders require accurate contemporaneous status reports of a project for various reasons. Likewise, all parties want to be aware of changes or delays as they occur. They want to know if the changes will affect critical path activities or simply deteriorate float, and whether they might threaten the projected project completion date. This provides certainty and minimises 'surprises'. It also allows the parties to take any necessary corrective measures to get the project back on plan.

Programmes are updated to:

- communicate actual project status from time to time;
- keep the programme relevant as a useful management tool;
- record actual performance of all parties alike;
- record changes to the original plan; and
- support forensic or prospective delay analysis.

Accurate updated programmes can also be used to document the performance of the employer, the professional team, designers, and the contractor and their ability to meet commitment dates. Contemporaneous updates provide a record of the accomplishments as to timeliness and completeness of each party's effort. These also measure the impact of change to the work and any changed methods or sequences of performance. A reliable programme will allow management the opportunity to assess the impact of changes or unforeseen events and implement remedial measures if necessary. When documenting a project's history, the causes of delays can be identified and measured from these updated schedules and this information can be used to support both contemporaneous and forensic delay analyses and negotiations. When updated properly, the final updated programme can be relied upon as an as-built programme (ABP).

Progress is a measure of completeness of an activity or group of activities, or of the project as a whole. Contractors update programmes for many reasons. Firstly, because it is often a contract requirement and may be required for payment purposes. Secondly, because it identifies the changing critical path and identifies out-of-sequence working, which may require an adjustment to the plan for completing the remaining work. Thirdly, because it identifies progress, or lack thereof, and can predict a more accurate completion date as of the date the project status is measured.

Updated CPM programmes are required because the initial CPM is merely a plan (as-planned) and cannot predict the outcome of the project. The initial CPM is usually out of date, as a management tool, as soon as a single activity deviates from its planned duration or start date. By establishing a new critical path following each progress update, pressure can be applied to the tasks which are critical to completion and, likewise, pressure taken off those which are not (i.e. those with float).

The updating frequency for preparing project programmes is defined by the contract documents. When no frequency is specified, it is unlikely that a contractor will submit updated CPMs to the employer until extensions of time are granted or significant changes to scope or sequence are incorporated into the project. There are no hard and fast rules on how often a CPM should be updated. It is, however, traditional for monthly updates to be prepared, and then submitted to the employer for comment and, sometimes, approval. On fast-tracked projects, updates are required more frequently, in order to keep designers aware of the site progress. On projects with many interfaces with operational facilities (e.g. hospitals, schools, power plants, water treatment plants) it is necessary to keep operational personnel aware of site progress and where work will be ongoing for safety reasons and to avoid unplanned interruptions to operations.

The frequency of job-site progress meetings should align with the preparation, submission and review of CPM updates. If job meetings are held weekly, an updated CPM programme should be available for discussion even if it is only required to be submitted and formally reviewed on a monthly basis. Unexpected events in the middle of an updating cycle could be cause for an unplanned update. These include major delays, added work scope, or instructions to accelerate performance.

When updating the programme, there are many obvious parameters which are progressed for each activity, including:

- remaining duration;
- percent complete;
- actual start;
- actual finish;
- resource usage; and
- cost expenditure.

However, there are underlying parameters which are not readily apparent in some programming software which could have a dramatic effect on the location of the critical path and the amount of float calculated to each activity. These are constraints and calculation protocols, sometimes hidden in the 'option' menu of particular planning software. The most important parameters are 'progress over-ride' and 'retained logic' protocols.

Progress over-ride is a method of calculating the critical path in partially completed projects taking account of 'out of sequence progress'. Where activities have been progressed out of sequence, 'predecessor dependencies' are ignored when progress over-ride is selected. The other option is retained logic, which is a method of calculating the critical path in partially completed projects taking account of out of sequence progress. Where activities have been progressed out of sequence, 'predecessor activities' are reduced to their 'remaining duration' and predecessor dependencies are maintained (see Figure 2.29).

Another factor which could influence whether progress achieved is accurately measured when compared to progress planned is placing certain forms of constraints on activities which affect their placement on the planned programme when float is present. For example, an as-late-as-possible constraint will affect the timing or positioning of an activity in a programme. An ALAP constraint will position an activity on its Late Start/Late Finish dates, such that there is no free float available to the activity with a potential effect on the timing of other activities in the programme, although initally the overall duration of the programme is not affected.

'Out of sequence progress' occurs when an event, or series of events, is performed in a different sequence than as represented by the logic in the programme. Most commercially available programming software packages identify when this occurs through 'out of sequence' reports, such as the one provided in Figure 2.25.

Activity	Predecessor	Rel	Lag	Description of Out of Sequence Progress
C1B357077	C1B357067	FS	0	started before its predecessor finished.
C1B451020	C1B403140	FS	12	started before its predecessor's lag would allow.
C1B512210	C1B516210	FF	0	started too early to allow it to finish on or after its predecessor's finish.
C1B513210	C1B516210	FF	0	started too early to allow it to finish on or after its predecessor's finish.

Figure 2.25 Out of sequence progress report.

When this occurs, the calculation of float, and the critical path, can be influenced by the programming software. Different packages are not all consistent in how they deal with out of sequence progress. The two most common calculation protocols for dealing with out of sequence progress are referred to as either 'retained logic' or 'progress over-ride'. The protocols are self evident, but the resulting float calculations may not be. This can be easily demonstrated by reference to Figure 2.26.

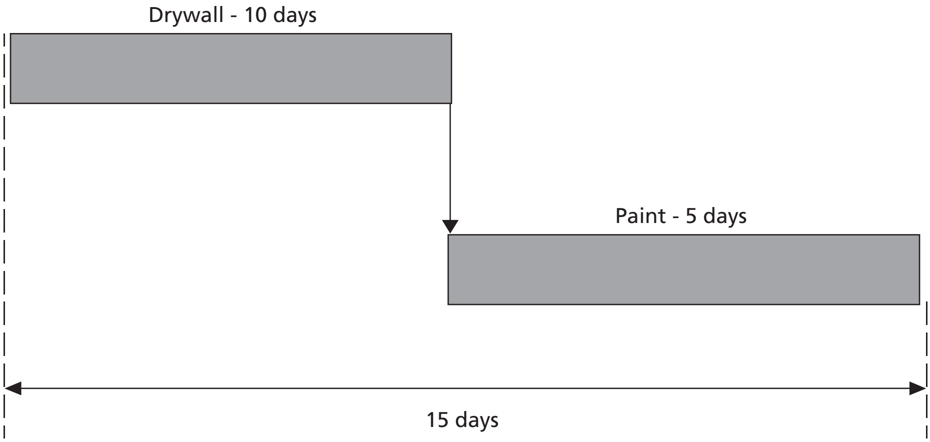

Figure 2.26 Originally planned sequence.

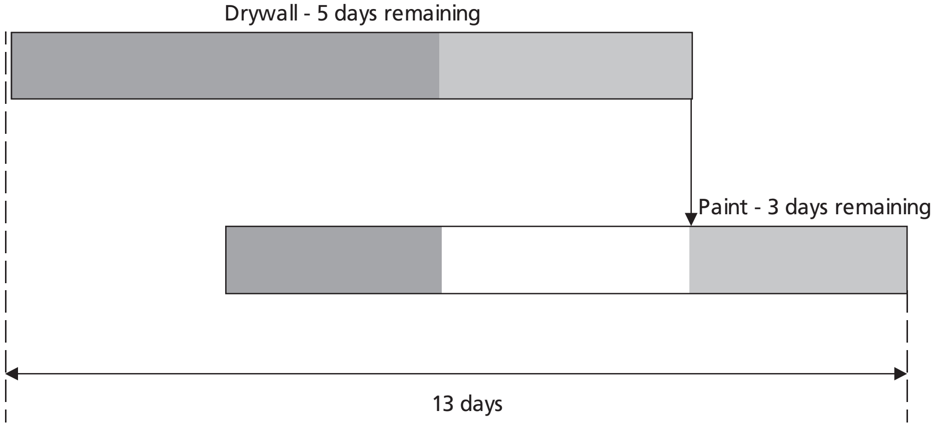

Figure 2.27 Out-of-sequence – retained logic.

For our example, let us assume Drywall started on Day 1, and Paint actually started on Day 3. If the 'retained logic' protocol was selected, Paint may start out of sequence, but the existing logic to Drywall will prevent it from completing until Drywall is complete. For example, Painting on a floor of a building cannot complete until all Drywall has been installed. The original plan may have been for Painting to start once all Drywall was completely installed. In reality, some Painting can be complete in areas where Drywall has been installed, and the two activities can overlap on most projects. However, although some Painting could be accomplished to reduce the amount of Paint remaining when the last piece of Drywall is installed, Painting clearly cannot be 100% complete until Drywall has also been completed. As of Day 5 in the project, the use of retained logic would result in a network similar to that illustrated in Figure 2.27.

The dark shading indicates actual progress, the light shading the remaining duration. In the above example, the programme would not anticipate any Painting taking place in the un-shaded period.

The selection of the 'progress over-ride' protocol effectively breaks the link from an activity to its predecessors when it starts out of sequence. In the example provided, if Painting was a 5 day event, and Drywall was a 10 day event, the use of 'progress over-ride' would indicate that Painting could complete before Drywall was complete in the event that Painting commenced three days after Drywall commenced (Figure 2.28).

One solution to repairing an illogical sequence that results from 'progress over-ride' is to replace the logic which was over-ridden with a more logical relationship, representing the true dependence of the two activities; see Figure 2.29.

Progress over-ride should be used cautiously to avoid illogical sequences, such as that illustrated in Figure 2.28. The use of retained logic is necessary to

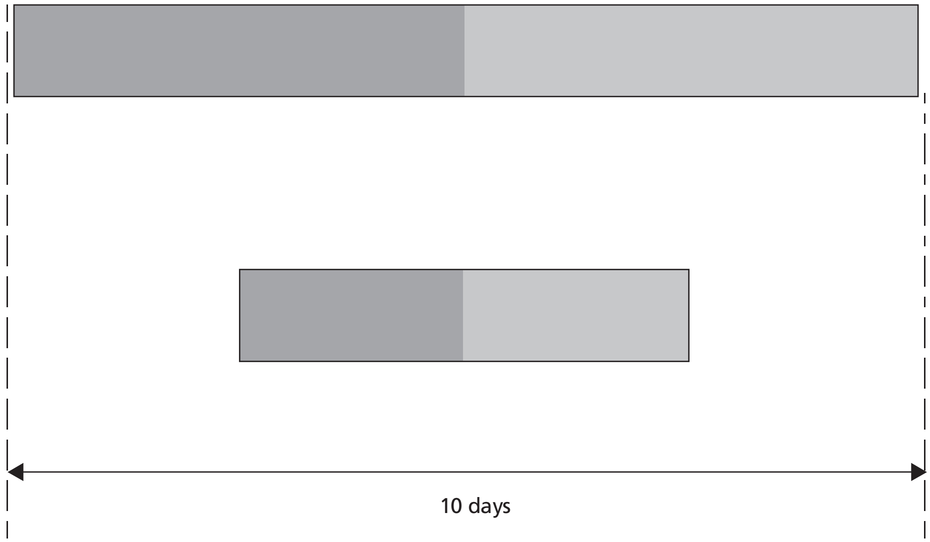

Figure 2.28 Out-of-sequence – progress over-ride.

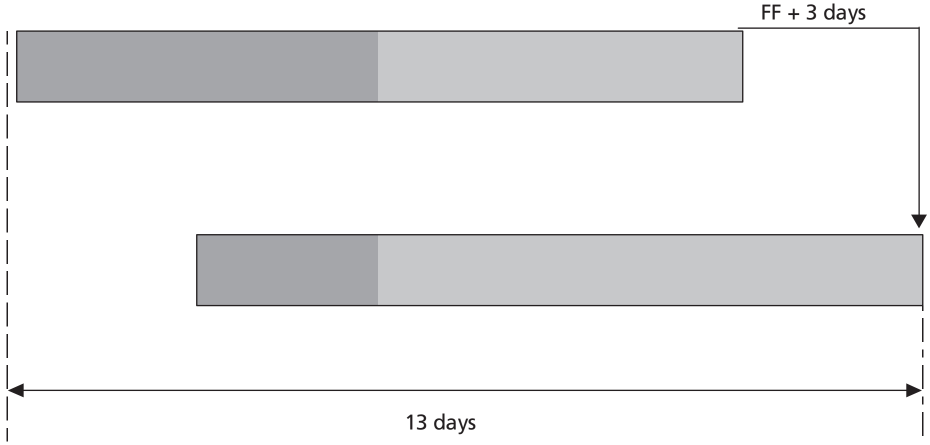

Figure 2.29 Out-of-sequence – corrected logic.

recognise that, although an activity may have started out of sequence, it cannot be 100% complete until its predecessors are also complete.

Maintaining valid logical relationships is fundamental to the reliability and credibility of the programme if it is to be used in a forensic delay analysis. For example, in the case of *Pacific Construction Co. Ltd* v. *Greater Vancouver Regional Hospital District*[4] the British Columbian Supreme Court emphasised the necessity of evaluating the validity and reasonableness of the contractor's

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[4] 1986, 23, CLR 35 (B.C.Ct).

baseline programme before it could be relied on to carry out forensic delay analysis.

When updating project status and task durations, programmers should evaluate each activity individually. Avoid grouping similar activities and generalising progress, or using the 'auto complete' functions provided in programming software. The programmer must manually and fastidiously gather data relevant to each task in progress or completed since the previous progress status report. The minimum data required to properly update a programme would be:

- percentage complete;
- remaining duration (%);
- actual start; and
- actual finish.

The simplest way of doing this is to prepare a report from the previous month's update, and simply track the activities that should have progressed, against their actual progress. A close working knowledge of field operations is required to ensure that any activities which progressed early, and possibly out of sequence, are identified and the progress captured accordingly.

Once the programme has been properly updated, analysed, and adjusted as necessary, the 'look ahead programmes' can be prepared for the subsequent window of work. Look ahead programmes typically span at a minimum, the work planned through the next planned update cycle. They are usually produced at Level 3 or Level 4 (level of detail), and assist by indicating which activities:

- should have started/completed in last period – but didn't; and
- need to be completed in next update period.

Accurate updated and as-built programmes minimise the involvement of planning and programming experts by providing readily available tools for measuring the impact of change.

2.8 Records, records, records . . .

Record keeping procedures need to be geared towards managing huge quantities of both electronic and hard-copy records. These can sometimes lead to unwieldy filing systems that often provide too much information for the forensic delay analyst to be able to digest in a reasonable period of time, or else are not administered consistently throughout the duration of the project's life cycle. When good record keeping procedures are established and maintained, contract administrators are often able to access key information quickly and in a timely enough manner to respond to crises and manage problems at the time they arise. This reduces or eliminates the need for forensic analysis of project delays.

Many standard forms require contractors to provide notice of an intention to make a claim for time and/or money within a reasonable time after the event which gave rise to the claim. These notice requirements are often linked to a requirement to keep contemporaneous records which can be inspected by the employer's representative from time to time. When contractors fail to comply with these provisions, their entitlement is often limited. The records required in the course of developing a properly substantiated claim for time and/or money would include those listed in Table 2.7.

Table 2.7 Main categories of job specific records.

Programme/Progress Information

- Baseline Programme setting out the order, sequence, timing and dependencies.
- Method Statement (i.e. supplemental information supporting programme).
- Intended resources and time to achieve the programme (i.e. supplemental information supporting programme).
- Revised programmes indicating contemporaneous intentions and any changes in resources and timing to achieve them.
- Time Impact Evaluations measuring the potential impact of proposed changes prior to carrying out the changed work.
- Progress programmes monitored and updated during the progress of the Works.
- Daily Meetings – minutes.
- Weekly Progress/Design Status Meetings – minutes.
- Monthly Meetings – minutes.
- Special Meetings – minutes
- Early Warning Meetings – minutes.

The Contractor's Daily Reports

- Identification of all contractor activities in progress or being delayed and the cause of such delays referenced, where possible, to the Programme (task IDs).
- Identification of all contractor's plant and equipment on site with hours worked, idle or down time and repair time given separately.
- Work performed to date giving the location, description and by whom and referenced, where possible, to the Programme (task IDs).
- Test results or inspections with references to any particular specification or code requirements. List of deficiencies along with the corrective action required.
- Photographs.

(*Continued*)

Table 2.7 *Continued*

Communications
• Letters (with or without attachments) • Transmittals (with or without attachments) • Faxes • E-mails • Requests for Information (RFIs) • Contractor Submittals • Certificates
Cost Information
• Job Cost Report (all costs coded to the project from accounting systems) • Labour Returns (timesheets, daily allocation records) • Plant Returns (daily allocation reports, hire records, daily inspection reports) • Subcontractor allocation reports • Cost Management Documents – including Payment Vouchers, Invoices, Purchase Orders • Change Orders (CO), Estimates, Negotiations
Contract Documents
• Conditions • Specifications • Employer's requirements • Drawings • Instructed Variations

The 'Model records clause' in Appendix C of the SCL is another helpful source for identifying which documents are usually relied upon when carrying out forensic delay analysis. The Protocol states:

> 'The following model clauses have been drafted to be included in the specification section of a project's tender documents (or in the contract conditions if the parties choose). Clause 1 is intended to be suitable for small projects and clause 2 for medium to high value or medium to highly complex projects. Clause 2 could also be used in part on smaller projects, and the employer could treat the list as a menu of potential documents that it would like to be submitted, depending on its level of risk, administrative staff and facilities.'

2.8.1 Electronic records

These model clauses are written in collaboration with mutual trust and co-operation between the parties in mind. In practice, many projects are moving towards web-based document management systems, which allow for real-time collaboration between all parties. This also allows the web-based server document control application to act as a central filing system available to all project participants who are granted access. It is recommended that parties save, back up and archive all documents which are made available to them for future reference. Once access is denied, or restrictions are placed on a party's access to the web-based document portal, gaining access to historical records will be difficult.

Whether on-line or hard-copy, each document received and sent should go through a document controls team and be entered into an appropriate electronic log or register which tracks all communications to/from each party. When assigning codes or file references to documents, it is advisable that the coding structure should mirror the work breakdown structure. Each document received should be stamped, coded and distributed within one day of receipt. Documents should be assigned 'cc' where distribution is for information only, and each document should be assigned to a specific person for 'action'. The project manager is probably the person best suited to assign the responsibility as to whether that action is a simple acknowledgement of receipt, or a reply to a fully substantiated claims submission in respect of a delay issue. In well run projects each participant designates a single individual for all correspondence to be addressed to/sent from; usually the project manager. Clearly, this could create difficulties for project managers on large projects unless they are well supported by document control staff who work to a daily routine ensuring each document is reviewed by the project manager, coded and distributed without delay. Delays or compensation events due to inadequate document controls systems are avoidable. Document controls must be systematic and effective in order to comply with the strict time periods (e.g. 'Period for Reply') designated, for instance, in contract documents for turning around replies to RFIs or drawing reviews.

A good document control system is usually managed by a centralised document control centre (DCC), which is established to process all project documentation. Administration of the DCC will rest with the document controls team, whose primary functions include logging, filing, copying and distributing documents, and maintaining the document control data-base. Originals of all project documents are to be submitted to the DCC for processing and kept for later retrieval as necessary. Many documents are often double, or triple filed, for ease of retrieval. Incoming Project Documents should be date stamped on the day of their arrival to the project by either the document recipient or the DCC. Project Documents received by 2 p.m. are usually processed by the end of the same business day. If received later than 2 p.m., they could be stamped as received the same day, or the following calendar day, depending on the agreed document processing systems. The file stamp will provide space for the DCC to input the following information as directed by the project manager:

- date received;
- contract/requisition number (if applicable);

- document control log (DCL) number;
- hard-copy project file (WBS) number;
- distribution ‘cc’ (if applicable);
- ’action’ – person identified to action any tasks.

Copies of project documents distributed may be kept by members at their discretion. The program/project-wide hard-copy project file should be maintained in the DCC. All documents requiring reply within a specified period should be responded to as directed by the project manager (project specific documents) or project director (program wide documents) so as to avoid a compensation event from occurring when the ‘period for reply’ is exceeded. Open document replies should be discussed at internal project meetings on a weekly or bi-weekly basis.

The DCC should also specify which DCLs will be maintained for purposes of assigning a unique sequential number to all incoming and outgoing project documentation. The DCC needs to be solely responsible for issuing document numbers. Normally, a DCL is established for:

- Incoming/Outgoing documents from each project participant;
- RFIs/Technical Queries; and
- Potential Compensation Events/Change Orders.

Some DCCs require faxes and e-mails to also receive sequential, unique identifying numbers for reference. When receiving design related submittals, the one copy, referred to as the ‘review copy’, should be circulated among designated reviewers in the time allotted, as per the master construction programme, for each member to record his comments before passing the review copy on to the next reviewer. At the conclusion of the review copy circulation process, reviewers will meet to discuss the design related submittal. A response should be issued within the designated period for reply to avoid any delays that would entitle any contractor or supplier to a time extension under their agreements.

On-line electronic data management systems are becoming more accessible with many on-line service providers offering standardised packages for the construction industry. The information shared on simple web-based systems includes:

- Project Team Member Contact Information;
- Meeting Schedules, Agendas and Minutes;
- Project and Progress Reports;
- Special Announcements;
- Open communications between parties;
- RFIs, CVIs, PCEs, and Compensation Event processing status; and
- Drawings and drawing registers.

Many on-line web-interface systems go much further and integrate CPM programming with accounting, warehousing and purchasing systems, cost, budgeting, design, O&M manuals and document control software. The use of on-line inter-operable software is becoming a common requirement in the US where BIM (Building Information Model and Building Information Modelling) is gaining favour with large clients. BIM is now the generic name for on on-line representation of the building process, linking construction documents, specifications, drawings, procurement details, submittal processes and other design requirements relating to building quality or environmental conditions and O&M manuals. BIM is seen to facilitate exchange and inter-operability of information in digital format to add efficiencies to the building process from design and specification through to operation and handover.

When used in a forensic analysis environment, the effectiveness of the project coding and retrieval systems can determine the effectiveness of the delay analysis and cause–effect arguments relying on those documents. Providing a forensic programming analyst with too few documents creates the risk that the analyst will not have seen documents which would have shown an argument regarding when an event occurred, or should have occurred, to be incorrect. Alternatively, providing an analyst with too many raw project documents, uncoded and unorganised, often leads to excessive research costs and possibly an analysis which is disproportionately costly and labour intensive to the amount of money in dispute. It will also increase the likelihood that key documents, which would assist the analyst greatly in arriving at succinct and helpful conclusions, could be overlooked. The SCL Protocol states:

> '2.4.1 It is often complained that there is a lack of good record keeping and a lack of uniformity of approach to record keeping in the construction industry. The Protocol recommends that the parties reach a clear agreement on the records to be kept. The starting point for any delay analysis is to understand what work was carried out and when it was carried out . . .'

The SCL Protocol 'Model Records' clause can be used as the basis of agreeing which records will be kept, by which party, as well as the frequency of each document (daily, weekly, etc.), and level of detail to be included in each. It is fundamental to the process of carrying out a delay analysis that an analyst first establishes the quantity and quality of contemporaneous records available. Reviewing a sampling of documents is insufficient considering that the conclusions of the analysis will be tested against the facts represented in these historic records. The available records, including programming records and updates, will usually be the most important factor in determining which method of delay analysis is available or appropriate for use by the delay analyst. Even when the process of analysis and application of a particular technique is carried out appropriately, when there are inconsistencies between the conclusions of the delay analysis and contemporaneous documents, the contemporaneous documents will usually prevail.

2.9 Predatory programming practices

Many contractors employ excellent planning procedures and provide forward-looking and transparent programmes as effective tools for planning the works. However, some may seek to maximise opportunities for extension of time by, for example, minimising the float presented in the programme. Others, if not expressly required to submit detailed CPM programmes or updates, will not issue a baseline schedule or updates at all. This makes extension of time negotiations very difficult and may require the employer to produce its own programme based on site records at great expense and time in order accurately to assess or defend spurious extension of time claims.

Contract administrators involved in reviewing schedules need to be aware of any approaches which undermine the reliability of the programme or the ability to determine accurately which events are or are not on the critical path throughout the project. Contract administrators must also be sufficiently skilled to detect a few other commonly applied techniques (whether applied mischievously or accidentally) such as:

- reducing employer's Design/Drawing review time;
- unrealistic early completion programmes;
- artificial activity durations to hide float;
- artificial logic to hide float;
- artificial logic to exaggerate known delays;
- selective issue of progress information;
- progress updates with no historic as-built data;
- incorrect actual dates in progress updates;
- changing historical data in final as-built; and
- unidentified logic/duration changes in updates.

All of these techniques have their defences and can readily be identified through traditional programme reviews. These are discussed in greater detail in Chapter 5. If these techniques are identified, or suspected, it is recommended that there are a number of steps an employer's project manager can take. For example, preparing and maintaining a 'shadow programme'. This is created by recording the employer's team perception of progress and updating the contractor's most recently submitted programme if there is one. This will assist in protecting the employer from lack of information, or misinformation, for example if reliable programming information stops flowing during the course of the project.

2.10 Guidance

Until recently there was limited guidance to assist contract administrators. Even now, several years after the Society of Construction Law published its

Protocol for Determining Extensions of Time and Compensation for Delay and Disruption,[5] there is a significant skill shortage in the construction industry both in the UK and the US. In the US the AACEI[6] has developed a Recommended Practice Guide (RPG) for Forensic Scheduling Techniques (see Chapter 5). The PMI College of Scheduling has commenced a Scheduling Excellence Initiative (SEI), which is tasked with developing products and providing services relevant to developing a comprehensive 'body of knowledge' focused on developing a *Best Practices Guideline Series*. It is anticipated it will include a multi-volume reference publication for scheduling concepts methodologies and best practices. These documents and initiatives will create even more awareness about the issues addressed in this book. While there is no global body regulating the role of planners and programmers, various organisations are also offering certification as professional scheduling or planning professionals. Internationally skilled planners and programmers with hands-on site experience will be in high demand for the foreseeable future.

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[5] Society of Construction Law, 'Delay and Disruption Protocol' October 2002. http://www.eotprotocol.com.

[6] AACEI (Association for the Advancement of Cost Engineering International).

Chapter 3

Identification of Construction Delays

3.1 Establishing a basis for identifying delay

A successful claim is one which adequately establishes causation, liability, and damages. Each of these factors has a different basis and grounding from which it is established. Liability is based in law and contractual obligations. Establishing causation requires arguments to found on facts. It also requires the demonstration of the cause–effect nexus between an event, e.g. one which is an employer's liability ('the cause') and the resulting impact on the contractor's ability to carry out the project works ('the effect').

The purpose of delay analysis is to satisfy the causation requirement in such a way that it can be used to assess the resulting damages. Ultimately, determining liability for each event will be decided by the engineer, architect, project managers, adjudicator, arbitrator, judge or other third party dispute decider.

Delays can be excusable, non-excusable, compensable and non-compensable. There are a few tests which must be satisfied for a delay to be considered excusable and compensable. If a delay event cannot be shown to be excusable, it will be deemed non-excusable, and if a delay event cannot be shown to be compensable, it will be deemed non-compensable by default.

When demonstrating that a delay is both excusable and compensable, the delay must be shown to be critical, by reference to a reliable critical path analysis. Secondly, the party claiming damages must be able to demonstrate that none of its own delay was ongoing concurrently with the delay events being relied upon. The party claiming damages must demonstrate that the delay damages sought would not have been experienced but for the other party's delay event.

The starting point for satisfying these tests, is establishing a basis for measuring delay, and identifying discrete events (employer risk events and contractor risk events) which can be analysed by reference to a project's critical path.

The scope and nature of construction in the built environment is vast, extending as it does from the erection of a simple single residential building on a 'greenfield' site to the complexity of constructing a multi-storey mix-used skyscraper within the boundaries of its own footprint, often in the middle of a bustling city centre such as London, New York, Hong Kong or Dubai. However, factors which most construction projects have in common are that they are frequently 'one-off' designs, with one-off employers, built in the open air using manpower, materials and plant marshalled and delivered to the construction site. The teams on these projects may never have worked together in the past, and may never work together again, but for the duration of the project they have a shared goal and must work together to achieve the timely completion of the project. Whatever the value, project management of the entire project life cycle[1] – feasibility through design, construction, and hand-over – is essential to a successful outcome. One of the primary tools relied upon by project managers in today's resource-constrained built environment is sound knowledge and skill in planning, programming and control using critical path method (CPM) techniques.

The importance of construction planning as a function in its own right has in the past not always been fully appreciated across all sectors of the construction industry. In the past (before the advent of personal computers) a site planner's main function during construction was to calculate bonus payments based on daily or weekly production rates. This was seen by many as a clerical role at best. Much has changed today with, for example, the introduction and success of adjudication, and the growth of contract documents which place emphasis on negotiating the time and cost of changes before the work is instructed as a 'compensation event'. The CPM programme is integral to linking liability and causation in construction contracts, and is essential when demonstrating the likely impact of events, or projecting a new planned completion date, following the receipt of a variation.

The authors believe that this has partly been born out of increased awareness and a better understanding of all the dimensions of a delay and disruption claim, due mainly to:

- industry debates in public forums;
- the SCL Protocol; and
- formal classes and training seminars focused on delay and disruption techniques, and construction law.

Many employers and contractors alike only develop an appreciation of the importance and necessity of effective planning after having the misfortune of being involved in a long drawn out litigation, arbitration, or adjudication over delay and disruption matters.

In this chapter the identification of delays, with reference to both as-planned baseline programmes and as-built retrospective programmes, will be examined.

3.1.1 General requirements

A planning and programming effort can be effective throughout the entirety of a project; from feasibility and design, through construction, to 'fit out' and 'turn key' hand-over. This chapter deals with the construction phase of a project

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[1] See Chapter 2, Section 2.1.

which is generally where the bulk of a project budget is spent. It is also the phase when design delays or lack of sufficient pre-construction planning often culminate into critical delays to completion. Preparing proper plans and programmes is a difficult and time consuming process. Contractors are required to prepare pre-bid programmes when responding to tenders. This need is even more acute on Private Finance Initiative or Private Public Partnership capital expenditures because the viability of the investment may hinge on the accuracy of the construction cost, duration, and, more importantly, cash-flow projections. Programmes, and all documents which rely on them (e.g. method statements, information required dates, cash-flow forecasts, planning permissions, performance bonds and insurance covenants), are required to be consistent with the tender documentation or employer's requirements to the extent that sectional completion dates or intermediate interface, or access, dates are specified, as are work scope, level of detail, content and duration. It is also becoming a common theme for invitations to tender to specify not only the method of planning, but also the software which is to be used. This is to ensure consistency with the programming software preferred by the employer's technical staff.

When a contractor puts in a successful bid a master programme for the works is often required within a short time of the tender being awarded, and before work is allowed to commence on site. In the case of work packages, specialist trade contractors or subcontractors, a programme will be required to fit within windows allowed in the master programme. Difficulties arise when contractors develop a master programme from the pre-bid tender programme which is adjusted merely to reflect any changes to work scope or completion dates which may have been negotiated or altered in some way after the submission of the bid but before the award of the contract. This tender programme should have been updated with any revised sequences or methods the contractor actually intends to apply.

Care must be taken when considering the re-use of tender programme data when arriving at an as-planned master construction programme. Considering that a contractor's success strike-rate (i.e. success rate for winning projects) might be 1 in 6, or less, many tender programmes are prepared in a compressed time scale to meet the tender cut-off date and are often not prepared to the level of detail required for construction. In some cases they are prepared very quickly, with little information or input from designers or technical staff, by individuals with little planning/programming training or experience. Good programmes can determine the success and protect the profit margin on a project. Poorly conceived programmes may have negative long-term implications well beyond the completion of the project.

To carry out a successful delay analysis, one usually needs a reliable as-planned programme as well as an accurate as-built programme. There are several methods of delay analysis which can be performed using an as-built programme as the base for measuring delay. The outcome and credibility of these methods can be greatly increased when the contractor can demonstrate that its as-planned programme was reasonable.

3.1.2 Validation of an as-planned programme

The baseline programme should serve as the starting point when identifying delays. Even if an analyst is relying on a method of quantifying critical delay which does not depend on a baseline programme, the baseline is useful contemporaneous evidence of a contractor's original intentions with regard to activity durations, resourcing, and logistics.

A review of the baseline programme may indicate inherent flaws or errors in a contractor's assumptions, or that it was simply not possible to construct the project in the manner represented on the as-planned programme, even though that programme may have been accepted, contractually compliant, and used for the planning and management of the project.

While undesirable, the analyst may need to correct the baseline programme before relying on it in any substantive way. When altering, or recreating, an as-planned programme, all deviations from a contractor's original as-planned programme must be made in a transparent manner. The as-planned programme is, after all, itself a theoretical model of how a particular contractor would like to build a project; it is not a record of fact. Thus, any changes or deviations which cannot be substantiated will undermine the integrity of any conclusions drawn from such a recreated as-planned programme. This will be likely to result in a situation where the entire analysis is called into question and treated with some scepticism.

Today's programming software contains many user defined 'settings' which are not apparent from the tabular or graphical reports generated in hard copy format. Some of these settings are buried deep in the pull-down menus that are only accessible when the programme is provided in its native software. The reviewer has to have access to the same version of that software to open and interrogate the programme. Due to the ability to manipulate the programme in this way, there are many areas an analyst must carefully check to establish the reliability of the as-planned programme for the purpose of analysis, including:

- confirm 100% of the work scope is represented in the programme;
- confirm there is at least one continuous chain of activities from start to completion;
- confirm all activities have at least one predecessor, and one successor activity (the start and finish activities should have appropriate start and finish constraints to allow the appropriate float paths to be generated along the critical path);
- confirm durations for all activities along critical, and near critical paths, are reasonable;
- confirm logic along the critical path, and near critical paths, is reasonable and feasible (based on information available at tender stage);
- confirm that there are no delays or changes incorporated that would not have been known at tender stage/contract award;

- confirm all milestones, constraints and sectional completion milestones are represented accurately in the programme;
- confirm any seasonal work is not scheduled to be performed out of season (if weather sensitive work is planned in the wrong season, research contractor's method statements to see if temporary weather proofing measures were anticipated);
- confirm appropriate regional/national holidays are allowed for;
- confirm appropriate working calendars have been assigned (5-day, 6-day and 7-day working);
- confirm all local trade working rules are accurately modelled in the calendars;
- confirm all third party interfaces are represented, with appropriate notification for statutory services, easements and rights of way; and
- confirm employer review times are adequate, and contractually compliant.

The analyst may also consider performing some 'what if' calculations, to test how, if at all, the programme reacts to changes to intuitive impacts on obvious critical events. Any identified errors, flaws or concerns should be identified, documented, and, if appropriate, corrected so that the programme can be used as a reliable basis for measuring delays. If the programme is found to have too many errors, inherent delays, illogical sequences, etc., it may be deemed unreliable for using as a basis for measuring delay.

In some instances, the analyst will not have access to an as-planned programme in its native software. If all the analyst has available is a hard copy printout of the baseline as-planned programme, this may not be enough to allow a faithful recreation. When reconstructing a baseline, the analyst will need much more data than a bar chart with selected logic links, or even the early start and finish dates for each activity. Generally, the analyst will require a fully linked bar chart, indicating relationship type, leads and lags. Alternatively he will require:

- a full successor printout, complete with list of relationship type, leads and lags;
- an activity list indicating activity duration;
- an activity list indicating calendar (working day) assignment; and
- a clear designation of non-work periods (e.g. weekends, holidays, river exclusion periods, traffic management periods).

Even with all of the above, it will be necessary for the analyst to iteratively confirm each early start, late start, early finish, late finish and the total float to each activity to ensure 100% consistency with the hard-copy printout. Where any remaining anomalies exist between the two, these must be identified and documented clearly.

3.2 Factual evidence and as-built programmes

One of the main objectives of delay analysis is establishing a factual matrix and succinct chronology of the delay events which caused delay to completion of the project works. Data identified during the research of contemporaneous records will be relied upon when considering the various delay analysis techniques available, and then deploying one, or more, of them. One particularly important use of this data will be in the preparation or validation of an as-built programme.

Where an as-built programme is to be used in any form of delay analysis, for example a comparison between a contractor's expressed intention (as represented in the as-planned programme) and what actually happened, it is very important to ensure that a high degree of both detail and accuracy are achieved in the preparation of the as-built programme. It is preferable that the level of detail and activity descriptions are consistent with the relevant as-planned programme, where possible, to assist with delay analysis. The as-built programme has the added feature of illustrating when an activity was active, as well as periods of inactivity.

The as-built programme illustrated in Figure 3.1 below is able to capture both days of activity (wide bar), as well as days of inactivity between (narrow connector bar). The white bars indicate days when progress was achieved, whereas the dark bars indicate days when a delay event was documented (excusable delay), as well as when re-work and repairs were documented (non-excusable delay).

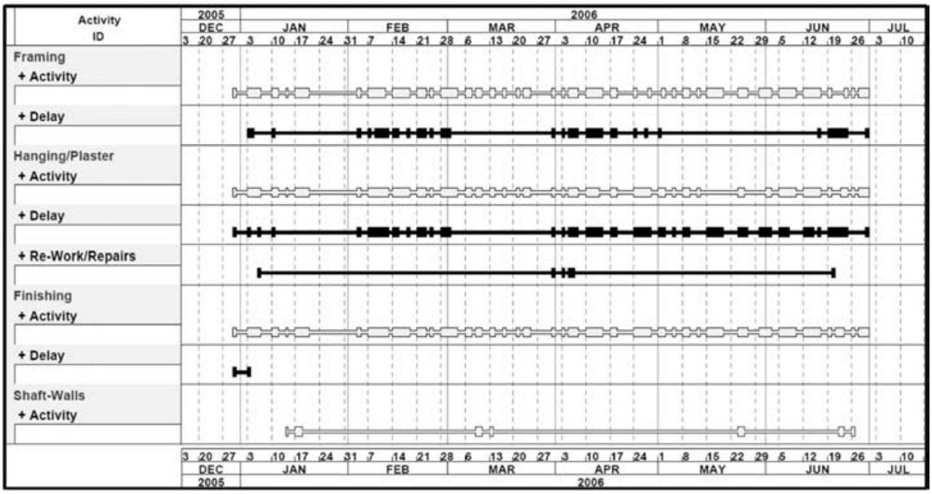


Figure 3.1 As-built programme.

3.2.1 As-built programme preparation

In the ideal situation, an as-built programme will have been prepared and maintained during the course of the works. However, if reasonably detailed records are available, an as-built programme can be prepared retrospectively if necessary.

As with most forms of time-related record keeping it is often easier to compile these records on a frequent basis contemporaneously when progress can be visually checked and verified. Also the knowledge of project staff will be more accurate in the future if they were actively involved with keeping detailed contemporaneous records of progress.

The improving standards and availability of information technology (IT) has meant that accurate and timely tracking and recording of progress through the format of an as-built programme is relatively inexpensive. Considering the sophistication and increased commercial awareness of all matters relating to both delay and disruption, it is important for employers' professional teams to maintain accurate and easily accessible as-built records to defend claims for delay and disruption which themselves rely on sophisticated delay analyses. While these sophisticated techniques do not have any more credibility than a properly prepared as-built analysis (i.e. relying on experience, common sense and relevant project records) they often resemble an ambush of sorts and create a monumental task for an employer's team to respond to. Systematic qualitative and quantitative record keeping will significantly reduce the time required to respond to these claims and will ensure the employer's best case is put forward.

During the course of a project the minimum data required periodically to maintain an updated programme which can be relied on for constructing an as-built programme is as follows:

- the progress of a programmed activity measured as a percentage of work complete;
- the activity start date; and
- the activity completion date.

Figure 3.2 illustrates the format of typical programme status data.

Traditionally this data is collected on a monthly basis in the form of a progress report or updated programme. Often this data is attached to a contractor's

Activity ID	Activity Description	Percentage Complete (%)	Actual Start	Actual Finish
1100	Lay foundations	100	15 Mar	20 May
1150	Drainage	75	17 Apr	
1200	Concrete slabs	20	5 May	

Figure 3.2 Sample updated programme data schedule.

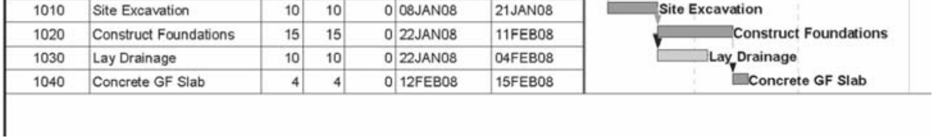
monthly report and used in support of interim valuations. However, it is surprising how often this data is not used contemporaneously to maintain an as-built programme. There is also an increasing trend for contractors to steer clear of the traditional detailed periodic percentage record in favour of a minimalist narrative report. This may reflect a growing concern amongst some contractors that a detailed record may prove prejudicial to their position where, for example, culpable delay may be a factor. In such circumstances it would be prudent for employers also to maintain an accurate as-built record of the contractor’s progress against the latest submitted and/or approved programme, effectively ‘shadowing’ the construction programme. It is often a requirement that project managers or contract administrators keep such records; thus maintaining a ‘shadow’ programme should require no more effort than originally anticipated.

Care must be taken when using current planning software which has functions which enable a planner to ‘auto update’ a construction programme or schedule. Where this function is used the software assumes that the project is going to plan, accordingly the activity durations in the ‘progress window’ (e.g. two week period) are updated with start and finish dates and duration as intended. If only part of the activity is covered by the progress update then the progress and resulting forecast completion date will be fixed in proportion to the original duration of the activity. However, it is rare for a project to progress exactly as planned in any window, be it a day or a month, and therefore while it is tempting to use this type of auto function when faced with hundreds or possibly thousands of activities it can lead to lazy progress updating practice. This in turn would result in poor record keeping and information which is defective for project management forecasting use.

In the simple example illustrated in Figure 3.3 a series of activities is ‘auto updated’ with the 31 January date.

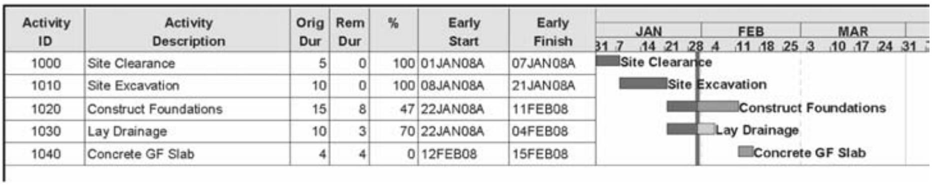
The resultant effect is that the forecast completion date of this series (e.g. activity 1040) remains as-planned at 15 February, see Figure 3.4.

However, assume one of the activities did not achieve the as-planned progress level; in this example activity 1030 achieved only 5% progress by 31 January. When this progress is manually entered the forecast completion date to activity is now seen to have changed from 15 February to 19 February, see Figure 3.5.



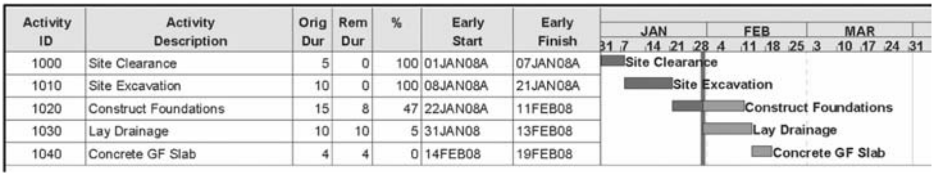
Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1000	Site Clearance	5	5	0	01JAN08	07JAN08
1010	Site Excavation	10	10	0	08JAN08	21JAN08
1020	Construct Foundations	15	15	0	22JAN08	11FEB08
1030	Lay Drainage	10	10	0	22JAN08	04FEB08
1040	Concrete GF Slab	4	4	0	12FEB08	15FEB08

Figure 3.3 As-planned sequence of activities.



Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1000	Site Clearance	5	0	100	01JAN08A	07JAN08A
1010	Site Excavation	10	0	100	08JAN08A	21JAN08A
1020	Construct Foundations	15	8	47	22JAN08A	11FEB08
1030	Lay Drainage	10	3	70	22JAN08A	04FEB08
1040	Concrete GF Slab	4	4	0	12FEB08	15FEB08

Figure 3.4 Activities updated using an 'auto update' function.



Activity ID	Activity Description	Orig Dur	Rem Dur	%	Early Start	Early Finish
1000	Site Clearance	5	0	100	01JAN08A	07JAN08A
1010	Site Excavation	10	0	100	08JAN08A	21JAN08A
1020	Construct Foundations	15	8	47	22JAN08A	11FEB08
1030	Lay Drainage	10	10	5	31JAN08	13FEB08
1040	Concrete GF Slab	4	4	0	14FEB08	19FEB08

Figure 3.5 Effect of inserting manual progress compared with auto update function.

This simple example illustrated in Figures 3.3 to 3.5 highlights the danger of indiscriminate use of auto update functions in programming software.

When it comes to both baseline and progress programme submissions, the problem of a contractor's non-compliance can be dealt with by drafting specific payment terms or non-compliance clauses. This would be an effective way to ensure contemporaneous evidence will exist to assist in agreeing which operations were critical, which activities had float, and which events are relevant when considering entitlement, concurrent delay and compensation for delay damages.

An as-built programme accurately maintained during the course of the works is an invaluable asset for use in forecasting delay and subsequent delay analysis. The more frequently the progress data is captured (e.g. bi-weekly, weekly or even daily), the more accurate the factual matrix and as-built programme will be.

When a detailed contemporaneous as-built programme does not exist, the primary sources of raw data required for the compilation of an as-built programme includes the following:

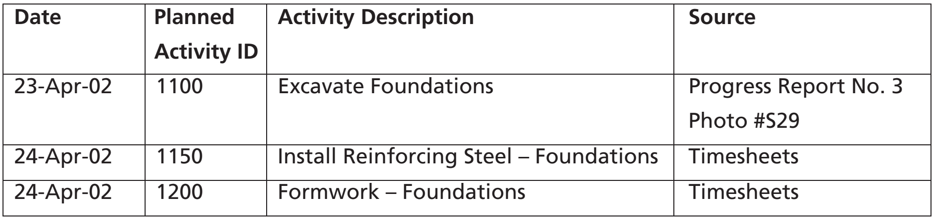
- Site diaries
- Clerk of works records
- As-built drawings
- Photographs
- Daily inspection reports
- Valuations/application for payment/invoices
- Material delivery notes and records
- Welding or testing certifications
- Concrete testing results

- Plant and labour returns
- Timesheets or payroll records
- Requests for information or approvals
- Subcontractor reports
- Meeting minutes
- Monthly progress reports
- Subcontractor applications for payment
- Instructions
- Site observations by project staff (later can be used as the basis of witness statements)
- Job correspondence

This list is in no particular order, and is not inclusive by any means. However, caution should be exercised here to guard against optimistic progress based payment applications or self serving records which may skew an otherwise accurate record of events. The hierarchy described below is a useful tool to avoid any such skewing.

Any record documents that are kept regularly and frequently, are to be preferred to ad hoc documents created after delays are known to exist. 'Padding the files' with inaccurate information, or even misinformation, is uncommon, but not unknown. This is less likely to occur in frequently issued documents which are sent to both parties at the time. The advantage of referring to valuation applications and meeting minutes is that they are open documents, and are revisited, commented upon and corrected on a frequent periodic basis (e.g. fortnightly or monthly).

Once the as-built data of each activity has been identified and collated it can be represented in a spreadsheet to show relevant start and finish dates for each activity on the as-planned programme, together with those added subsequently.[2] It is also important that the sources of documentary evidence which identifies the start/finish dates and/or activity durations are properly recorded in tabular format. This provides an audit trail to the source data relied upon when preparing the as-built record. Figure 3.6 indicates a typical data capture table.



Date	Planned Activity ID	Activity Description	Source
23-Apr-02	1100	Excavate Foundations	Progress Report No. 3 Photo #S29
24-Apr-02	1150	Install Reinforcing Steel – Foundations	Timesheets
24-Apr-02	1200	Formwork – Foundations	Timesheets

Figure 3.6 Example of data capture schedule.

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[2] Activities added subsequent to the as-planned programme and thus appearing on the as-built programme should include both additional works and periods of contractor delay.

Further, documents should be given a hierarchy, establishing their level of accuracy and reliability. For instance, when relying on payment applications, they are accurate only as to the duration of the progress period being applied for (30 days for instance). Weekly meeting minutes are only accurate to within seven days. Daily reports on the other hand, are accurate to the day, as are date stamped photographs and some diary entries. Certain documents will be reliable as to the date of an activity, but might not be equally reliable as to the location of the work being carried out (photographs on projects with repetitive sequences for example). Likewise timesheets might be reliable as to the date a task was carried out, but less reliable as to the specific location.

Establishing a hierarchy of documents will assist the programming analyst in determining which documents should be relied upon in the event of a conflict. One sample hierarchy might be as shown in Table 3.1.

Any weighting can be applied to each source, and the weighting may vary from project to project. The weightings above are described in Table 3.2.

There is often conflicting information regarding the location or progress of a work item due to inaccuracies and inconsistencies between available contem-

Table 3.1 Hierarchy of documents.

Source	Accuracy (days)	Reliability (Location)	Scope of Work
As-built drawings	Varies	1	1
Clerk of works records	1	1	1
Concrete testing results	1	1	1
Daily inspection reports	1	1	1
Daily reports	1	1	1
Delivery notes/invoices	Varies	4	1
Job correspondence	Varies	3	Varies
Labour returns	1	1	2
Material delivery records	Varies	4	1
Meeting minutes	Varies	4	Varies
Monthly progress reports	30	3	3
Monthly reports	30	2	3
Photographs (date-stamped)	1	1	1
Plant and labour returns	1	1	1
Requests for Information or approvals	7	1	1
Site diaries	7	1	1
Site observations by project staff	Varies	4	1
Subcontractor applications for payment	30	3	1
Timesheets	1	2	1
Timesheets or payroll records	1	2	2
Weekly reports	7	2	2
Weekly subcontractor reports	7	2	2
Welding or testing certifications	1	1	1

Table 3.2 Sample as-built source reliability hierarchy.

Accuracy	Varies	–	level of certainty varies (when work was carried out)
	1	–	accurate to within 1 day (daily)
	7	–	accurate to within 7 days (weekly)
	30	–	accurate to within 30 days (monthly)
Location	1	–	highest level of certainty (where task was carried out)
	2	–	moderate level of certainty
	3	–	low level of certainty
	4	–	no certainty as to location of task
Scope	1	–	highest level of certainty (what work was carried out)
	2	–	moderate level of certainty
	3	–	low level of certainty
	Varies	–	certainty varies in documents

poraneous records. Regardless of the as-built record conflict (date, locations, type of work) a hierarchy will ensure the process is systematic, transparent and correctable. Establishing a hierarchy of which documents over-ride others will assist in ensuring the process is systematic, objective and reliable in the face of opposition.

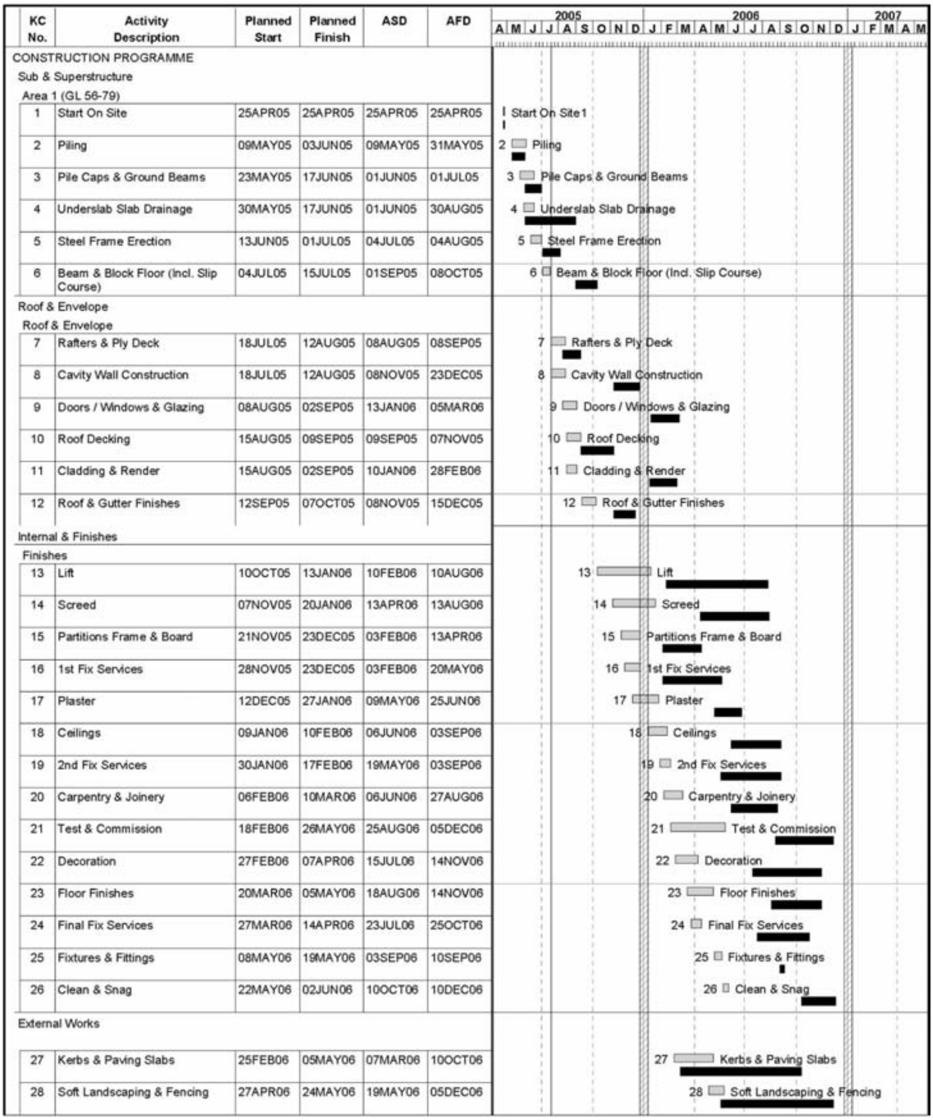
Once this data is compiled it can be imported into project planning software. The next step is to integrate the as-built data with the as-planned to provide a clear picture of the project performance.

This is a very important output which can be used in a number of ways:

- Initial review to identify obvious areas of delay to all planned activities
- Identify areas of potential damages (e.g. seasonal working, stacking of trades)
- Identify overall delay to contract completion date as a fact
- Identify overall extent of slippage to critical path
- Identify periods of potential concurrent delay
- Identify periods of suspension (or inactivity)
- Isolate large delays to focus the emphasis of the delay analysis
- Use as a ‘reality check’ to compare findings of modelled methods of delay analysis

Even when data is not captured on a daily basis, updated project programmes which capture as-built data for all as-planned activities provide a good reference for the initial as-planned versus as-built analysis. Figure 3.7 illustrates a typical as-planned and as-built programme layout which could be prepared from an updated contemporaneous progress programme.

The level of detail required will depend to a certain extent on the level of detail in the as-planned programme and the type of delay issues to be analysed. It is important to maintain a balance between the delay analysis



KC No.	Activity Description	Planned Start	Planned Finish	ASD	AFD
	CONSTRUCTION PROGRAMME				
	Sub & Superstructure				
	Area 1 (GL 56-79)				
1	Start On Site	25APR05	25APR05	25APR05	25APR05
2	Piling	09MAY05	03JUN05	09MAY05	31MAY05
3	Pile Caps & Ground Beams	23MAY05	17JUN05	01JUN05	01JUL05
4	Underslab Slab Drainage	30MAY05	17JUN05	01JUN05	30AUG05
5	Steel Frame Erection	13JUN05	01JUL05	04JUL05	04AUG05
6	Beam & Block Floor (Incl. Slip Course)	04JUL05	15JUL05	01SEP05	08OCT05
	Roof & Envelope				
	Roof & Envelope				
7	Rafters & Ply Deck	18JUL05	12AUG05	08AUG05	08SEP05
8	Cavity Wall Construction	18JUL05	12AUG05	08NOV05	23DEC05
9	Doors / Windows & Glazing	08AUG05	02SEP05	13JAN06	05MAR06
10	Roof Decking	15AUG05	09SEP05	09SEP05	07NOV05
11	Cladding & Render	15AUG05	02SEP05	10JAN06	28FEB06
12	Roof & Gutter Finishes	12SEP05	07OCT05	08NOV05	15DEC05
	Internal & Finishes				
	Finishes				
13	Lift	10OCT05	13JAN06	10FEB06	10AUG06
14	Screed	07NOV05	20JAN06	13APR06	13AUG06
15	Partitions Frame & Board	21NOV05	23DEC05	03FEB06	13APR06
16	1st Fix Services	28NOV05	23DEC05	03FEB06	20MAY06
17	Plaster	12DEC05	27JAN06	09MAY06	25JUN06
18	Ceilings	09JAN06	10FEB06	06JUN06	03SEP06
19	2nd Fix Services	30JAN06	17FEB06	19MAY06	03SEP06
20	Carpentry & Joinery	06FEB06	10MAR06	06JUN06	27AUG06
21	Test & Commission	18FEB06	26MAY06	25AUG06	05DEC06
22	Decoration	27FEB06	07APR06	15JUL06	14NOV06
23	Floor Finishes	20MAR06	05MAY06	18AUG06	14NOV06
24	Final Fix Services	27MAR06	14APR06	23JUL06	25OCT06
25	Fixtures & Fittings	08MAY06	19MAY06	03SEP06	10SEP06
26	Clean & Snag	22MAY06	02JUN06	10OCT06	10DEC06
	External Works				
27	Kerbs & Paving Slabs	25FEB06	05MAY06	07MAR06	10OCT06
28	Soft Landscaping & Fencing	27APR06	24MAY06	19MAY06	05DEC06

Figure 3.7 Typical as-planned and as-built programme.

objectives and the costs of preparing the as-built programme. For example, in a retrospective scenario it would be likely to be disproportionate in terms of cost to identify the exact start and finish of each and every activity in a programme which comprised some 2500 activities where the main delay event only impacted on a small fraction of them. If the main delay issues are concerned with curtain walling installation, there is little point in preparing painstaking research and detailing every aspect of the sub-structure works.

Also, from a practical view point, when illustrating the as-built programme, it might be useful when there are a large number of activities, to collapse those that are not directly pertinent to the delay analysis into single summary bars or activity hammocks.

One task for a delay analyst engaged on a retrospective as-built creation exercise will be that of interviewing project staff who were present on site and who have a good working knowledge of the job, including work sequence, logic and what was actually done.

One common difficulty when preparing an as-built programme is the identification of conclusive start and finish dates for each activity. Certain activities may reach a completion state of around 95%, but remain unfinished for many weeks. It is helpful to designate this point on a programme, to ensure that an 'actual finish' date represents 100% completion. The last 5% may actually be the critical bit! Key decisions and assumptions such as these must be set out clearly.

However, when building a forensic as-built, it is desirable to represent intermittent progress of an activity with a number of broken bars on a programme. Where possible, and particularly when dealing with activities that are affected by delay events, it is prudent to seek corroborating evidence of as-built progress.

Often it will not be possible to construct an as-built to the exact level of detail as the as-planned programme where there may be no record of activities in the as-planned actually having been carried out and nomenclature for some as-built activity descriptions may have no relation to any tasks listed on the as-planned programme. This will not invalidate the as-built but, wherever possible, the as-built activities should be aligned with their respective as-planned bars for comparison purposes.

The as-built validation process is more important than the as-planned process. The proof of compensable delay hinges on establishing when a delay event occurred, and how much time-related prolongation was experienced as a direct result of that event. When delays are built up from as-built records, it is easier to assess the level of compensation due in the period in which the delay occurred.

3.2.2 Summary

You can only plan so far into the construction phase of a project with accuracy. Circumstances will change due to the impact of unforeseen events, e.g. elected changes in methodology or sequence, or any number of issues arising with employer's representatives/third parties, designers, subcontractors, or suppliers. When there are significant deviations from the as-planned programme, the as-built programme is fundamental in demonstrating the impact of events based on what actually happened. An as-built programme is a historical record of the timing of each activity. However, unless it is reconstructed with reliable and non-contentious as-built logic (see deductive methods of analysis below) an as-built programme will normally not represent a logic linked programme.

When preparing an as-built programme as part of expert evidence it is important to be able to substantiate the contents of the as-built programme to the extent that the as-built dates can be confirmed and the process of creating the as-built programme can be audited, agreed, and emulated if necessary. This exercise establishes, to a limited extent, that actual delay has been experienced. The delays identified by reference to an as-built programme alone can only demonstrate the effect of a delay event.

Arguments over entitlement and damages may continue well beyond the establishment of actual delay, and can be influenced by contract interpretation, the nuances and application of recent or past case law, the quality of the cost records maintained during the course of the project and expert quantum advice. Much of the determination of entitlement, as well as damages, can also be left to an adjudicator, arbitrator or judge, who will be familiar with the standard forms of contract, legal arguments and approaches to calculating damages. Therefore, if the analyst can demonstrate which events were critical, which events were concurrent, how much time each event contributed to the critical delay experienced, and when each event occurred, some tribunals may have sufficient evidence (along with the submissions by both parties) to assess entitlement, causation and damages on the basis of a proper and comprehensive delay analysis.

3.3 Identification of delay events

The identification of delay events is one of the more difficult, time consuming and yet important aspects of delay analysis. Delay to planned work scope can occur in only three forms:

- Delay to commencement;
- Extended duration; or
- Suspension during performance.

Each of these will have an impact on the completion of a delayed task. Many events can be entered into the analysis based purely on identification of potential delay events. Only those events which can be shown to have contributed to delays to progress or critical delays to completion are relevant to establishing delay damages and/or extension of time entitlement and compensation for delay damages. Without proper experience and training in the application of CPM programming and forensic methods of delay analysis, those representing employers and contractors alike may be doing little more than ‘horse-trading’, based on rudimentary, possibly flawed, or even impressionistic, methods of delay analysis.

Delay analysts and tribunals alike are likely to value contemporaneous, as-built records over computer generated impact assessments. Computer generated models sometimes involve the creation of hundreds of iterations of impact simulations generated through automated processes, and result in conclusions which have no relationship to common sense, intuition or what was being reported as critical during the course of the works. It is possible that those contemporaneous programmes were incorrect, and that the parties were relying on flawed critical paths throughout the project. When CPM programmes are updated regularly, submitted and reviewed by the employer's team frequently, and used by the contractor to direct resources to critical scope of work in an attempt to remain on programme and avoid delays, these programmes should be preferred to any forensically created computer model attempting to simulate 'what if' scenarios throughout the project.

3.3.1 Delay identification

The process of identifying delays can be undertaken by a delay analyst in two primary ways:

- One starts with an as-built programme and works backwards, identifying deviations from the as-planned schedule (these are the effects of delay events), and is therefore referred to as an 'effect-based' approach.
- The second develops a set of issues, events and potential delay events and attempts to measure the impact of these causes of delay on a base programme. Because this process relies on causes it is known as a 'cause-based' approach.

An 'effect-based' approach is heavily dependent on a reliable as-built programme, and a strong factual matrix. The 'cause-based' approach is heavily dependent on a reliable as-planned programme, or CPM updates, and clear cut 'events' in the form of compensation events, for example:

- Delay or deferment in granting possession of the site
- Unforeseeable ground conditions
- Instructions (e.g. additional works, open up works for inspection and testing)
- Variations or changes to work scope
- Increase in quantities
- Inaccurate quantities in contract bills
- Late design information
- Suspension of works
- Delay caused by statutory undertakers
- Exceptionally adverse weather conditions
- Delay caused by the employer or his representatives

- Civil commotion
- Strikes or industrial action (e.g. lockouts)

Usually causes will be categorised as Contractor Risk Events, (CRE) or Employer Risk Events (ERE). Until any of these events are confirmed as having caused actual delay, they are only risk events.

On complex projects this task can be particularly difficult for project staff, untrained in forensic skills. Attempting to include every RFI, PCE, CE, CVI, etc., into the list of events to be analysed, without some form of filter, is a Herculean task on most large civil engineering, transport, EPC (Engineering, Procurement and Construction), or other complex building projects. This in turn may result in wasted time and resources chasing irrelevant chronologies. By applying proper methods of delay analysis, including delay identification, the contractor, or the employer's team, can be focused and effective in identifying the events which are relevant to causation and damages.

Because of the cost implications as well as the potential liability outcome, the approach to delay cause identification must be both systematic and pragmatic. Notwithstanding the importance of this activity, it is also essential to keep a sense of balance and proportionality with regard to what is an appropriate cost to benefit ratio. Deciding what is appropriate is subjective and varies from person to person. If one party to a dispute decides to apply a disproportionate approach to identifying or measuring the impact of delays, it is unfortunate, but likely, that the responding party will have to respond in kind. The cost implications of applying a method of delay analysis which requires a disproportionate level of effort to prepare, respond to and develop during a hearing in arbitration or litigation, cannot be overstated. While proportionality should not be the only factor which decides the method of delay analysis to be applied, clients should be made aware in advance of the effort involved in order to avoid potentially unrecoverable costs.

Delay can take many forms and is described in various ways. Table 3.3 sets out some of the more frequently used delay definitions.

The creation of an as-planned versus as-built programme, as described previously, will provide a good initial view of where potential delay issues are likely to have arisen. Following the initial comparison of the as-planned versus as-built programme, or in parallel with it, initial interviews with project staff also provide valuable first indications of delay problem areas. Often there will be delay-specific issue files or correspondence relevant to time extension applications (or rejections) which will assist this initial analysis.

3.3.2 Recording delays

On any medium to large scale project there are frequently multiple potential causes of delay to be investigated which can number in the hundreds and occasionally thousands. From the initial as-built analysis it should be possible

Table 3.3 Types of delay.

Compensable delay
A compensable delay is one where a contractor is entitled to financial recovery in the form of direct and indirect time related costs arising from an employer risk event.

Concurrent or parallel delay
Concurrent or parallel delays occur when there are two or more independent delays during the same time period. Concurrent delays are significant when one is an employer risk event and the other a contractor risk event, the effects of which are felt at the same time.

When two or more delay events arise at different times, but the effects of them are felt (in whole or in part) at the same time, this is more correctly termed 'concurrent effect' of sequential delay events.

Critical delay
A delay to the progress of any activity on a critical path of a project which causes delay to the project completion.

Excusable delay
Excusable delay is a delay for which a contractor will have relief from damages (extension of time) and potential financial entitlement depending on contractual circumstances.

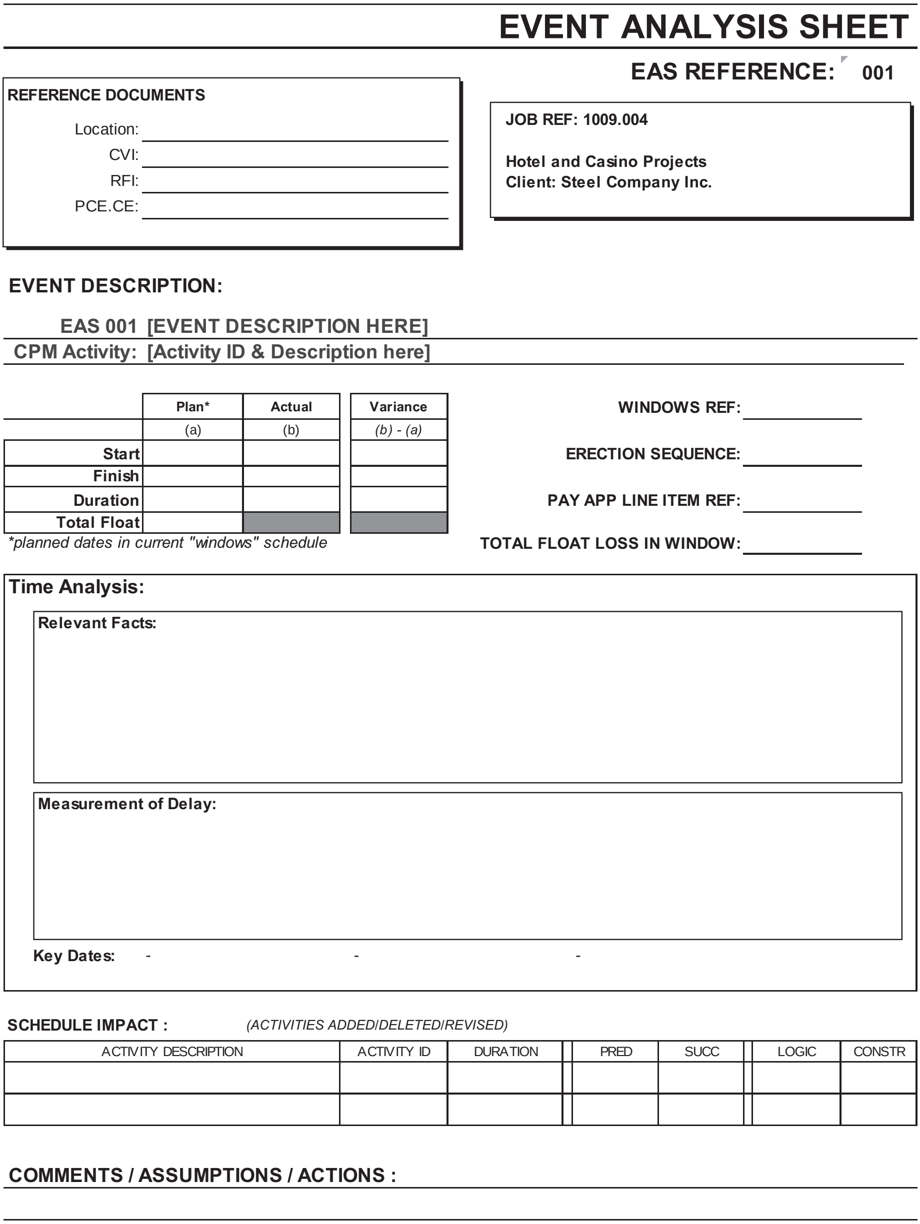
Non-excusable delay
Delay caused by contractor.

Global delay claim (total time claim)
A claim for the total project over-run, calculated by comparing the actual completion date with the planned completion date, where there has been no discrete causal link established between the delay claimed and the individual employer risk events relied upon.

Local delay
A delay to a group of isolated activities which are not on a critical path and which do not impact upon the planned completion date.

to identify a number of categories or areas of delay which require further research. From this analysis, preparation of issue chronologies, and a review of the available factual matrix, a list of potential delay events should then be created. For each potential delay event an 'event analysis sheet' should then be prepared (see Figure 3.8). The event analysis sheet assists in gathering all relevant information:

- documents;
- changes;



EVENT ANALYSIS SHEET

EAS REFERENCE: 001

REFERENCE DOCUMENTS

Location: ____
CVI: ____
RFI: ____
PCE.CE: ____

JOB REF: 1009.004

Hotel and Casino Projects
Client: Steel Company Inc.

EVENT DESCRIPTION:

EAS 001 [EVENT DESCRIPTION HERE]
CPM Activity: [Activity ID & Description here]

	Plan*	Actual	Variance
	(a)	(b)	*(b) - (a)*
Start			
Finish			
Duration			
Total Float		▨	▨

**planned dates in current "windows" schedule*

WINDOWS REF: ____
ERECTION SEQUENCE: ____
PAY APP LINE ITEM REF: ____
TOTAL FLOAT LOSS IN WINDOW: ____

Time Analysis:

Relevant Facts:

Measurement of Delay:

Key Dates: - - -

SCHEDULE IMPACT : *(ACTIVITIES ADDED/DELETED/REVISED)*

ACTIVITY DESCRIPTION	ACTIVITY ID	DURATION	PRED	SUCC	LOGIC	CONSTR

COMMENTS / ASSUMPTIONS / ACTIONS :

Figure 3.8 Typical event analysis sheet.

Ref No.	Cause and Effect of Delay or Disruption	Delay to Section or Part of Works	Delay to Completion Date	Contract Clause Relevant to Delay	Date of Delay Notice and Particulars
1.	**Under-slab drainage** Additional works arising out of discovery of ground beam clash	16 days	4 days	25 Relevant Event 25.4.5.1	Contractor's letters: 23 November 2005

Figure 3.9 Sample of delay register or schedule.

- contract entitlement clauses;
- programming information (including predecessors and successors); and
- actions required to quantify or verify the impact of the event.

Details of all the delay issues identified should be recorded in a delay register or table, similar to the one illustrated in Figure 3.9. This table is designed to capture all those delays, no matter how small, which could have contributed to the cause of the critical delay incurred. Effective project controls teams will keep live registers of 'early warning notice' files, 'P-Files' (Problem Files) or simply chronological issue files of potential problems throughout the course of the works. These projects are more likely to avoid long-term disputes due to the transparency added to the perspective of both parties allowing issues to be resolved in the first instance, on the ground level. If prepared forensically, a register of events should remain a working document throughout the forensic fact finding research phase and be added to or amended accordingly.

Delay registers can include additional information from the event analysis sheet, and can be as complex or simple as required. Once the initial list of delay issue files and event analysis sheets has been prepared, and the delay register is up and running, the main phase of forensic research can be undertaken. This essentially comprises a review of all job specific documentation, media and records demonstrating what actually happened. In the course of this exercise the delay analyst will require access to a wide range of records which may include categories of documents listed below in Table 3.4.

The listing in Table 3.4 is not exhaustive, but serves to provide an overview of the likely sources of data which will need to be considered for review. During the course of this research, some heads of delay initially identified may be dropped and replaced with new ones which have emerged. During this process the delay register and event analysis sheets should be developed, revisited and continually refined.

Once the documentation and records have been compiled, the next stage is to marshal this information into a format in which it can be used effectively, regardless of which delay analysis technique is being pursued.

Table 3.4 Categories of source data.

Tender documents:
- tender programmes
- drawings issued for construction

Contract documents:
- contract form(s)
- specifications
- employer's requirements
- contractor's proposals
- bills of quantities
- drawings issued for construction

Construction programmes:
- construction programme
- subcontractor programmes
- short-term programmes
- revised programmes
- updated 'as-built' programmes
- information required by

Project and site records:
- programmes
- project meeting minutes
- contractors' progress reports
- subcontractors' reports
- photographs and videos
- site diaries or logs
- job correspondence
- requests for information (RFI)
- labour returns
- drawing issue registers
- plant hire registers
- certificates (time and money)
- confirmation of verbal instructions (CVI)

Project documents:
- drawing revisions
- document/drawing transmittal sheets
- instructions
- design change orders
- project staff list and attendance record
- computer discs and hard-drives

Claim related records:
- computer-aided 3D simulations
- delay notices
- failure to release information notices
- claim specific files/documents (e.g. previous claim submissions, time extension awards)

3.4 Identification and analysis of disruption

3.4.1 Disruption and delay

Disruption and delay are two terms that are often used in the same breath. This is understandable as delay and disruption often result from the same events. However, disruption, unlike delay, has a direct consequence on financial loss. There are many reasons why delay events may not have a direct impact on the critical path or delay damages. Disruption on the other hand, once established, has a direct measurable financial consequence, even if concurrent or co-contributory culpable factors are present.

It is nonetheless important to understand and appreciate the significant difference between delay and disruption for the purposes of assessing the impact and quantification of the effects of each.

In construction, 'disruption' may be defined as an interruption to the flow, continuity or sequence of planned work; a bringing of disorder to an activity or project. Disruption may be a cause of delay, and delay may be a cause of disruption, but they are not one and the same. Like delay, disruption comes in many forms and demonstrating disruption is also more of an art than a science, much more so than the process of analysing delays. There are some guidelines and procedures that should be followed for an analysis to be acceptable and effective in demonstrating loss related to disruption.

Disruption is the act of preventing the regular flow or sequence of an operation. Simply establishing that disruption has been experienced is half of the equation. Like delay, disruption also requires the claimant to demonstrate entitlement, causation, and damages.

Disruption is often measured in terms of decreased productivity or loss of efficiency. The SCL Protocol defines disruption as:

> 'Disruption (as distinct from delay) is disturbance, hindrance or interruption to a Contractor's normal working methods, resulting in lower efficiency. If caused by the Employer, it might give rise to a right to compensation either under the contract or as a breach of contract.'

And:

> 'In the construction context, disrupted work is work that is carried out less efficiently than it would have been had it not been for the cause of the disruption.'

One of the main differences between delay and disruption in the context of construction delay analysis is that in the case of disruption the work activities or operations may not necessarily cause the construction completion date to be delayed; the works might be disrupted but the contract works could still be completed on time or indeed earlier than planned. In such circumstances, where the disruption was affecting non-critical activities, the contractor may well not have a claim for an extension of time, but rather a claim for the related costs of the reduced efficiency of labour and plant resources.

Alternatively the disruption may have impacted on a critical activity, but the application of more resources avoided critical delays. In practice, delay and disruption go hand-in-hand, with disruption often being the cause of critical delay. Delay analysis does not measure and identify disruption, but it may identify delay events, or factors, which cannot be quantified discretely, owing to layers of overlapping causes of delay and disruption interacting.

For example, if a critical activity is prolonged from 10 weeks to 20 weeks which results in a 10 week extension of time entitlement, examination of the reason for the prolongation may be that the work scope was doubled, or that the conditions under which the work was required to be carried out made it 50% less efficient than planned, requiring twice as many hours to do the original task. In this example, disruption was the cause of critical delay. If the contractor was able to double the amount of hours worked in the original 10 weeks, there may have been no critical delay, but the same level of disruption. For this reason, the effect of delay (time) and disruption (hours) must be analysed independently using different methods of analysis.

Both disruption and delay analyses should be approached in a common sense and logical way. The conclusions need to be understood by site management staff as well as head office staff, and potentially a third party tribunal. Disruption is a measure of lost production, pure and simple (input versus output). If more input is required to get the same output, there is disruption of some sort present.

Efficiency and productivity are often used interchangeably. This is not correct. Efficiency is a measure (ratio) of planned production compared to actual production. Productivity is normally measured as production per unit of effort or output divided by input (units/h). Productivity can also be expressed as input divided by output (h/unit). Efficiency is a measure of productivity, as a ratio or percentage during those periods. A control group or undisrupted period of production is usually compared with production actually achieved during a period of disruption. If target production is 10 units per day and actual production is 5 units per day, given the same input, the efficiency of operation would be 50% (5 divided by 10). If actual production was equal to the target production, given the same level of input, efficiency would be '1', or 100%.

Determining these ratios for discrete periods or on individual tasks is more complex and relies on accurate and comprehensive project records. The formula must take into account variable input (resources) as well as output (production). Organising the data to align the hours with a particular measurable unit of progress is often a challenge on projects of any size, and should be the focus of improved record keeping on projects (see record keeping in Chapter 4). However, merely keeping more records may be of no assistance to demonstrating disruption; it is the quality and relevance of the records that counts.

3.4.2 Calculating disruption

The following illustrates a calculation of disruption on a given scenario:

- 100 square metres of drywall is planned to take 8 hours with a two man crew. This equates to an input of 16 hours per 100 square metres.
- If actual production (output) is only 50 square metres of drywall in an 8 hour day with a two man crew then 32 hours input will be required for each 100 square metres of drywall.
- Efficiency is then measured as:

$$\frac{\text{Production Planned}}{\text{Production Actual}}\ \frac{100\ \text{units}/16\ \text{hours}}{100\ \text{units}/32\ \text{hours}} = \frac{1}{2} = 50\%\ \text{efficiency}$$

Disruption is a measure of the loss of productivity between the two production rates. Efficiency is the measure of the ratio of planned production to actual production, as set out above. The disruption experienced caused a loss of 16 hours for 100 square metres of drywall. This disruption factor could be expressed as a percentage of hours lost, when compared with the total hours spent (16/32), or alternatively, when compared with the total hours planned (16/16). In any case 16 hours were lost due to whatever disruption was present.

If efficiency is equal to one, the actual output is in a state of parity with planned output. If the efficiency is greater than one, then the actual output is better than the planned output, and so on.

Many in the construction industry often use the terms productivity and efficiency interchangeably. While they are relative measures of the same factors, they are different, and are expressed in different terms. Take, for example, a project that is forced into acceleration ('instructed or constructive'). To accelerate you must increase overall daily or hourly 'production'. Acceleration involves measures such as increased resources, plant, labour, supervision, overtime and additional shift working. Although acceleration requires increased production, acceleration is not synonymous with efficiency. In fact, acceleration is usually less efficient and more expensive, per unit of production, than normal non-accelerated working conditions.

When approaching a disruption claim the 'cause–effect' burden of proof is similar to establishing critical delay. Firstly it must be established that the event or factor causing disruption was a compensable event to satisfy a liability test. Secondly, it must be established that the disruption factor was actually present to satisfy the causation test. Lastly, the amount of disruption resulting due to that factor must be demonstrated to satisfy the damages test.

3.4.3 Establishing cause

There are many causes of disruption and factors that affect productivity (loss of efficiency) that may arise during the course of a construction project. Many of these factors are listed in Table 3.5.

Many of the above causes are similar to those associated with delay events. Decreased efficiency, however, is not always directly related to the original 'event' which caused critical delay, and vice versa. Disruption analysis should not be confined to events along the critical path as disruption can be experienced from events with no proximity to the critical path.

While the factors listed in Table 3.5 are fairly self evident they are by no means exhaustive. Liability for disruption caused by some of the causes listed may arise through poor on-site management. Any models attempting to

Table 3.5 Causes of disruption and loss of efficiency.

- Late design
- Inaccurate detailed drawings
- Rework/corrective work
- Ripple effect of multiple changes
- Delayed or hindered access
- Adverse weather (usually severe)
- Environmental conditions
- Crew overloading/crowding
- Out of sequence working
- Learning and ‘un-learning’ curves (learning curves repeated)
- Fatigue (overtime/shift working)
- Dilution of supervision
- Stacking of trades in confined space
- Repeated learning cycles or curves
- Out of sequence access to work faces
- Congestion at work faces (confined space, confusion, safety hazards)
- Stacking of trades (activities, accomplished concurrently)
- Increase in labour gangs or labour force (above optimum levels)
- Increase in shifts
- Out of sequence working or changes in sequence of works (based upon industry standards and practice)
- Changes and variations to work scope
- Changes in working conditions (e.g. restricted working hours)
- Discovery of hazards
- Premature moves between activities
- Work carried out in less than ideal conditions
- Double handling of materials
- Constructive changes
- Contract changes
- Overinspection
- Works undertaken by others
- Fatigue
- Joint occupancy
- Beneficial occupancy
- Morale and attitude
- Reassignment of manpower
- Crew size efficiency
- Dilution of supervision
- Interruption of job rhythm
- Overtime (physical fatigue and depressed mental attitude)
- Acceleration
- Revisits or re-doing work (morale issue)
- Excessive rework

calculate disruption should be capable of isolating the loss experienced due to both excusable, and non-excusable factors.

Establishing the presence of the factors that cause disruption requires the same entitlement arguments and factual evidence as any delay event would when advancing an extension of time claim. Establishing the level or the loss due to disruption may be dependent on expert evidence if there is no agreed model or method for quantifying the effects of those factors in advance. A number of approaches have been developed for use in efficiency analysis which include:

- the measured mile;
- measured productivity method;
- work sampling;
- modified total cost approach; and
- site sampling (time and motion studies).

Additionally, a number of industry studies have been carried out and published by various organisations providing standard losses which can be expected for various disruption factors. A contractor must establish the relevance of these studies if they are to be used for claiming losses due to disruption, prospectively or forensically. The following bodies have published tables and guidance for predicting the effects of various disruptive factors:

- The Mechanical Contractors Association (MCA)
- The Business Roundtable, Bulletin 917
- The National Electrical Contractors Association
- The Chartered Institute of Building (CIOB)
- US Department of Labor

Each of these studies has different applications and should be used cautiously in conjunction with factual evidence demonstrating that disruption in fact occurred. The use of this data will also be more effectively applied by those familiar with the factors as well as the type of operation which was disrupted.

The approach for quantifying the impact of disruption which has been relied on by the court more than any other in recent years is the ‘measured mile’ approach. The measured mile approach compares work performed in one period not impacted by events or factors causing loss of productivity with the same, or similar, work performed in another period that was impacted by disruptive events or factors. Due to its reliance on relevant factual evidence and historical data for a particular project, the measured mile approach is one favoured by many. This method requires a period of uninterrupted performance and sufficient cost records to measure productivity. A more detailed explanation of this method is contained in the following sections.

Another approach accepted by the courts is based on reliance upon the MCA publication, *Factors Affecting Labour Productivity*. The MCA guidelines set expected loss of efficiency for 16 disruption factors on a scale, depending on whether the frequency or magnitude of the factor is assessed as ‘minor’, ‘average’ or ‘severe’.

3.4.4 Total cost claims/global claims

A technique traditionally used for measuring disruption (and still practised today) is one which, in its simplest form, comprises a comparison of the planned spend to the actual spend, and claiming the overspend on labour as the loss experienced due to disruption. In this situation a contractor seeks simply to recover the difference between anticipated and actual labour costs. Total cost claims are often packaged as something other than global claims. Nonetheless, whichever form it is presented in, this approach is generally known as a global or rolled up claim.

One form of the total cost claim which is attempted when apportioning losses discretely to each event or factor is a 'cumulative effect' claim. This is also known colourfully as the 'death by a thousand cuts'. When applying this form, a contractor may have received 100 instructions which varied the work, and had the effect of disrupting the work each time a new instruction altered the works, and so increased the overall volume of work. The disruptive effect of each one of these 100 variations, in isolation, may have been minimal. If a global assessment is attempted, the contractor would simply make a single claim for the total of the increased costs, alleging that all of the increase was due to the combined effect of the 100 changes, rather than claim for each individual variation.

A more sophisticated application of this approach has been developed and is referred to as a 'top down', or 'modified total cost claim'. When a modified total cost claim is presented, it relies initially on the total cost differential, but then subtracts any culpable costs incurred as a result of contractor risk events. The balance is claimed as compensable disruption. In any form of the top down approach, the contractor starts with the total cost, and subtracts from that as many known discrete costs as possible, both CDE and EDE. By using this approach, the contractor can reduce the severity and relevance of the common criticism of a typical total cost claim and the usual defence raised against it.

In a recent Scottish case (*Doyle* v. *Laing*),[3] the court confirmed that the logic of a global claim required that all the events which contributed to the loss arising from the global claim must be compensable events. In that case it was stated that:

> 'The global claim may fail, but there may be in the evidence a sufficient basis to find causal connections between individual losses and individual events, or to make a rational apportionment of part of the global loss to the causative events for which the defender has been held responsible.'

The court thus allowed the claim to proceed. Secondly, a common sense approach to causation was referred to when it was held that:

> 'if any event or events for which the employer is responsible can be described as the dominant cause of an item of loss, that will be sufficient to establish liability, notwithstanding that other events played a part in its occurrence.'

In the commentary leading up to the decision, it was observed that there is a burden of proof which must be met for a total cost claim to succeed in its entirety. This burden is that:

- the bid must be shown to be reasonable;
- the actual cost must be shown to be reasonable;

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[3] *John Doyle Construction Ltd* v. *Laing Management (Scotland) Ltd* (2002).

- all events contributing to the loss must be compensable;
- it must be demonstrated that there is no other way to calculate the bid; and
- it must be established that the contractor did not contribute to the increased cost in any way.

The global approach assumes that a number of EREs had the aggregate effect of increasing the contractor's costs above the tender allowances. Unless one of the modified approaches described above is applied, this technique does not automatically make allowance for disruption or increased costs caused by non-excusable events (e.g. poor site management, plant breakdown, inappropriate plant selection, labour shortages or bad weather). In a nutshell they fail to show a direct link from the events relied on to a discrete loss.

The problem with the top-down approach is that there will always be a remaining portion of the claim which is not allocated to each individual event (e.g. each variation instruction or disruptive issue).

When the claim value is built up, event by event, this is said to be a bottom-up approach. There are hurdles to cross with the bottom-up approach as well, such as avoiding double recovery, establishing reasonable rates when estimates are relied upon, and demonstrating the applicability of bill rates.

Similar to delay analysis, this approach finds only limited support in the courts, where there is an overwhelming requirement to show discrete causation, by linking the cause to the effect of each event or factor relied on. The principles and validity of global or rolled up claims are shaped by case law both in the UK and the US. While it is not the purpose of this book to provide a legal case law commentary on the development of planning and programming principles, there are a number of interesting cases which mark the narrow acceptability of global claims under certain circumstances and which are worth referring to. The first case which gave legal validity to global claims was *Crosby* v. *Portland* (1967).[4] However, it should be remembered that information and document processing technology, together with mobile communications as we know them today, were virtually non-existent at the time of this case. A second English case[5] some 18 years later applied and approved the rolled up claim approach as enunciated in Crosby, but again emphasised that such claims:

> 'can only be made in the case where the loss or expense attributable to each head of claim cannot in reality be separated and secondly, that a rolled up award can only be made where, apart from that practical impossibility, the conditions which had to be met before an award can be made have been satisfied in relation to each head of claim.'

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[4] *Crosby and Sons Ltd* v. *Portland Urban District Council* (1967) 5 BLR 121.

[5] *London Borough of Merton* v. *Stanley Hugh Leach Limited* (1985) 32 BLR 51; (1986) 2 Const. L. J. 189.

Notwithstanding the significant leap forward in information technology and communication systems, there have been more recent cases involving global claims. Moreover, the principle that a global claim may be advanced under the right circumstances remains the current position. The objective of compensation for disruption is to put contractors in the same financial position they would have been in if the disruption had not occurred.

In summary, if a claimant hopes to succeed with a global or rolled up claim (and rely on the principles established in the *Crosby* and *Leach* cases) his chances of securing an award will be that much stronger if he has properly identified the disruptive factors (e.g. employer risk events) and attempted to break the project, events and losses down into manageable bite-size windows, in accordance with Lord McFayden's findings in *Doyle* v. *Laing*, as referred to above. Even if he has found it impossible to allocate financial consequences to each head, part of the global claim may still succeed in establishing some level of financial recovery. Also, if the contractor contributed to the overall loss for which the defendant has no responsibility, these elements are required to be identified and excluded from the global claim wherever possible.

Due to the limited costs involved in preparing global claims, they will most likely continue to be predominant in construction disputes.

3.4.5 Measured mile

One of the favoured techniques for analysing disruption is the 'measured mile'. When carrying out a measured mile analysis, the main goal is to compare the actual hours spent, and output achieved, during a period unaffected by disruption events with the hours spent and output achieved in a period which was affected by disruptive events. The production achieved during the unaffected period is said to be the measured mile. The difference between the effort required during the measured mile and the disrupted period is established, and claimed as the loss associated with the disruption factors present in the affected period. This approach is endorsed by the SCL Protocol, as well as US Federal courts.

The measured mile approach relies on the accuracy and completeness of contemporaneous records as well as the skill and care of the analyst so as to avoid garbage-in/garbage-out conclusions. Additionally, the process relies on transparent data, to allow the underlying assumptions to be tested and challenged as necessary. Typically, the quality of the data will define the precision or duration of the periods being analysed. For instance, if weekly labour returns were available, and corresponding weekly progress reports were available, it would be possible to measure efficiency achieved on a weekly basis. Alternatively, if the only true measure of progress is by way of monthly pay applications, the accuracy will only be possible to the month, and attempts to analyse the data more precisely will result in 'adding science where there is none'. If assumptions are required to analyse data to a higher level of precision than represented by the data available, these should be stated clearly, and ranges of opinion should be presented in the event that the assumptions are proven unreliable.

One frequent problem is the standard of contemporaneous records kept. To show confidently that a tradesman worked at a certain output during an undisrupted phase and later to record accurately his output during the disrupted period would require meticulous and diligent record keeping more akin to a factory shop floor 'work study' standard than a building site. In addition, a further hindrance for a main contractor is that records which might usefully indicate productivity performance are usually maintained by the subcontractors and are consequently not readily available.

It is important to compare like with like, that is similar parts of the works, to avoid distortions such as would occur for example if a part of the works selected as the unaffected part were measured during a period when a learning curve was taking place. Care must also be taken to factor out unrealistic construction programme expectations and inefficient working outputs.

If a project has been so heavily disrupted that it is not possible to identify a part of the works that has not been affected then it may be possible to compare the productivity on other similar projects. This would of course depend on the quantity and quality of the records available and whether they were able to demonstrate that the job was sufficiently similar to the disrupted job. Alternatively it may be possible to use other norms such as productivity model data (e.g. productivity curves and standard production rates) developed by various organisations. Such comparisons must take into account the type of construction and working conditions and determine whether they are relevant to the task being measured. This chapter is not intending to validate, or promote, the use of such standard production and efficiency ratings. These standards should be used with caution, supported by expert evidence and contemporaneous observations and records, and should only be relied on when factual evidence does not allow a measured mile to be established, or to corroborate other methods of calculating efficiency.

It is important to use actual site productivity during un-impacted periods as the comparative measure and not tender rates/outputs. Tender rates may not have been achievable, and may contain assumptions that are not relevant to the actual scope and site conditions. If the measured mile establishes that the tender rates were overly optimistic, an adjustment must be made if any damages are to be calculated on the basis of tender rates.

An example of the measured mile approach in use is given in the following. Firstly, there is an example of the disruptive effect of acceleration on labour productivity and secondly, an application of the measured mile approach when acceleration is present.

Figure 3.10 illustrates a case history where the number of resources (men) per floor was increased from 22 to as many as 78 men to accelerate the project. The line connecting each block is a measure of the efficiency of each man (measured in £ earned for each hour expended) for the full duration of the

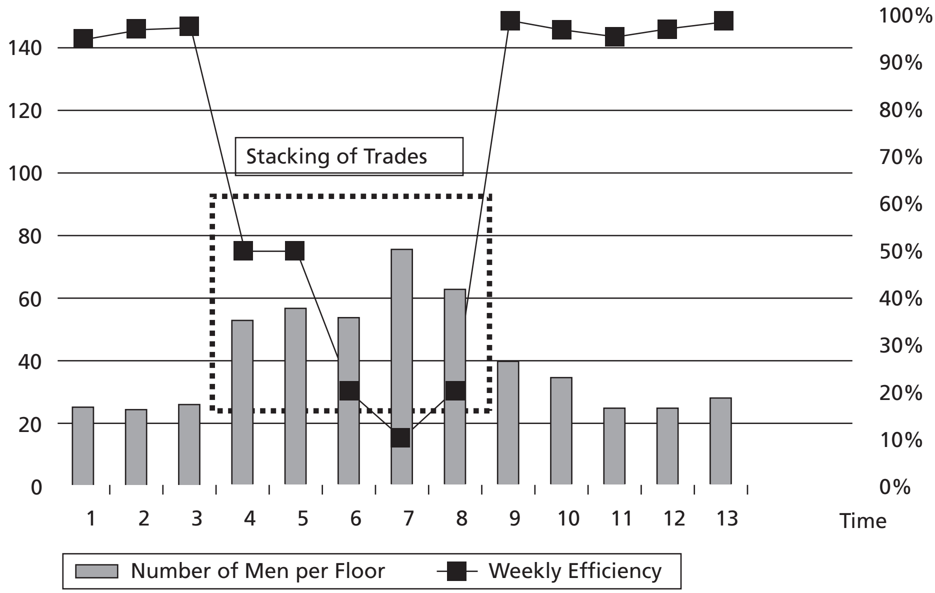

Figure 3.10 Stacking of trades.

13 week task. The presence of 'crowding' as a disruptive factor was identified in weeks 4 through 8. Although this example may be an extreme case, the effects of crowding resulted in deceleration and resulted in lower output per man as well as a delay to the works.

In the example in Figure 3.10, the progress per man was also affected by other factors such as the dilution of supervision (more men per supervisor) and the lack of sufficient detailed design to support the proposed acceleration. Because the disruption was made up of many factors, the measured mile approach was deemed to be acceptable. Identification of each hour lost due to each factor discretely would have been impossible.

Figure 3.11 represents a simplified application of the 'measured mile' approach on the same project. The project did not have an as-planned or as-built CPM programme, but did have good plant and labour returns, and payment records. Using these records it was possible to demonstrate when the project would have finished 'but for' the disruptive factors that were present and causing both delay and disruption. The dotted line represents the theoretical progress that would have been achieved. From these curves we were able to compare the productivity (slope) of the two lines to determine the decreased efficiency that resulted in the 'period of inefficiency'. This demonstrated and quantified the number of hours that were 'lost' to inefficiency.

The measured mile technique has been the preferred approach recognised in many cases in which reliance is placed on either the productivity achieved

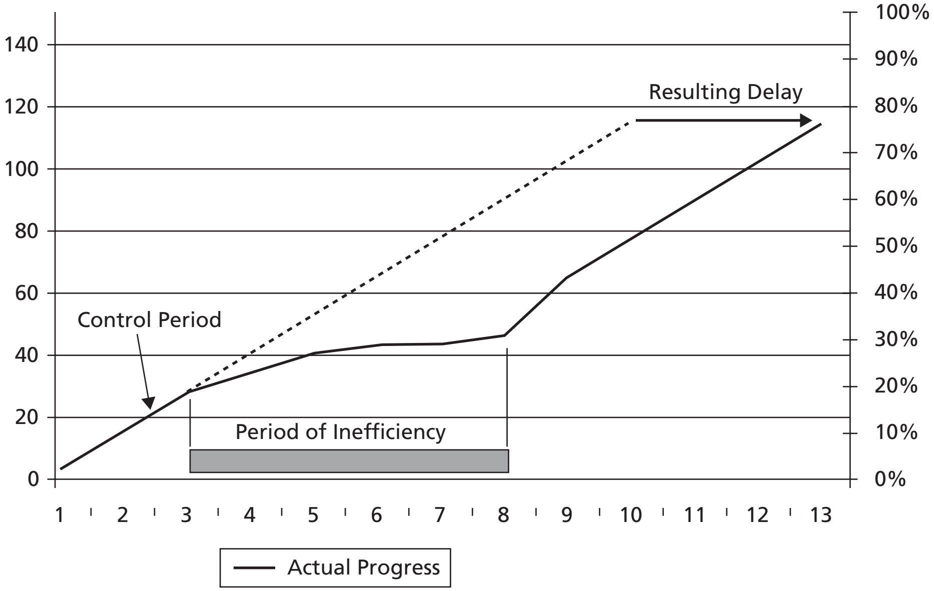

Figure 3.11 Disruption – measured mile.

during un-impacted periods[6] or tender allowances (or both[7]). In the case of *Clark Construction Group Inc.*[8] there was no period of undisrupted progress to rely on as a control group and the MCA guidelines were used as an alternative approach.

The MCA approach

There is no guarantee that MCA, Business Roundtable or other productivity models will be applicable to a project under analysis and they should therefore be used with caution. In the US case *Hensel Phelps*[9] these issues were covered and it was stated that:

> 'because acceleration took place while the work was being impacted by various delays and disruptions, it was extremely difficult to separate acceleration costs from impact costs.'

Hensel Phelps advanced a claim using the MCA guidelines and it was decided that 'there is considerable merit in the approach' and where the contract 'calls

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[6] *Whittal Builders Company Ltd* v. *Chester-Le-Street DC* (1985) 11 CLR 40.

[7] *How Engineering Services Ltd* v. *Linder Ceilings, Floors and Partitions* (1999) 64 CLR 67.

[8] *VABCA-5673-5676, Clark Construction Group Inc.* v. *VA Medical Center*.

[9] GSBCA 14744, 14877, January 11, 2001.

for adjustment of the contract price to reflect increases in the contractor's cost of performing work whether or not that work is changed' and 'where the parties are committed to assessing the impact of change or disruption on unchanged work, we have no objection to a qualified expert using these factors for that purpose.' These findings were recently supported in the case of *Ace Constructors* in 2006.[10]

Additionally, Lord Justice Carnwath concluded that:

> 'There might be lessons to be learnt from the progress of this reference and appeal. If, as here, the parties were intending to rely on a complex valuation exercise, based on a computer model, it was of the utmost importance that they should seek to agree a common model.'[11]

When measuring productivity it is essential to the reliability of the results to supplement any empirical or hypothetical data with experience and knowledge of the specific project or activity being measured. Where practicable it would clearly be advantageous to agree with an opposing party as soon as possible the model, curve or guidelines to be used to estimate the effect of disruption and inefficiency.

3.4.6 Graphical presentation

The adequacy and necessity of quality contemporaneous records has been referred to previously. Good records go a long way to providing the source data required from which to calculate any recoverable loss entitlement. However, it is not just the records, kept well, badly or indifferently, that will determine the outcome of a claim, but also how they are analysed, sorted, collated and presented.

To assist in the fast and efficient presentation of this analysed data the use of computer generated graphical presentation is important. Whilst there must always be a sound and checkable audit trail behind any graphic used to support a claim, their use in the early analytical stages provides an excellent way of quickly getting to the heart of a claim for disruption. A number of examples are given in the following text, but this is by no means prescriptive and any graphic that speeds up claim preparation and presentation should be considered. The corollary of this is that graphics which have been prepared carelessly should be treated with caution as they may obfuscate or even contradict the claim being made.

One of the all-important tasks with a disruption claim is to link the loss suffered with the cause. With prolongation claims the task is perhaps a little

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[10] Ace Constructors Inc, United States Court of Federal Claims, No. 04-299C (March 31, 2006).

[11] *Railtrack plc* v. *Guinness Ltd* (2003) 1 EGLR 124.

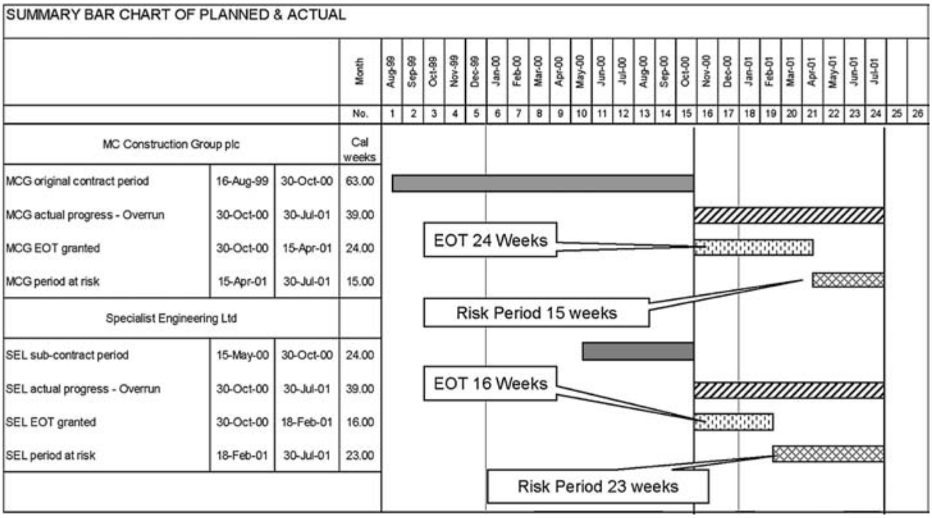

Figure 3.12 As-built programme summary.

easier, but disruption not so, particularly if there is a multitude of events or indeed a consistent flow of disruptive events throughout the course of the works which have resulted in additional costs but no obvious cause.

There are a number of approaches that can be used depending upon the nature of the events leading to the disruption and the raw data available. Many contractors' claims fail because they amount to little more than a total cost or global claim. That is where the claimant claims the total cost of his actual spend less the original contract sum.

In Figure 3.12 a summary as-built programme has been prepared which shows over-run periods on both the main contract and the subcontract. The subcontractor is a mechanical and electrical specialist and has incurred an over-run of 39 weeks. An extension of time has been granted of 16 weeks, leaving a shortfall of 23 weeks which is determined to be at the contractor's risk. This scenario is the starting point for both delay and disruption analyses.

Figure 3.13 is an example of a labour histogram of planned and as-built labour for the mechanical works. The light grey line represents the planned level of effort, expressed in man-hours, required to complete by the original completion date of 30 October. The dark line shows the actual level of effort (hours) expended. In this instance it appears that the labour hours did not increase dramatically, but the works were severely delayed with resultant additional time related damages. Also the actual effort histogram indicates a fluctuation of man-hours, as well as an unplanned period of inactivity during the holiday period December/January that had not been allowed for. Each of these results in inefficiencies related to learning-curves (when new resources

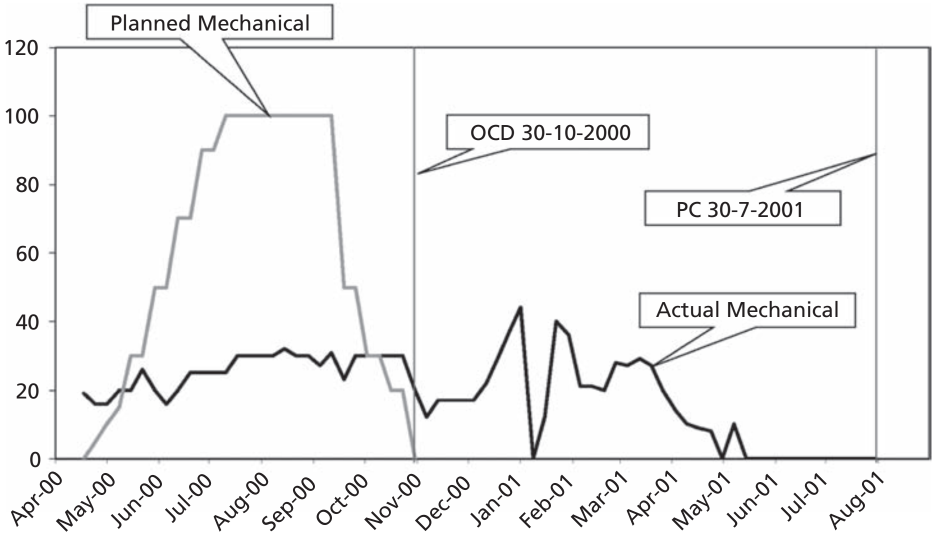

Figure 3.13 Labour histogram for mechanical labour hours.

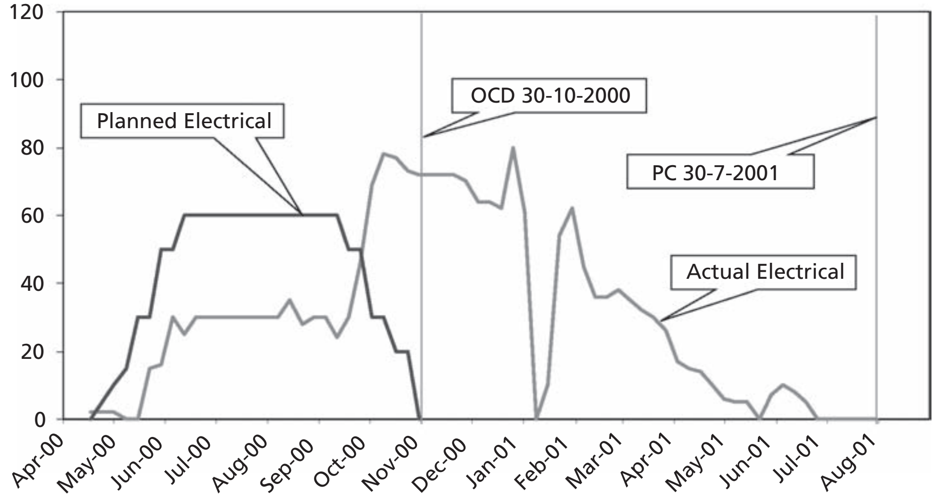

Figure 3.14 Labour histogram for electrical labour hours.

are recruited), discontinuity of work, re-allocation of manpower, demobilisation costs, remobilisation costs and other related factors.

A similar histogram was prepared for the electricians' hours. Here the picture is somewhat different as illustrated in Figure 3.14. In this case the planned hours have been significantly exceeded, and the holiday 'slow-down/start-up' curve is that much steeper.

These graphics do not prove entitlement. However, they are important when identifying the periods in which disruption occurred, and the potential cause.

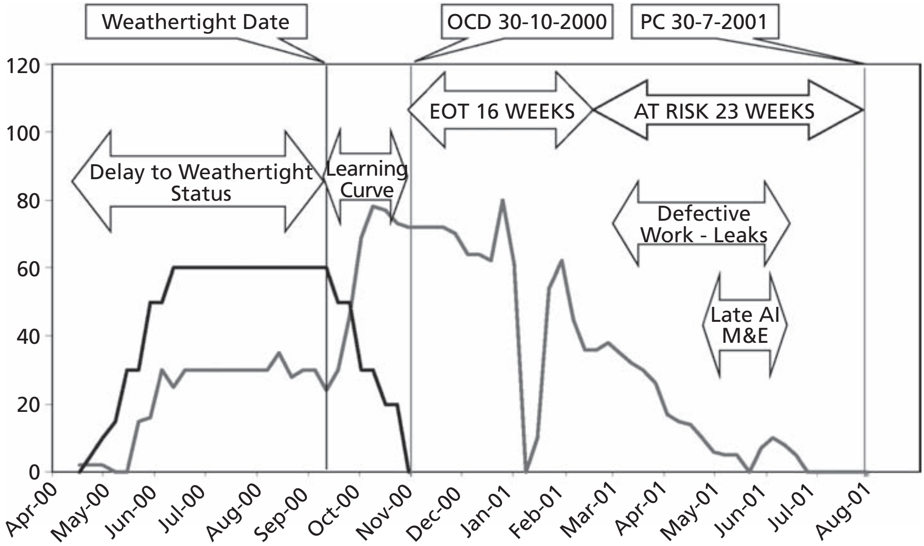

Figure 3.15 Labour histogram for electrical labour hours with additional information.

Of course the causes can be manifold and indeed there can be a combination of factors including:

- the instruction of additional works;
- the actual conditions in which the works were required to be carried out;
- logistic or access restrictions; tender deficiency;
- inadequate supervision; and
- insufficient co-ordination of the works.

In the final illustration of this sequence a little more data has been added to the histogram chart. Figure 3.15 shows the subcontract delay periods imposed on the time line together with a number of initial potential delay heads of claim. This type of chart is also a useful illustration of the close relationship that can exist on occasion between delay analysis and disruption analysis where a number of disruption issues may also be common with delay issues. This simple example indicates that there was an access problem early on indicated by the late 'weather-tight' status being achieved. The chart later also indicates potential culpability where a 'defective works – leaks' issue will have to be investigated.

In the chart in Figure 3.15 a summary resource profile has been overlaid with the findings of extensive analysis of contemporaneous documents to conclude that there were delays and inefficiency experienced due to:

- delayed weather-tightness of the facility;
- increased learning curve due to late access being provided;

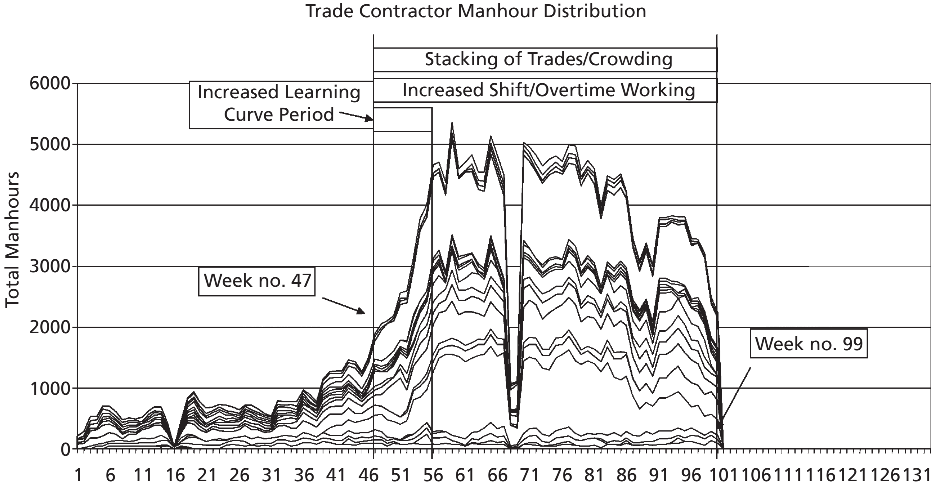

Figure 3.16 Illustration of multiple trade labour distribution.

- defective works (leaks); and
- late instructions to mechanical and electrical works.

While illustrations alone cannot convey liability, causation and damages, they assist in reducing down the evidence and conclusions into a readily accessible format. This in turn assists in the conveyance of complex details about the case and the analysis of the available progress data. When charts are illustrated in colour this adds a useful dimension in terms of reading and interpreting the data so displayed. Further, more sophisticated analysis charts are shown in Figures 3.16 and 3.17. These diagrams illustrate models which were produced for live commissions and indicate the different way in which quite complex and 'fairly dry' evidence can be effectively communicated.

Figure 3.16 illustrates all of the various trade contractors (in various shades) and the periods in which various disruption factors were identified as being present, including 'increased learning curve', 'stacking of trades/crowding', and 'increased shift/overtime working'.

Care must be taken with the use of graphics as it is easy to get carried away with the vast capability offered by information technology. All charts used should be fully explained and with full back up available of checkable source data.

The illustration in Figure 3.17 shows, cumulatively, the amount of hours spent, and lost, due to five overlapping and interacting disruption factors. The total amount of hours spent (60,000) can be seen alongside the amount of 'productive hours' (approximately 40,000). These remaining productive hours

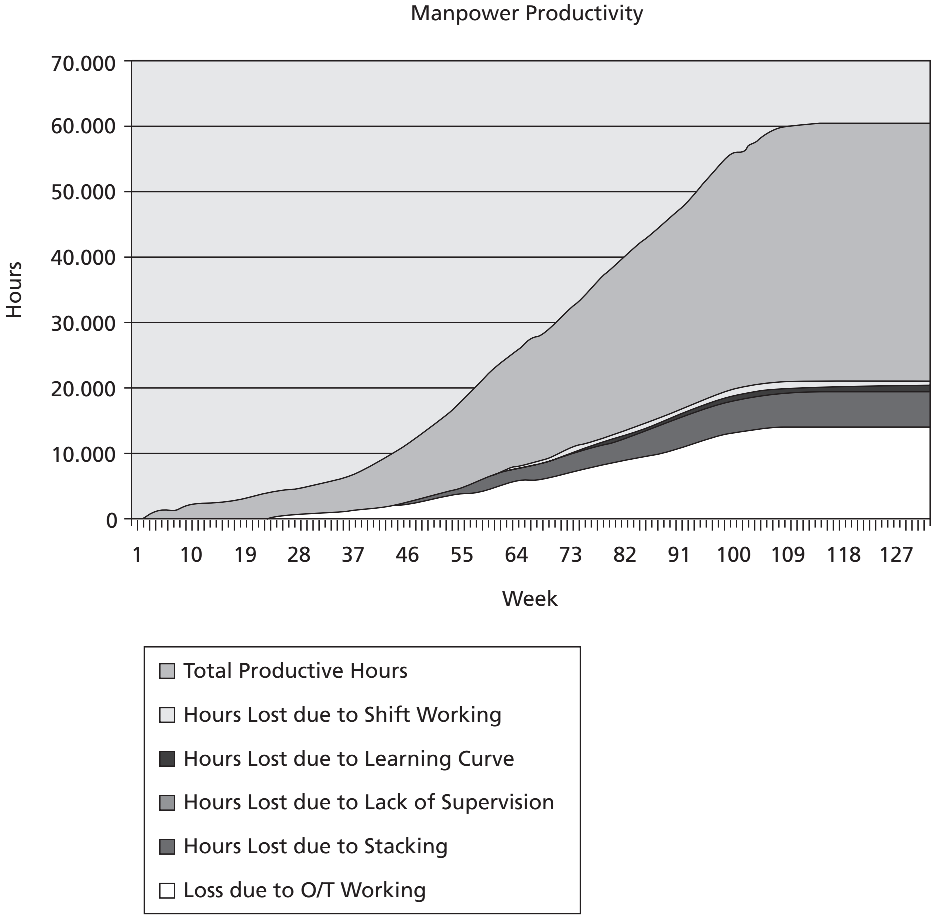

Figure 3.17 Productivity curves.

can then be compared with the tender to determine if the amount of hours spent, productively, is in alignment with the amount of hours in the contractor's tender. Whatever the approach adopted, contractors should show they have considered and if necessary taken account of:

- tender sufficiency;
- efficiency of own and any subcontract labour performance; and
- sums recovered through variations or separate agreements, i.e. acceleration.

Whilst relatively modest claims will benefit from a simple approach, more complex and high value claims may benefit from the use of more sophisticated techniques and presentation. For example, multi-million pound disruption claims on major projects could well benefit from the use of computer generated 3-D virtual graphical display models which would speedily show a dispute decider sequences of events in far less time and more effectively than reading the data (i.e. contrasting as-planned with as-built sequences and the impact of various acts of prevention). The cost of this technology continues to come down lowering the threshold whereby it becomes a cost-effective tool.

Another important aid in presentation of disruption is the all important photographic record. With the advent of cheap digital technology there is now very little excuse for not keeping comprehensive progress photographs. Photographic evidence, when used judiciously, is an excellent method of demonstrating facts, for example site conditions, progress, dangerous working environment etc. Photographs have their place in virtually any size claim.

3.4.7 Summary

In summary, disruption claims can be more difficult to establish and prove than delay claims. An analytical approach will go some way to either 'shaking out' poor claims, or gathering, in a logical way, the necessary evidence required to support a claim for disruption and compensation. In analysing disruption claims, the focus is not upon the construction programme but upon labour hours and supervision. Thus three initial steps are suggested before embarking on the full analysis:

- as-planned labour estimate – validate the estimated labour hours and costs (this is in anticipation of a defence that the planned estimate was insufficient);
- identify actual hours and costs expended on the project – remove hours recovered elsewhere (e.g. through variation accounts or side agreements) to allow for an 'apples to apples' comparison, and to prevent any potential double recovery of hours; and
- identify labour cost over-runs to the highest level of detail required – to allow the losses to be attributed to specific incidents of delay or factors of inefficiency.

This should allow the analyst to establish the magnitude of the cost over-run as a fact (assuming the contractor's records are accurate) and the period in which the costs were experienced.

When measuring productivity it is essential to supplement any empirical or calculated inefficiency data with experience and knowledge of the specific project or activity being measured. Agreeing the model, curve or guidelines to be used to estimate the effect of disruption will avoid disputes and arguments regarding the method rather than the underlying facts.

Identifying recoverable loss and expense is directly dependent on establishing the actual amount by which contractors are 'out of pocket' compared with where they would have been had the disruption caused by employer risk events not occurred. It is the equivalent of common law damages and not a payment for extra work or expenditure in the same way as a variation. That said it is not easy to ascertain in the same way as a variation, particularly where it relates to inefficiencies caused by multiple overlapping and interacting factors.

Chapter 4
Analysis of Construction Delays

4.1 Introduction to delay analysis techniques

Delay analysis techniques are known by many generic titles. Each method can be applied in several ways and the widely known methods of delay analysis are subject to frequent misuse. The application of the same technique by two opposing experts often produces varying and inconsistent conclusions. The name applied to a technique is not as important as the application of that method. While there are many variations on the themes, all of the commonly applied forensic delay analysis techniques generally conform to one of the following primary categories:

- Impacted As-Planned
- Collapsed As-Built
- As-Planned versus As-Built
- Time Impact Analysis

Many in the industry also list ‘windows analysis’ as a technique, but the term ‘windows’ simply refers to the period of time being analysed. Windows can be identified at regular intervals (e.g. weekly, monthly) or irregular periods determined by the completion of significant key tasks (e.g. the achievement of a key milestone). When key milestones are relied on, the same approach is sometimes referred to as ‘watershed’ analysis. The use of watershed analysis instead of windows analysis could be indicative that the nature of the project has changed in some way, following the completion of a major milestone. For instance, delays during the design phase will require a different form of analysis than delays experienced during the construction phase. Similarly, the nature of delays experienced during start-up and commissioning, will be different from delays experienced during the earlier construction and design phases. The transition from one set of tasks (construction) to another (commissioning) could be said to be a watershed. The form of analysis carried out between each watershed can vary, but will require a derivative of one of the above four primary forms of analysis to quantify the delay experienced in each of these ‘windows’ of time.

Each of these primary techniques have many secondary derivatives, depending on the number of delays being analysed, the frequency and/or duration of the windows, the time periods being analysed, and whether they are to be

Table 4.1 Categories of delay analysis.

General Approach	Primary Method	Secondary Derivative Methods
Additive	Impacted As-Planned	Chronological Addition of Delays (one at a time) Gross Addition (all delays at once)
	Time Impact Analysis	Chronological Event Analysis Watershed Analysis Windows Analysis Contemporaneous Impact Analysis
Subtractive	Collapsed As-Built	Chronological Insertion of Delays (one at a time) Gross Insertion (all delays at once) Windows Analysis (delays in each window)
Analytical	As-Planned vs As-Built	Contemporaneous Float Mapping As-Built Critical Path Deduction Total Time Claim (gross difference) As-Planned vs Contemporaneous Updates Gross time reconciliation (total time claim)

applied prospectively (contemporaneous, forward-looking, predictive modelling) or retrospectively (forensic, after the fact analysis, as-built delay modelling). In Table 4.1 the primary categories are listed along with some of the more commonly applied derivatives of each. These have also been sorted into the general approach applied, namely ‘additive’, ‘subtractive’ and ‘analytical’.

The strengths and weaknesses of each of the primary methods will be discussed further below along with a step-by-step approach for carrying out a few of the secondary derivative methods. While there is much guidance on the pros and cons of the primary methods, few publications provide guidance on step-by-step applications of these secondary derivates.

While this chapter explains not only how to carry out and present several secondary derivative methods, it also contrasts the strengths and weaknesses of each method and considers the underlying assumptions the analyst must make when using any of these techniques. Whichever process of delay analysis is used, it should be readily understood by any construction or legal professional. The process should be auditable and capable of being recreated from the same factual matrix and critical path method programmes, and the assumptions made should be transparent and documented at every stage. These underlying assumptions are often not documented as part of a contractor's submission and are only uncovered through unnecessary and painstaking analysis and research by opposing experts. The lack of auditable transparent processes has resulted in the term 'delay analysis' being equivalent to a 'dark art' to many in the industry. The following chapters will shed some light on these dark arts to assist attorneys, owners and construction professionals peel away the layers and simplify even the most complex forms of delay analysis.

4.1.1 The use of CPM techniques

One of the earliest books[1] on the application of critical path method (CPM) scheduling or programming opens with the acknowledgement that 'Scheduling continues to be more of an art than a science'. This was the view held in 1969 by one of the earliest champions of CPM scheduling usage on construction projects when CPM was still gaining ground as a standard in the industry. Not long before this (1966), the view held by others was:

> 'at or about the time of contract, a programme is required of the builder. This programme will be produced and agreed. But such agreement cannot be undertaken at this stage except by collusion in acceptance of unreality by all parties. It is not possible to put exact dates to specified phases of the project at this time. The future holds too much uncertainty'.[2]

While this statement is not entirely supportive of the reliability of CPM scheduling, both statements could be said to be still true today, 40 years later. CPM scheduling is still an art and it is not capable of predicting the future. The practice of CPM scheduling is supported by many international professional bodies[3] though not regulated by any one institution.

Firstly, one must accept that a CPM programme is simply a model of only one possible sequence of events required to complete a given project. The assumptions that were relevant to establishing that sequence are also relevant to the analyst carrying out a forensic delay analysis. Each assumption relied upon when creating the original CPM programme (e.g. labour levels, activity durations, activity sequences and relationships) are risks which could be affected by unforeseen events, conditions, or implemented change. These all require management, regular monitoring and intervention to keep a project on course or move the goal-posts when necessary. These assumptions and man-

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[1] O'Brien, James. *CPM Scheduling Handbook*, 1969.

[2] Tavistock Institute, *Interdependence and Uncertainty*, 1966.

[3] PMI-COS, AACEI, ASCE, PEO, CIOB, ICE, CMAA, AGC, RICS.

agement interventions all have a bearing on the actual performance on-site and the as-built critical path.

The CPM programme allows float values of both critical and near critical work to be identified at a given point in time. Float values of individual activities are influenced by many factors, including constraint dates, calendar assignments, resource assignments, imposed float constraints and CPM calculation protocols, such as 'retained logic' or 'progress over-ride' calculations. These influences have been exacerbated by the functionality of today's CPM programming and project management. Float is therefore a relative value, indicating which activities are more critical than others at that point in time. The movement of the completion date from month to month is an absolute measurement. Float values are influenced by working calendars, activity durations, start or finish constraints, float constraints, absolute (hard) logic, preferential (soft) logic and other imposed deadlines, such as project-wide 'must finish by' constraints.

CPM programming is the tool which identifies activities as being either critical or non-critical. The CPM schedule therefore is the key to demonstrating those events which caused delays to the critical path and thus to completion, and those which did not. While common sense and experience are essential, quantifying the impact of events must be based, in whole or in part, on sound CPM calculations. Using CPM programmes to demonstrate delay has been a requirement in US courts for some years to the point where delay analysis in US courts almost exclusively relies on CPM methods. It is recognised in the UK courts, the Technology and Construction Court (TCC), that a delay must be shown to be critical in order for it to be relevant for an award of time, or time-related damages. There are still fundamental differences between US and UK views on legal matters related to a contractor's right to early completion, as well as established US doctrines on 'cardinal change', 'abandonment of contract' and 'impossibility of performance'. Where these issues are relevant to delay analysis, they will be addressed in Chapter 5.

It is commonly accepted that events which delay critical tasks also delay the project completion (i.e. by extending the critical path). When quantifying the impact of contractor or employer risk events, each 'delay event' must be clearly identified as a task, and all must be analysed chronologically so that the impact of earlier delays is taken into account when considering the impact caused by a later event.

The critical path and float values of remaining tasks will change from time to time due to the impact of change, unforeseen events, work performed faster or slower than planned and the contractor's prerogative to change the means and methods. When this occurs, sub-critical paths (or near critical paths) become critical and critical tasks become sub-critical. CPM programmes are required to identify delay events which affect the critical path to completion, delay the project completion date and prolong the overall contract duration. Only the simplest of activity sequences can be evaluated intuitively. On any traditional construction project, quantifying the effect of delays must be performed within a framework of CPM programming.

Establishing that a delay event affected the critical path, and the completion date, is frequently a precondition to a claimant being entitled to additional time and/or money. This is due to the fact that in order to be awarded prolongation damages, a contractor must demonstrate that completion was actually delayed. It is only when the project duration is extended (by way of the critical path) that prolongation damages are incurred. When arguments over 'float ownership' are present the same logic applies, with the exception that a contractor will argue that it was the anticipated, or planned, 'project duration' which was extended. Float ownership is discussed separately in Chapter 5.

4.1.2 Project planning software

With the advent of personal computers and easy to use commercially available project management software, the techniques available for managing construction programmes and analysing the impact of change and unforeseen events have advanced considerably.

There is a variety of project planning software available and it is becoming easier for project staff to produce charts without any training whatsoever in CPA, CPM, the use of work breakdown structures, or proper project planning or management techniques generally. Nevertheless, due to the current shortage of skilled programmers in the industry many projects still suffer from programmes produced in haste by untrained and inexperienced staff. These efforts often result in what have been deemed 'rotten bananas' in a planning paradise.[4]

Because it has become so easy to create programmes in today's software 'paradise', there is a growing tendency to give project staff the task of programming the works and indeed preparing extension of time claims. This occurs without a proper understanding of CPM techniques or the benefit of practical hands-on experience in negotiating the issues relevant to proving the need for extra time and the impact of change. The cost of hiring specialist programming services retrospectively is significantly more expensive than if the appropriate level of programming effort was put in place during the development of the baseline programme and applied during the course of a project.

Some specialist forensic delay analysts tend to apply a given 'technique' of forensic delay analysis uncompromisingly, often with very precise, albeit sometimes highly inaccurate, conclusions. Precision should not be confused with accuracy when carrying out delay analysis in construction. Adding science and precision to a project where such precision did not exist during the course of the works will usually require reliance on some form of theoretical calculation. These calculations must align with common sense and the conclusions

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[4] Richard Korman with Stephen H. Daniels, *Critics Can't Find the Logic in Many of Today's CPM Schedules.*

must be consistent with the facts and contemporaneous documents. Such analysts, often highly competent in computer modelling, employ large teams of technicians capable of producing expert reports which go 'wide-and-deep', resulting in reports with commensurate expense. Such approaches are often necessary, but should be avoided when disproportionate to the complexity or size of the dispute.

The problem with many computer modelling techniques is that the ability to predict accurately the precise completion date of a project has not increased dramatically in the past 40 years. The CPM programme is no more than an estimate of likely durations linked together by probable sequences, based on assumptions which may or may not prove to be accurate. A CPM schedule is a prediction in the form of a series of 'time-risk allowances' of what may happen in the future. Even baseline and approved CPM programmes are 'what if' scenarios and the results of any modelled technique must be balanced and considered along with common sense, contemporaneous evidence, experience and professional judgement.

The projections produced by the CPM schedule from month to month in updated programmes are fundamental tools used by the project management team. The CPM is considered with many other factors affecting progress, including labour or supervision availability, material availability, site congestion, plant utilisation, weather, holidays, design and missing information, shop drawing status, cash-flow, as well as subcontractor and supplier payment status to name a few. When managing the works these are all factors which must be considered, in addition to the activity bars on a 3-week look ahead produced from the most recent CPM programme. It is possible for too much reliance to be placed on the CPM, forensically. A review of contemporaneous considerations is necessary when considering the impact of change or where to focus resources from month to month , in addition to the CPM, which may have been just one of many pieces of information available to the project management staff at the time.

CPM programmes continue to provide a logical and systematic method for planning the works and, regardless of how accurate/inaccurate, detailed/general, useful/useless such programmes are, they will continue to be key source documents in delay and disruption disputes. Accordingly, the significance placed on the CPM in dispute resolution forums should not be underestimated. For this reason, and to prepare for more technical challenges to delay analyses, approaches, and underlying assumptions and challenges, it is necessary to consider the current guidance regarding the methods of analysis presently accepted in the industry.

4.1.3 Identifying delays – cause or effect?

The goal of delay analysis is to satisfy the burden of establishing 'cause and effect'. Whether the analyst undertakes the analysis starting from the cause or the effect is a factor which must be considered when determining whether a prospective or retrospective forensic method of analysis is applied. The cause is the event, circumstance, or factor which resulted in a potential delay to completion of the project. Once an actual delay has been experienced, the effect is a delay period which is measurable in some way, using the available as-built progress documents, achieved milestones or programme information.

Starting with the 'cause' requires the analyst to identify the likely effect of that event. Alternatively, commencing the analysis based on the actual delay suffered (the 'effect'), requires one to work backwards, by determining the most likely 'cause' of that effect.

Many disputes require both prospective and retrospective methods to be applied to determine both the likely effect of a delay, from the time it occurred, as well as the actual effect of that same delay event based on what actually happened. When attempted or achieved acceleration is present, this may provide a tribunal with one method to quantify the amount of recovery achieved. If a properly performed prospective analysis indicates that the likely delay could have been greater than the actual delay suffered, the tribunal may consider this outcome when assessing compensation for acceleration. This may also assist in demonstrating periods of non-compensable delay by demonstrating a variance between the delay that should have been experienced, due to a particular employer risk event, and the delay which actually resulted, due to unknown causes which were, in any event, not employer risk events.

Delays to completion can be categorised as being either 'excusable' or 'non-excusable' and 'compensable' or 'non-compensable'. A great deal has been written on delay analysis in the US, which has led to the introduction of US terminology alongside, and sometimes in preference to, existing UK terminology. For example the Society of Construction Law used many US terms in its Delay and Disruption Protocol, a document which has received judicial recognition in the Technology and Construction Court.[5] The following definitions use both UK and US terms to assist in classifying each of the events referred to throughout this chapter. The potential effect of these events is summarised in Table 4.2.

Table 4.2 Delay classifications.

Type of Event	ERE	CRE	Both CRE and ERE
Excusable	●		●
Non-Excusable		●	
Compensable	●		
Non-Compensable		●	●

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[5] *Mirant* v. *Ove Arup*, EWHC 918 (TCC), before His Honour Judge Toulmin CMG,QC, 2007.

Firstly, risk events can be at either the employer's risk or the contractor's risk and are defined below for ease of reference.

- *Employer Risk Event* (ERE) – an event, circumstance or cause which, under the Contract (or by subsequent determination of a formal tribunal), is at the risk and the responsibility of the employer.
- *Contractor Risk Event* (CRE) – an event, circumstance or cause which, under the Contract (or as later formally determined), is not at the risk and the responsibility of the employer.

Secondly, delay events can be either 'excusable' or 'non-excusable', depending on who carries the risk of the event, cause or circumstance which contributes to the delay.

- *Delay Event* – a CRE or ERE which is found to contribute to delay to either planned or contract completion.
- *Excusable Delay* – a delay event caused by an employer risk event which prolongs planned completion (whether that date is earlier, or later, than the Contractual date for completion).
- *Non-Excusable Delay* – a delay event caused by a contractor risk event, which could have been prevented, or was a result of a breach of Contract or contractor's negligence (e.g. actions of domestic subcontractors).

Thirdly, and arguably the most difficult to determine, are the periods of time in which time-related delay damages are recoverable and the periods in which they are not. These are classified as 'compensable' or 'non-compensable' periods of time. A compensable delay is one where damages, in the form of direct time-related costs, as well as indirect time-related costs (site or head-office overheads), are recoverable under the contract.

- Compensable Delay – a period of time during which a critical delay event is experienced which is:
  - an employer risk event; and
  - expressly identified as being recoverable under the contract terms and conditions.
- Non-Compensable Delay – a period of time during which a critical delay event is experienced which is:
  - a contractor risk event; and
  - not expressly identified as being recoverable under the contract terms and conditions.

The term 'neutral' event has arisen in recent years. A neutral event is a non-compensable and excusable event which may result in the contractor being awarded time, but no damages for delay. Whether an event is excusable or not will be determined by the terms of the contract. Neutral events (e.g. force majeure, exceptionally adverse weather) should be well defined to avoid doubt when additional time or compensation for delay is sought.

These event categories are set out in matrix formation in Table 4.2.

The analyst must make a provisional assignment or risk for each event to assign each event to one of the above categories. Interpreting contractual obligations and determining whether a risk event is truly an ERE or CRE is for the contract administrator, project manger or tribunal to decide.

All of the methods available require a process of deduction, through analysis and observation, using experience and judgement as applied to the available factual matrix. Other techniques require sophisticated methods of deterministic modelling which calculate precise impacts and sometimes create an unwieldy number of residual CPM programmes and activity fragnets[6] as a result of each iterative simulation. There is little agreement as to which method is most 'accurate'. Most cases turn on the facts and it is more important to rely on a technique which is appropriate in the given circumstances, and transparent, understood and accessible to the tribunal.

Each of the primary methods, and some of their secondary derivatives, will be explored in detail in the following sections, followed by a consideration of the factors which determine which analysis is appropriate under a given scenario.

4.2 *Explanation of the available techniques*

The methods discussed below are not exhaustive, but set out a comprehensive summary of the most widely used methods of delay analysis, both in prospective circumstances as well as forensically in dispute forums. The four primary methods of delay analysis – impacted as-planned, time impact, collapsed as-built and as-planned versus as-built – are reviewed in detail in this section, complete with a step-by-step guide in their usage and an indication of some secondary approaches which can be derived from each of these primary approaches.

4.2.1 Additive methods of delay analysis

Additive modelling approaches are mainly applied prospectively, that is during the course of a project when the full extent of a delay is not yet known. At this stage any delays to the completion must be projected or forecast, based on the best information available at the time. These approaches rely on either the as-planned CPM logic or the most recently updated, submitted and

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[6] A fragnet is a term used where an activity or sequence of activities is broken down into a number of sub-activities to provide greater detail.

approved CPM programme. Additive modelling techniques are by their nature a theoretical calculation using information available at the time the event occurs. The 'cause' is known, at the time, but the 'effect' must be estimated or projected.

Estimating the risk at the time allows the contracting parties to negotiate the effect of the delay event, thus setting a new deadline and price for the remaining work and a new date from which 'liquidated damages' can be assessed and recovered by the employer.

Additive methods can be applied to a baseline programme or to a programme representing the status of the project at intermediate points leading up to project completion.

4.2.2 Impacted as-planned

The impacted as-planned (IAP) technique is arguably the simplest form of critical path-based analysis. The SCL Protocol[7] refers to this technique as the 'impacted as-planned' and in the US the AACEI[8] RP-FSA refers to this technique as the 'Modelled/Additive/Single Base (MIP 3.6)'. The SCL Protocol states that:

> 'Impacted as-planned is based on the effect of employer risk events on the planned programme of work. This is thought to be the simplest form of delay analysis using CPM techniques since it involves the least amount of variables. The usefulness of the impacted as-planned technique is restricted due to the theoretical nature of the projected delays that are determined using this technique and uncertainty as to the feasibility of the contractor's as planned programme.'

The SCL Protocol envisaged the IAP technique as one which would assist in demonstrating extension of time entitlement only, and not prolongation costs. It was not concerned with using the IAP technique for identifying concurrent delays. In fact, this technique is not able to demonstrate true concurrency. This can only be done with as-built records and approaches which rely on as-built programmes. However, the AACEI recognises that the approach is able to identify 'approximate concurrency' for the purposes of estimating concurrent delay and extension of time entitlement. Approximate concurrency is defined as follows:

- Where an IAP model impacted solely with an employer delay event (EDE) projects a delay that is greater than an IAP model impacted solely with a contractor delay event (CDE), then the contractor may be entitled to

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[7] Society of Construction Law *Delay and Disruption Protocol*, October 2002 (p. 16).

[8] The Association for the Advancement of Cost Engineering International, RP-FSA (p. 61).

Prolongation to the extent the EDE IAP model is greater than the CDE IAP model.

- Where an IAP model impacted solely with an EDE projects a delay that is less than an IAP model impacted solely with a CDE, then the contractor is not entitled to any Prolongation. The contractor is entitled to a Time Extension equal to the amount of delay projected by the EDE IAP.

The IAP approach has been widely criticised by commentators and courts alike. Yet it still remains one of the most widely used methods as a first 'port of call' due to its simplicity and its ability to demonstrate what 'would have happened', assuming the delays modelled (EDE or CDE) were the only delays which occurred (and assuming all else went to plan). However, these very assumptions call into question the usefulness of the approach. The strengths and weaknesses of the impacted as-planned technique are summarised in Table 4.3.

Table 4.3 Strengths and weaknesses of the impacted as-planned technique.

Strengths	Weaknesses
• Easy to understand • Least amount of variables in 'cause–effect' equation • Does not require as-built programme • Can be carried out contemporaneously • Does not require progressed programmes	• Does not account for changes to logic or durations of planned activities • Produces theoretical results based on a hypothetical question • Cannot identify true concurrent delay

Execution of impacted as-planned

The only programme required to carry out an IAP analysis is a baseline programme which is contractually compliant and represents a contractor's true intention prior to commencing any works. If the available baseline programme is not contractually compliant, or contains known and readily identifiable logical or duration errors, it may be necessary to modify the baseline prior to using it in an IAP analysis. Considering the hypothetical nature of the impacted as-planned approach, this is undesirable and adds a layer of subjectivity to the process. As a last resort, it may be necessary to reconstruct a baseline for analysis. Employers should treat any forensically created or adjusted/amended baseline programmes with caution as it may not be possible to confirm whether the logic included in a modified, or recreated programme is consistent with the contractor's original intentions. Thus any form of reconstructed programme or modified baseline programme should be avoided, unless agreement as to the approach, application and building blocks used in the analysis can be reached with an opposing party; in this case there may be merit in using the approach as a negotiating tool between contractor and employer.

Once a baseline for analysis is identified, then either, or both, EDE and CDE events are added to the baseline programme. If they are added independently, this is known as a 'non-integrated impacted as-planned' (with either CDE or EDE, but not both). If both are added jointly, then this is a 'combined IAP'. Combined IAP models require that the impacts are inserted in the chronological order in which they first arose. This allows cumulative delay liability for either EDE or CDE to be allocated to specific events.

This is performed by inserting additional tasks as discrete programme activities, complete with logical relationships and durations, to the original contract baseline programme. These tasks can represent either CDE or EDE. Each task or activity entry requires the following information:

- Estimated Duration;
- List of Logical Predecessors; and
- List of Logical Successors.

Some analysts insert activities with start constraints, thus avoiding the need to provide a predecessor in the existing baseline programme. This is appropriate in certain circumstances but should be avoided when natural construction predecessors can be identified in the baseline programme.

EDE activities can be inserted into the baseline programme either one at a time or all at once, depending on the purpose of the analysis. If the analyst is concerned with the total impact of the events, then they could be inserted all at once. If the analyst is concerned with the individual additive impact of each subsequent event, then they should be inserted one at a time, in chronological order.

The resulting delay impact on the completion date, if any, is then measured and recorded. If events are inserted individually, then the impacted completion date is recorded successively, event by event, until all events are inserted. This assists in identifying which events contributed to critical delay, and by how many days. The resulting total impact to the completion date, following the impact of each of the events, represents the time to which excusable delay may be present, and the amount of time extension which is due. Both employer and contractor events can be inserted in this way to identify an approximate compensable delay period. However, payment for time related costs during this approximate period can only be estimated by way of average daily rates, or some other pre-agreed daily rate which is acceptable to both parties. The resulting compensable delay period will not identify the actual period in which the delay was being experienced, or the actual delay which was experienced to the completion date.

The SCL Protocol defines 'prolongation' as 'the extended duration of the works during which costs are incurred as a result of a delay'.[9] It also states that:

> 'Unless expressly provided for otherwise (e.g. by evaluation based on contract rates), compensation for prolongation should not be paid for anything other than work actually done, time actually taken up or loss and/or expense actually suffered.'

While IAP models can only estimate the impact of events prospectively, it is foreseeable that the IAP model could be used as the basis for estimating prolongation on the basis of pre-agreed rates if parties are inclined to accept the results of such an analysis.

When CDEs are also identified, one can follow one of two procedures for determining if there was any concurrent or critical delay caused by these events. Concurrent delay in this respect is more accurately referred to as 'concurrent effect' in the SCL Protocol, and 'approximate concurrency' by the AACEI RP-FSA.

Firstly, a 'combined chronological IAP' (CC-IAP) can be developed. In the CC-IAP each delay, both CDE and EDE, is identified and listed chronologically, in the order in which they were experienced. Each event is inserted individually and cumulatively until all delays have been inserted into the programme. The insertion of delay events can take many forms, including:

- delaying the start of an existing, or inserted, activity with a constrained start date;
- delaying the finish of an existing, or inserted, activity with a constrained finish date;
- increasing the duration of an existing activity;
- increasing or decreasing the hours available during a working week;
- inserting a new activity, logically linked to existing activities in the programme;
- inserting a new fragnet, logically linked to existing activities in the programme; or
- adding or deleting existing logical links to reflect the impact of changed conditions and dependencies.

Any method of insertion must be recorded as part of a transparent and auditable process. Following the insertion of each event, the resulting delay caused by each event is tabulated. Depending on whether the impact was caused by either a CDE or an EDE, the critical delay to completion is 'banked' into a respective category. The sum of all CDEs could be said to represent the non-

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[9] SCL Delay and Disruption Protocol, October 2002.

compensable period of delay. The sum of all EDEs could be said to represent the compensable period of delay. The sum of EDE delays and all CDE delays will be greater than the pure EDE IAP carried out initially. However, the EDE IAP carried out initially will continue to represent the excusable delay period. The difference between the sum of the EDE in the CC IAP model and the EDE IAP model represents the amount of concurrent delay identified in the models. While this is not true concurrent delay, because it is based on a theoretical prospective model, it provides a measure of approximate concurrency.

Secondly, an alternative method is to create a 'non-integrated IAP' (NI–IAP) programme which only considers the impact of CDE separately from the EDE in two isolated models. The resulting delay could be said to represent the amount of concurrent delay caused solely by the CDE. The use of the NI–IAP approach results in two models, one with only CDE, and one with only EDE considered. If the CDE model predicted a delay greater than the EDE model, there is no period of compensable delay. If the CDE model predicted a delay less than the EDE model, the difference between the two is the period of compensable delay. Examples of each of these potential scenarios are illustrated in Figure 4.1.

By estimating the amount of CDE that exists in a 'non-integrated' impacted as-planned programme, the amount of concurrent delay present can be estimated when the results are compared with the completion date generated through a 'combined' IAP model. The duration of the non-integrated CDE period is subtracted from the impacted completion date of a combined model. To the extent that this reduces the impacted completion date to a date less than the independent EDE model, this is the amount of approximate concurrency identified.

These are useful as negotiation tools when, for whatever reason, more in-depth and detailed methods of analysis are ruled out or not available to the parties. One should always keep in mind, however, that the results are theoretical 'what if' scenarios at best and should be treated with caution.

If a pre-agreed daily rate for prolongation is available, accounting for compensable delay in a cumulative, combined and forward-looking manner is also possible using the IAP modelling approach.

For example, assume a project has a planned completion date of 1 January 2009 and a total of seven delay events have been identified and quantified. Four of these events are deemed employer delay events (EDE) and three are contractor delay events (CDE). The results of the analysis are set out in the schedule in Table 4.4.

Using this approach, it is assessed that the employer was responsible for nine days of critical delay and the contractor was responsible for eight days of critical delay. This accounts for 17 days of delay to the completion date. It must be remembered that these assessments are only estimates of approximate liability. The actual delay experienced in total may not be equal to the 17 days of total delay determined by the IAP model. The above method is only recommended when:

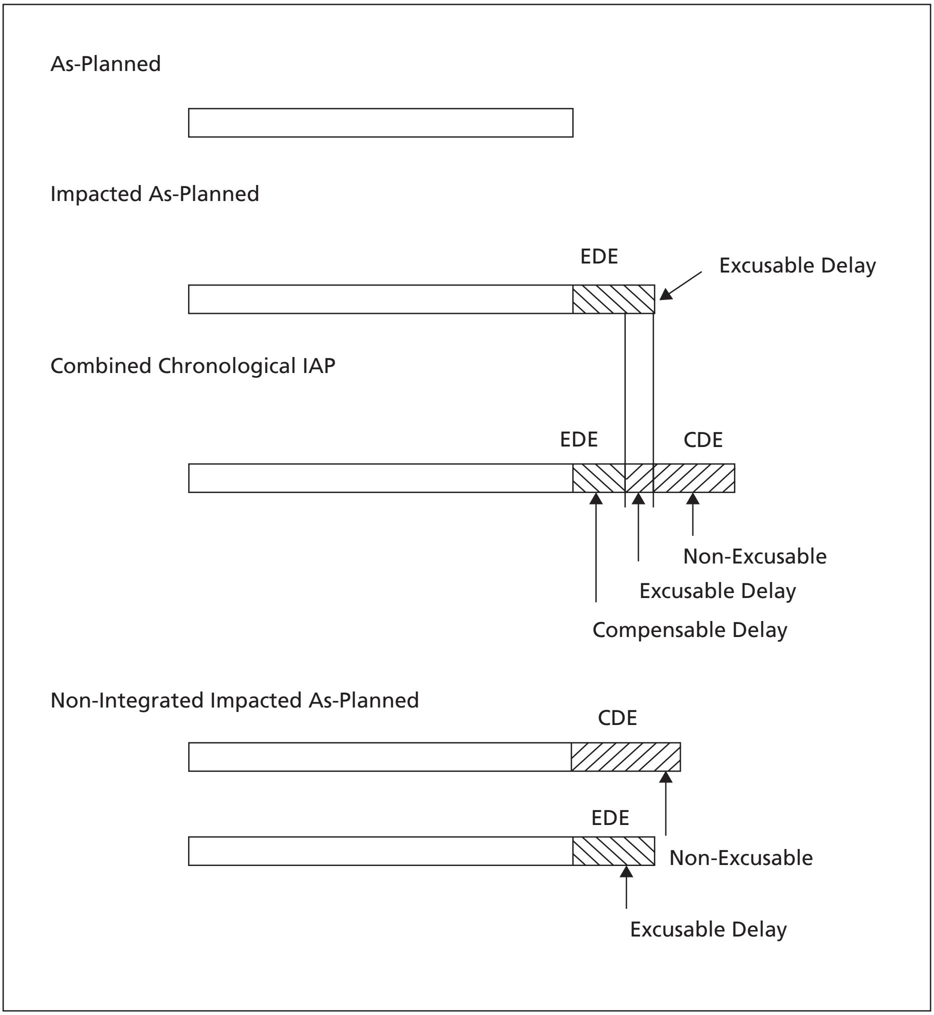

Figure 4.1 Programme comparison.

Table 4.4 Combined IAP model results.

Combined Impacted Liability Table			**Cumulative Delay**	
Event	**Event Type**	**Impacted Completion Date**	**EDE**	**CDE**
Baseline		1-Jan-09		
001	EDE	2-Jan-09	1	
002	EDE	5-Jan-09	3	
003	CDE	8-Jan-09		3
004	EDE	10-Jan-09	2	
005	CDE	15-Jan-09		5
006	CDE	15-Jan-09		0
007	EDE	18-Jan-09	3	

- there is no as-built programme;
- there are insufficient progress records allowing an as-built to be created; and
- both the employer and contractor agree to use the procedure.

If the approach is to be used to identify both compensable and excusable delay, a daily rate for prolongation costs will also be necessary. This approach is useful in calculating delay if one accepts the following series of assumptions:

- the as-planned logic was accurate;
- the as-planned durations were accurate; and
- the contractor followed the as-planned logic.

Due to the impact of re-sequencing and the fact that actual durations rarely reflect the exact duration included in the as-planned programme, the resulting delay 'which should have been experienced' is rarely the same as the actual delay experienced. The difference between the IAP impacted contract completion date and the actual contract duration achieved can be explained by several factors, including deviations from the as-planned sequence, deviations from the as-planned durations, additional delays not considered in the IAP model, or mitigation achieved along the critical path.

4.2.3 Time impact analysis

An evolution of the impacted as-planned (IAP) method is known as the 'time impact analysis' (TIA). There are many names used in the construction industry for the TIA approach, probably because there are as many ways to apply the technique. The AACEI refers to the TIA approach as 'modelled/additive/multiple base'. The main difference between the IAP and TIA method is the use of 'multiple base' programmes in the TIA, as opposed to a 'single base' (i.e. the baseline) in the IAP. The SCL Protocol states that the TIA method is the 'preferred technique to resolve complex disputes related to delay and compensation for that delay'. It also states:

> 'Time impact analysis is based on the effect of delay events on the contractor's intentions for the future conduct of the work in the light of progress actually achieved at the time of the delay event and can also be used to assist in resolving more complex delay scenarios involving concurrent delays, acceleration and disruption. It is also the best technique for determining the amount of extension of time that a contractor should have been granted at the time an employer risk event occurred. In this situation, the amount of extension of time may not precisely reflect the actual delay suffered by the contractor. That does not mean that time impact analysis generates hypothetical results – it generates results showing entitlement.'[10]

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[10] Ibid, page 47.

The TIA method is an additive and 'modelled' technique because it is based on 'what if' simulations of various CPM baseline programmes. Similar to the IAP method, the TIA approach consists of the insertion or addition of activities, or fragnets, which represent EDE or CDE into a network analysis model designed to determine the impact to the network.

The TIA methodology differs from the IAP technique because it uses multiple baselines, rather than the original as-planned baseline, to measure the likely impact of delay events. Each base programme is a CPM schedule representing the contractor's intentions for completion of all remaining work, prior to the insertion of delay events.

When carrying out a contemporaneous TIA, prospectively during the course of the work, the parties will be forced to rely on estimated durations for delay events in the future. When carried out forensically, the parties will have better information regarding the logical sequence in which the delay events were actually carried out, the activities which were truly dependent, and delayed, by them, as well as the actual duration of each delay event. These additional facts must be considered when carrying out a forensic TIA, or the results are likely to be considered too theoretical to determine compensation for prolongation.

There are many variables, assumptions and options to consider when carrying out a TIA and all should be stated as clearly as possible to ensure openness and transparency in the process. When any form of modelling is carried out, it is important that the process used is capable of being reproduced and audited. The TIA is a modelling technique which can be automated, and is therefore easily adjusted if any of the underlying assumptions are later found to be incorrect. There are many options available to the analyst and a step-by-step guide to using one form of the TIA approach is contained in Table 4.5.

Item 11 may only be possible upon completion of the project. When applied retrospectively, anomalous results will be more readily apparent. Examples of anomalous results may include:

- projected commencement dates of successor activities far in excess of their actual commencement dates;
- impacts to completion projected far in excess of the actual completion date; or
- no impact resulting to the relevant milestone when large scale impacts/fragnets are inserted on what were known to be critical events in the as-built state.

Anomalous results may not be obvious and may require evaluation of resource requirements, logical sequences, or a comparison of impacted start and finish dates in the TIA with the as-built start and finish dates for the same tasks. Anomalies are often the result of changes to logic and sequences incorporated into later programmes due to attempted recovery, or simply changed intentions and different methods to carry out the works. These could also result

Table 4.5 Stages in the application of the TIA technique.

Guide to the Time Impact Analysis Approach (TIA)

1. List all identified delay events in a table, complete with the duration, predecessors and successors, and commencement date (when the event was first identified or first had an effect on the work).
2. Assess the liability for each delay event based on circumstances, risks and contractual obligations.
3. Obtain progress data for all activities in the programme at the point immediately prior to (or as close as reasonably possible to) each subsequent delay commencement date.
4. Create a series of TIA base programmes by either:
   - relying on updated contemporaneous progress programmes closest to each commencement date – a 'contemporaneous update TIA'; or
   - identifying the contemporaneous progress programmes closest to the date of each delay event and then updating each of those programmes with progress data up to the point immediately prior to the commencement date of each delay event. This is a 'chronological event TIA' which will result in one pre-impacted 'base' programme per delay event (unless multiple delay events share the same commencement date).
5. Tabulate the data-dates and the projected completion date of each of the base programmes prior to inserting any of the delay events. Copy, rename, and save each of the base programmes for impacting.
6. Convert each delay event to a new subset of activities, or 'fragnet', complete with estimated durations and identified predecessor and successor activities in the base programme. (When carried out retrospectively, the analyst has the option of using as-built durations for the 'fragnets'. Using actual sequences and durations is preferred and reduces the theoretical nature of the TIA results. It also reduces the likelihood of anomalous results which do not align with common sense or reality.) Whether a single activity is used or a fragnet of related activities is relied on, a detailed explanation as to how the durations were arrived at is an essential part of any subsequent negotiations based on the TIA approach.
7. Insert each of the fragnets, one at a time, chronologically, into their respective base programmes. This process can be carried out once for EDE, and separately for CDE, or they can be considered in the same series of TIA base calculations (see table below).
8. When two or more events commence on the same day, the analyst has the option of entering them one at a time, or in a combined TIA model. Inserting them in a combined model is preferable when all events are either EDE or CDE, as it will determine the event with the largest impact. However, if a CDE and a EDE commence on the same date, it will require the analyst to create three models on the same date to identify concurrent delay:
   - one to demonstrate the impact of the EDE;
   - one to demonstrate the impact of the CDE; and
   - one to demonstrate the combined impact of both in the same base programme.

(Continued)

Table 4.5 *Continued*

Guide to the Time Impact Analysis Approach (TIA)

9. The calculated change to the completion date (loss or gain) for each successive delay event is tabulated and inserted chronologically (according to date of impact) into the table.
10. Cumulative loss, or gains, are determined for EDE, CDE and concurrent periods.*
11. Any anomalous results are reviewed, identified and, where corrections are deemed necessary, the process is repeated as required.

*The TIA model can also incorporate 'neutral' events, such as *force majeure* and weather impacts. These are treated the same as concurrent delays in the TIA model.

from relaxations to contract requirements for working periods, non-work periods or other contractual constraints or exclusion periods.[11] Where a correction to accommodate one of these situations would have a drastic effect on the impact predicted in a TIA model, an optional model should be produced demonstrating what the impact would have been, if this later changed circumstance were considered in the earlier base programme. Often disagreements between opposing experts could be avoided if options such as these were presented jointly, as optional conclusions, to the finder of fact/tribunal.

Whether applied retrospectively (after the impact of the delay event has occurred) or prospectively (during the life of the project, before the full impact of the event is known) the most recent contemporaneous programme[12] should be relied upon. This programme will represent the contractor's plans at that time, which may incorporate revised logic and any plans to recover previous delays then known.

The TIA technique is a multiple base method, performed on multiple network analysis models representing the plan (typically an updated base programme) which can be a contemporaneous, modified contemporaneous or recreated programme. Each base model creates a period or a window of analysis that isolates the quantification of delay impact by measuring the impact of each event one window at a time.

Events should only be entered once and the newly created activities should be consistent with the original baseline programme requirements. For instance, the contract specification may have required the duration of each programme

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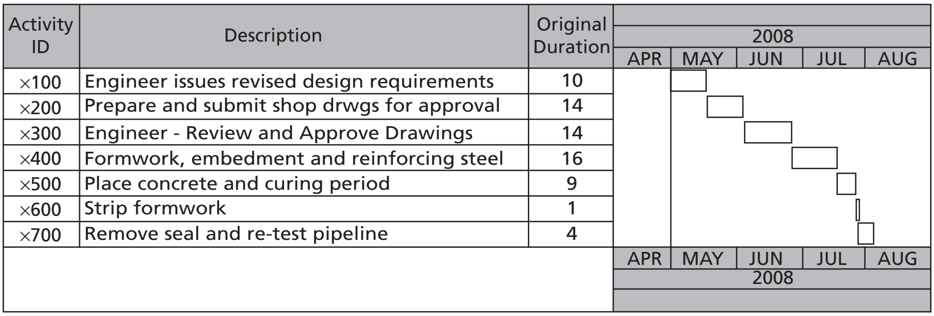
[11] Exclusion periods are typical in many industries to accommodate operational concerns or weather sensitive environments where periods of non-working are defined by operations staff, statutory authorities or other governing bodies.

[12] This would preferably be the most recently accepted programme. However, it is recognised that not all projects will have both progressed and accepted programmes available at frequent intervals.



Activity ID	Description	Original Duration
×100	Engineer issues revised design requirements	10
×200	Prepare and submit shop drwgs for approval	14
×300	Engineer - Review and Approve Drawings	14
×400	Formwork, embedment and reinforcing steel	16
×500	Place concrete and curing period	9
×600	Strip formwork	1
×700	Remove seal and re-test pipeline	4

Figure 4.2 Fragnet.

activity to be less than 15 days. If the duration of a delay event exceeds the duration of several windows, the analyst should attempt to break the impact down to several events. For example, if an instruction for the addition of an access manhole to a pipe-line is issued in May 2008, the sequence of events, the 'fragnet' could look like the example in Figure 4.2.

This whole process of work represented by the 'fragnet' is 68 working days, or 95 calendar days, long. The impact of this fragnet is represented over a period spanning three updating cycles – May, June and July (assuming monthly updating cycles are applied). It may be appropriate to insert a 95 day fragnet into a May 2008 base programme; but it may be more appropriate to break the above fragnet into three discrete base programmes. The impact of activities X100 and X200 could be measured in the May 2008 programme, the impact of X300 and X400 could be measured in the June 2008 base programme, and X500 and X600 could be measured in the July 2008 programme. Alternatively, the impact of the events could be parsed, as of the date of each subsequent update, to ensure that the duration of the fragnets inserted does not exceed the period addressed by each base programme.

Inserting fragnets with excessive durations (spanning several updating cycles) will effectively over-ride progress achieved during that entire period, and will not allow the base programme to account for any delays due to concurrent events, lack of progress or logic changes implemented in the relevant monthly updates. This might prevent potentially critical delay events from emerging as critical until the conclusion of the fragnet. Every attempt should be made to make the fragnets as discrete as possible so the impact of each event can be limited to the period of time being analysed. Breaking events into bite-sized chunks for analysis is one of the reasons the TIA approach is known as being labour intensive and technically complex. The longer the fragnet, and the longer the duration between each base programme, the more prospective and theoretical the results will be.

If the TIA is used prospectively, the analysis will produce 'likely effects' of delays. If the fragnets are as discrete as possible, limited to durations less than a single updating cycle (i.e. 30 days), and if those fragnets rely on actual

Table 4.6 Windows for analysis.

Window 1	is the Baseline to the first update, UD01
Window 2	is from UD01 to UD02
Window 3	is from UD02 to an updated version of UD02 through 14 August 2008 – UD02A
Window 4	is from UD02A to UD03
Window 5	is UD03 to completion

durations, the results are going to be closer to the actual effect of delay experienced and mitigated from progress update to progress update.

Table 4.6 was developed from the events relied on when assessing the same delay events above under the IAP method (as tabulated in Table 4.7). In this model, there were five base programmes relied upon. This could be said to contain five windows being analysed.

In this model, there are both EDE and CDE events analysed in a cumulative, transparent and forward-looking fashion, while the 'events' could be discrete single activities, or fragnets of several related activities.

- In Window 1, there were two events. These were both EDE and both occurred within a week of the baseline data date, 1 June 2008. It was decided that the baseline was an appropriate base to impact for these purposes.
- In Window 2 there were two events, a CDE and EDE. These were impacted both individually and in tandem. When impacted individually, the CDE had a delay impact of three calendar days and the EDE had a delay impact of five calendar days (3 days concurrent with the CDE and 2 days in excess of the CDE). Therefore, it was determined that 3 days were concurrent and not solely due to the contractor.
- In Window 3, UD02 to UD02A, there were no events.
- In Window 4 there was one CDE delay event. This event commenced 15 days after the most recent contemporaneous update, and it was deemed necessary to create an intermediate (or bifurcated) schedule on 14 August 2008, immediately before the CDE commencement, which is between update UD02 and UD03. This update was referred to as UD02A.
- In Window 5 there were two delay events, a CDE and an EDE. In this window the results concluded that the contractor delay of one day was concurrent with the EDE, and that the EDE caused a delay of 3 days in excess of the CDE. Therefore, one day of delay was considered neutral or concurrent.

In Table 4.7, a contemporaneous update TIA was applied, using a combination of fixed-update periods (Window 1, 2 and 5) and variable-update periods (Windows 3 and 4) and using an intermediately created update for fragnet 005, which occurred in the middle of the updating cycle between UD02 and UD03. This required the creation of UD02A. In this example a

Table 4.7 Time impact liability table.

							Cumulative Delay		
Event (Fragnet)	**Event Type**	**Event Actual Start Date**	**Base Schedule**	**Base Schedule Data Date**	**Projected Completion Date**	**Net Loss/Gain**	**EDE**	**CDE**	**Concurrent**
			Baseline	1-Jun-08	1-Jan-09				
001	EDE	3-Jun-08		1-Jun-08	2-Jan-09	1	1		
002	EDE	5-Jun-08		1-Jun-08	5-Jan-09	3	3		
			UD01	30-Jun-08	5-Jan-09	0			
003	CDE	2-Jul-08		30-Jun-08	8-Jan-09	3			3
004	EDE	2-Jul-08		30-Jun-08	10-Jan-09	2	2		
			UD02	31-Jul-08	6-Jan-09	–4		–4	
			UD02A	*14-Aug-08*	*8-Jan-09*	2		2	
005	CDE	15-Aug-08		31-Jul-08	15-Jan-09	7		7	
			UD03	31-Aug-08	14-Jan-09	–1		–1	
006	CDE	4-Sep-08		31-Aug-08	15-Jan-09	1			1
007	EDE	7-Sep-08		31-Aug-08	18-Jan-09	3	3		
					Totals:	**17**	**9**	**4**	4

combination of 'gross insertion' (all delays in a window) and 'stepped insertion' (where EDE and CDE were non-integrated) were employed to identify concurrent delays when both CDE and EDE were present in the same window.

The results of this analysis are as follows:

Total Delay Experienced:	**17**
Total pure EDE Delay Experienced:	9
Total pure CDE Delay Experienced:	4
Concurrent Delay Experienced:	4

Thus the contractor is entitled to receive nine days of excusable-compensable extension of time, and four days excusable-non-compensable extension of time. In total 13 days of additional extension of time and relief from liquidated damages should be recognised. The employer, on the other hand, is entitled to withhold at least four days of liquidated damages (assuming the project actually completes on 18 January 2009) and no further critical EDE events are identified.

The example in Table 4.7 relies primarily on monthly progress updates. The TIA approach is also frequently applied using re-created progress updates which update the most recently approved progress programme to the point immediately prior to each delay event. The creation of these intermediate base programmes requires discipline, skill and care to ensure the process is transparent and that the data is reliable. Often project records do not allow progress to be assessed to each day accurately. Therefore the analyst must assess the status of the project (% complete, remaining duration and any required logic/sequence revisions) each time a new base is created. This is appropriate when a few, large, impacts are being analysed. When many small delay events are being evaluated, the process of calculating and rationalising the impact of each event, using a new base programme for each event, becomes a project in and of itself, requiring many assessments regarding the status (% complete, remaining duration) of each activity in the programme. This approach should only be adopted if appropriately detailed data exists, and the resulting impacts can be reconciled with as-built data and grounded in fact.

By impacting and updating the programme using this method, the chances of the results going off course and diverging from reality are lessened. The larger the windows and the longer the periods addressed by the fragnets, the more likely the results are going to diverge from the as-built and require correction at the beginning of each subsequent updated data date.[13] The course of the programme analysis is effectively 'corrected' at each monthly update, when the baseline is reset according to the actual progress achieved and any changes to the logic to the remaining activities.

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[13] The 'data date' is the date on which a schedule is updated with current information.

Table 4.8 Strengths and weaknesses of the impacted as-planned technique.

Strengths	Weaknesses
• Easy to understand • Can be carried out contemporaneously • Relies on contemporaneous intentions (accounts for changes to logic and duration of remaining activities from time to time) • Considers dynamic critical path • Does not require as-built programme • Can identify approximate concurrency	• Produces theoretical results based on a hypothetical question • Cannot identify actual concurrent delay • Labour intensive • Technically complex • Requires frequently prepared progress schedules

The projected completion date is also adjusted according to the actual progress achieved in each 'window' and any resulting gain, or loss, calculated in each subsequent base programme is allocated to the benefit of the contractor. This occurred in the above analysis when UD02 was updated, when UD02A was updated, and again when UD03 was updated. Losses and gains achieved due to the natural progress of the work are not EDE, and any delay which is unexplained is by definition a CDE.

Although concurrent delay was identified above, this is only estimated or approximate concurrency. A predictive modelling technique cannot, by itself, identify actual concurrent delays. IAP and TIA are both prospective methods of analysis and may not produce results which can be readily aligned or priced using records relating to actual cost. The perceived strengths and weaknesses of time impact analysis techniques are summarised in Table 4.8.

There are some analysts who will attempt to carry out this technique under any given circumstances. There are as many wrong ways to do a time impact analysis as there are correct ways and it takes a keen eye to spot the errors in many claims which rely on the TIA methodology. Ideally, the best circumstances in which this method, or any prospective technique, should be applied are where the technique has been pre-agreed between the parties. Even when carried out under controlled circumstances, where the base programmes are agreed, there are still many variables that can enter the equation, such as:

- determining the duration of the events in each fragnet;
- linking the delay events to predecessor activities in the base programme;
- linking the delay events to successor activities in the base programme;

- adding progress to the base programme to the point immediately prior to each delay event;
- estimating remaining durations for all activities 'in progress' at the commencement date of each delay event; and
- determining the order of impacting both CDE and EDE when they occur in the same window, or commence on the same date.

When applied correctly, the TIA method can be an extremely persuasive method of demonstrating the impact of delays on a contractor's programme. However, due to the many assumptions required and many variations on the approach to conducting a TIA it is equally open to potential scrutiny and criticism. Weaknesses can be amplified when the assumptions relied upon are successfully challenged.

4.2.4 Collapsed as-built

The 'collapsed as-built' (CAB) approach is another modelling technique which is traditionally carried out on a single-base programme, e.g. the as-built programme. The CAB relies on a simulation of a 'what if' scenario based on a CPM which models not the contractor's intentions, but rather the contractor's actual sequences and durations. Whereas the IAP approach is an *additive* approach, which involves inserting delays into a planned sequence and identifying what 'would be' the impact to completion if these delay events were the only change, the collapsed as-built is a *deductive* approach, using exactly the opposite philosophy to that relied on in the IAP and TIA methods. The 'what if' questions posed in the collapsed as-built method are 'What if these delay events didn't occur?' or 'When would the project have finished *but for* these events?'. The approach, while not a prospective method, is just as speculative and theoretical as the IAP and TIA methods, albeit with different sets of weaknesses and layered assumptions.

In relation to the CAB method the SCL protocol states:

> '4.7 Collapsed as-built is based on the effect of employer risk events on the programme of work as it was actually built. Similar to the as-planned versus as-built, the use of this technique is restricted by its inability to identify concurrency, re-sequencing, redistribution of resources or acceleration. This is particularly the case when the nature of the as-built logic is complex, requiring subjective reconstruction of as-built logic. Where acceleration, redistribution of resources or re-sequencing has taken place during the course of the works to overcome the effects of events, this form of analysis may produce unreliable results.'

The SCL Protocol is justifiably cautious about recommending the CAB approach. On anything but the most simple, intuitive and linear of projects, the layers of assumptions and subjective logic required to establish the as-built logic in a base programme for collapsing can be surprising. Before carrying out the delay analysis, the analyst needs to ask many questions of the data, including:

- Is there an appropriately detailed as-built programme in existence, or does one need to be constructed from base raw documents? If not, does sufficient data exist to allow one to be reconstructed?
- Secondly, if a detailed as-built programme exists, can the start and finish dates for each activity be verified?
- Thirdly, once the as-built start and finish dates have been verified, and corrected where necessary, can periods of inactivity be identified along any of the tasks?
- Lastly, if all of the above can be verified, can the as-built logical relationships and dependencies between each activity on the programme be accurately identified and simulated in the base programme?

The analyst must be satisfied that the as-built programme is contractually compliant, in that all milestones are represented accurately, all scope is represented to the appropriate level of detail, all off-site work, including design and procurement activities are adequately represented (to avoid over-use of constraints to represent this lead-in off-site work), and that calendar assignments accurately reflect the way in which the work was carried out (duration of working day or working week).

The analyst must confirm whether any start dates of as-built activities were determined by constraints, interfaces or restraints which were not logically driven by progress or predecessor shown on the original as-planned or the as-built programme. If logic exists, including constraints, and that logic can be shown to have been followed, the collapsing process should not involve any adjustment to logic or the removal of constraints.

It would be extremely rare for the logic in any large scale complex project to be exactly the same in the as-built state as it was in the as-planned state. For this reason, many adjustments to the planned logic are often necessary before the CAB base programme can be used to calculate accurately the as-built start and finish dates for each activity, using underlying CPM logic and activity durations. When such adjustment or removal is found necessary, each modification must be expressly and transparently identified to allow the process to be audited and reproduced by an independent party if required.

The potential for an analyst to steer the conclusions in one direction or another should not be underestimated as this stage. Whether unwittingly, or by way of an act of deliberate manipulation, the retrospective creation of the underlying as-built logic is the single most subjective step in the process.

The as-built programme used for collapsing will only collapse dynamically if the as-built start and finish dates are replicated identically in a CPM programme model used as the CAB base. In the CAB base model the ‘as-built’ dates are actually calculated, early finish dates determined by re-setting the project ‘data date’ back in time to a point when no delays had yet been experienced (or at the beginning of the window being analysed). This CAB base model relies on CPM theory, as described above. The start and finish date of each activity must rely on its as-built duration and one of four types of logical relationships used in CPM networks to connect related tasks to their successors, as described in Chapter 2, finish to finish, start to start, start to finish, and (the most common) finish to start. Taking each of these below, the assumptions required when work commences (or finishes) out of sequence will be apparent.

In Figure 4.3 a finish to finish relationship was incorporated in the as-planned between the completion of Final Paint, and Carpets, with a lag of five days (i.e. Carpets cannot complete until five days after the completion of Final Paint).

In the event, Carpets actually completed before Final Paint, owing to acceleration and changes to paint colours and wall coverings to areas after carpets had already been laid. The as-built sequence is illustrated in Figure 4.4.

The analyst now has the option of representing the as-built logic in several ways. The finish to finish logical relationship, as-planned, could be adjusted to reflect as-built sequence (Figure 4.5).

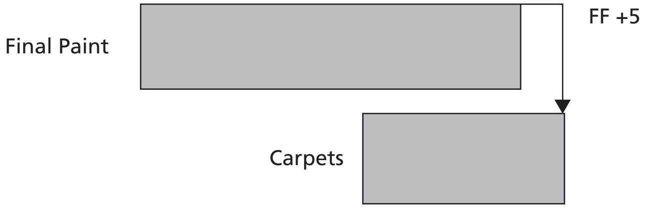

Figure 4.3 As-planned sequence with as-planned logic.

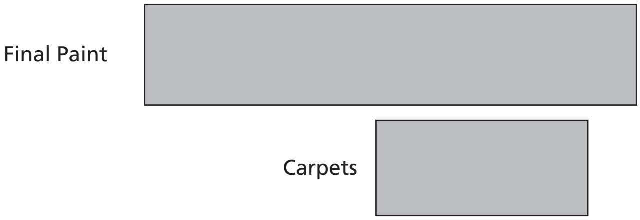

Figure 4.4 As-built sequence 1.

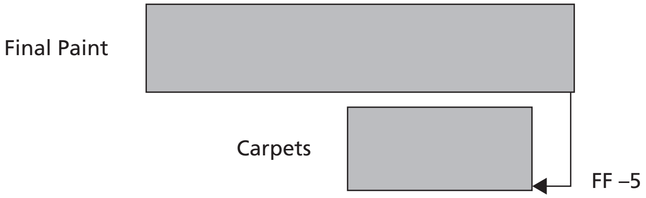

Figure 4.5 As-built sequence with as-built logic.

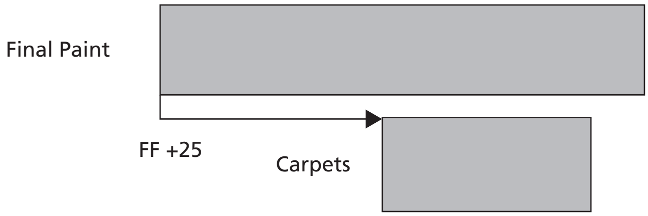

Figure 4.6 As-built sequence with alternative as-built logic.

This would result in a change to the finish to finish lag from plus five days to a minus five days. The logic, although it can be expressed mathematically on a CPM diagram, is not consistent with common sense. The Carpets did not have to finish five days in advance of the Final Paint. The Carpets simply finished in line with its as-planned duration, therefore the date Carpets commenced was more important than the date Final Paint was complete. This could be expressed as shown in Figure 4.6.

The logical relationship illustrated in Figure 4.6 would more accurately represent what actually happened. Carpets commenced following 25 days of Final Paint progress and finished in accordance with their as-planned duration. Final Paint on the other hand, over-ran its as-planned duration, but with no resulting delay to Carpets.

On a project with thousands of activities the analyst may have to make literally thousands of amendments such as the one demonstrated above. While the resulting CPM as-built base programme for analysis may successfully replicate the as-built dates, using CPM logic, the calculations (deductions) must be treated with caution. Forensically created logic is derived with the singular purpose of collapsing that same logic to demonstrate liability for delay along an as-built critical path. Where assumptions are required to reconstruct that logic, each assumption is a risk which could call the entire analysis into question if found to be incorrect.

The AACEI RP-FSA provides useful guidance for dealing with the addition of logic to replicate the as-built sequence as follows:

> 'h. In most cases, simulating the actual performance of work using CPM logic requires the use of logic ties other than standard, simple, consecutive finish-to-start ties (FS0). The following is a set of guidelines to be used in assigning CPM logic ties to simulate as-built performance:
>
> i. Replace with a schedule activity any FS logic with lag values 50% or longer than the duration of its predecessor or its successor.
> ii. Replace with a schedule activity any SS Logic with lag values 50% or longer than the duration of the predecessor.
> iii. Replace with a schedule activity any FF Logic with lag values 50% or longer than the duration of the successor.

> iv. Replace FS logic with negative lag values whose absolute value is larger than one unit of duration with another type of logic with a zero or a positive lag that does not violate the rules stated above.
> v. Replace SS or FF logic with negative lag values whose absolute value is larger than one unit of duration with another type of logic with a zero or a positive lag that does not violate the rules stated above.
> vi. Where more than one type of logic ties is applicable, use the type that would use the smallest absolute lag value as the controlling logic tie.
>
> i. This highlights the importance of this logic process, but do not expect to perfect the logic at this stage. This is because the collapsed as-built method is most efficiently implemented as a multi-iterative process involving rapid modelling and a subsequent trial collapse which reveals faulty or incomplete as-built logic. This is repeated until the model is debugged. However, this does not excuse the analyst from using a judicious combination of expert judgment, common sense and extensive input from project personnel with first-hand knowledge of the day-to-day events during this step of the process.'[14]

A method of analysis that relies on a 'multi-iterative process involving rapid modelling' to reveal faulty or incomplete logic, is difficult to recommend. If the input is altered because the analyst isn't happy with the output, then any corrections or debugging of the model are clearly subjective. The process could theoretically be repeated until the model is 'debugged' in the eyes of the analyst, with a result favourable to the client.

The logic being applied in any CAB model should be treated with caution and even healthy scepticism. Often the conclusions derived from CAB models (which can only be constructed retrospectively) collapse like a house of cards when enough of these assumed as-built logical dependencies are shown to be inaccurate.

The above scenario could just as easily be represented for a finish to start, start to start or start to finish relationship. Activities often start and complete out of sequence. It is the nature of construction.

The as-built programme, and logic, also has difficulty distinguishing 'driving' activities from concurrent 'pacing' activities. The duration of a paced activity may appear to be critical when a driving activity is collapsed from the base CAB programme. It is important that the analyst also identifies, and collapses, any dependent or paced activities, along with their corresponding driving activity, otherwise as-built critical paths will be determined erroneously (through non-driving activities). Whether an activity was paced or truly being performed as fast as possible at the time, is not something that may be readily apparent to most analysts. When non-driving dependent activities are found to be on the as-built critical path, and are not consistent with common sense

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[14] Association for the Advancement of Cost Engineering International – Recommended Practice No. 29R-03 *Forensic Schedule Analysis*, page 75.

or contemporaneous reporting of progress and delays, these resulting as-built critical path activities will weaken the findings of the entire analysis.

Finally, before any collapsing can take place, the delay events relied upon, either EDE, CDE, or both, must be discretely identified among the as-built activities. These can be in the form of 'fragnets' representing increased or changed scope, or individual activities representing each delay event.

Once the above assumptions have been addressed, and documented for the benefit of opposing experts and the tribunal's collective understanding, the analysis can commence. A step-by-step guide to using the collapsed as-built approach is contained in Table 4.9.

Table 4.9 Stages in the application of the collapsed as-built technique.

Guide to using the collapsed as-built approach (CAB)
1. Identify the window for analysis. If the analysis carried out is a 'single base' then the CAB model window is the entire project duration. If the CAB model is carried out as a 'windows' analysis, then justification for each window needs to be given. 2. Identify all known delay events in the as-built model. Extracting only selected events will sometimes produce predictable or predetermined results. The strength of the CAB approach is that it relies on the entire as-built and accounts for concurrent delays at the point in time in which they occurred. It is likely many events will not have any impact or influence on the CAB as-built critical path. However, this will allow near critical paths and concurrent delays to be identified. 3. Identify the sequence of extraction of delay events in each window. Delay events can be extracted all at once, to see the resulting critical path before and after the events have been extracted, or the events can be extracted one at a time, on a 'stepped' basis. When extracted on a stepped basis, the usual approach is to extract, or collapse, the activities in reverse order, based on the latest actual finish date, and working back to the beginning of the window, one at a time. It is also traditional to extract both EDE and CDE from the same CAB model, with CDE removed first, to allow the contractor the benefit of any pacing or concurrent delays. 4. Identify the method of extracting delay events. The process of subtracting delay events from the CAB model can be carried out by simply deleting the delay events (which is not recommended), dissolving the delay events (the delay events' successor activities are tied to their predecessor activities) or reducing the delay event durations to zero. Each method could result in a different answer, depending on the logical relationship applied and the residual logic remaining or existing between unchanged work tasks in the CAB model. The analyst should be consistent in the method of extraction to avoid criticism for inconsistent application of the methodology.

(*Continued*)

Table 4.9 *Continued*

Guide to using the collapsed as-built approach (CAB)
5. Remove the first delay (or set of delays) from the CAB as-built. Log the movement, if any, to the CAB calculated completion date. If the CAB calculated completion date is earlier, then the delay event (or set of delays) contributed to critical delay. If there is no movement, the impact of the delay was concurrent, and sub-critical, to critical path delays. If near critical paths are being tracked, note the change in float along the path of the delay event extracted. 6. Before extracting the next delay event (or set of delay events) confirm that the residual CAB is reasonable for the purpose of collapsing further. If any anomalous results are encountered after collapsing the programme, these require adjustment prior to any subsequent collapsing. If the correction affects the critical path, it is advisable to make the same correction to the original CAB base as-built programme and repeat the process of extracting delays (step 5) from the first delay event. Then repeat any previous extractions. 7. Extract the next delay event (or set of delays). If the CAB calculated completion date is earlier after extraction, then the delay event (or set of delays) contributed to critical delay. If there is no movement, the impact of the delay was concurrent, and sub-critical, to the critical path delays. Repeat step 6. 8. If a windows approach is being applied, repeat steps 6 and 7 only for those events whose completion dates fall within the window being analysed. Record all movement to the calculated completion date from all CAB simulations (for each delay event). Calculate the projected completion date at the beginning of the subsequent window (prior to extracting any delays). The programme used to establish this projected delay could be a contemporaneously progressed progress update programme. It could also be a recreated progress programme based either on the original as-planned programme or the as-planned programme with as-built progress through the data date of the end of window being analysed. 9. Repeat the process in reverse chronological order, until all delays have been accounted for and their impact on the CAB model recorded on a liability summary table.

The liability table in Table 4.10 is for an analysis of a recreated as-built CAB programme with an actual completion date of 18 January 2009. This collapsed as-built programme analysis was carried out using the 'stepped-extraction' technique, and was carried out in multiple windows which consisted of both variable and fixed length (see 'Base Schedule Data Date').

In Table 4.10 the model determined that event (fragnet) 001 (with an actual completion date of 11 September 2008) was the first activity to be extracted. A dissolve function in the planning software (effectively deleting an activity while maintaining the logic and work flow sequence of the network) was used to ensure that no hanging activities resulted in the collapsed model. This

Table 4.10 Impact liability table – collapsed as-built technique.

									Cumulative Delay		
Event (Frag-net)	**Event Type**	**Event Actual Start Date**	**Event Actual Finish Date**	**Event Duration (Days)**	**CAB Base Schedule**	**Base Schedule Data Date**	**Projected Completion Date**	**Net Loss/ Gain**	**EDE**	**CDE**	**Concurrent**
					CAB	**31-Aug-08**	18-Jan-09				
001	EDE	7-Sep-08	11-Sep-08	4	**CAB**	**31-Aug-08**	18-Jan-09	0			
002	CDE	4-Sep-08	5-Sep-08	1	**CAB**	**31-Aug-08**	15-Jan-09	3		3	
					UD03	31-Aug-08	14-Jan-09	1		1	
003	CDE	15-Aug-08	24-Aug-08	9	**CAB**	**14-Aug-08**	9-Jan-09	5		5	
					UD02	31-Jul-08	6-Jan-09	3		3	
004	EDE	2-Jul-08	7-Jul-08	5	**CAB**	**30-Jun-08**	1-Jan-09	5	5		
005	CDE	2-Jul-08	5-Jul-08	3	**CAB**	**30-Jun-08**	1-Jan-09	0			
					UD01	30-Jun-08	5-Jan-09	–4		–4	
006	EDE	5-Jun-08	8-Jun-08	3	**CAB**	**1-Jun-08**	5-Jan-09	0			
007	EDE	3-Jun-08	6-Jun-08	3	**CAB**	**1-Jun-08**	2-Jan-09	3	3		
				Contract Completion Date:			1-Jan-09	1		1	
							Totals:	**17**	**8**	**9**	**0**

activity had no effect on the actual completion date of 18 January 2009. The subsequent fragnet 002 was, however, determined to be critical and reduced the as-built completion date by three calendar days to 15 January 2008. These two events occurred in the first window being analysed (on 31 August 2008). The next event analysed occurred on 15 August 2008. The data date, progress and logic in the CAB programme were reset to 14 August 2008 for analysis. Prior to being collapsed, it projected a completion date of 14 January 2009. After extracting fragnet 003, the completion date moved to 9 January 2009, a critical delay of five calendar days.

The contemporaneous progress update UD02, dated 31 July 2008, indicated a projected completion date of 6 January 2009. This indicated that there was a loss of three days from 31 July 2008 to 14 August 2008. This is not attributable to an EDE, and is therefore, by definition, a CDE of three days. The next delay analysed commenced on 2 July 2008. The data date, progress, and logic in the CAB were then reviewed and the data date and progress reset to 30 June 2008 to allow events between 30 June and 31 July to be analysed. The fragnet representing an EDE (fragnet 004) was extracted first, and then a CDE (fragnet 005) in the same window. A loss of five days was measured for the EDE event, but no further delay was measured for the CDE. The CAB calculated a projected completion date of 1 January 2009.

Programme update UD01, dated 30 June 2008, indicated a projected completion date of 5 January 2009, a gain of four days when measured against the CAB programme on the same date. This accrued to the contractor as this was likely to have been due to re-sequencing, or mitigation, which was not the result of any employer instructed mitigation or acceleration.

In the final window analysed, there were two EDEs. By extracting these two events the projected completion date collapsed by a further three calendar days to 2 January 2009. The contract completion date was originally 1 January 2009. Therefore there was one day of inherent delay remaining in the CAB when all known delays were extracted. The difference accrued as if it were a CDE risk event. By definition, if a delay cannot be attributed to an EDE, it is treated as a CDE.

Table 4.10 is just one way of representing the results of a CAB analysis. However, the analysis can become extremely complex and technical where, for example, it has to address multiple windows and hundreds of delays. Accordingly, this approach is more suited for smaller, easily managed programmes, with linear sequences of work. This way, the results are more likely to align with common sense and intuition. The more complex and technically advanced the analysis becomes, the less likely it is that it will be able to pass a reality check based on intuition. While the analysis may be technically competent, its theoretical nature often make its use less attractive for tribunals not well-versed in such techniques – the risk being that the tribunal might be more easily persuaded by doubts cast by the potential areas for manipulation and the general subjective nature of the CAB technique.

The primary advantage of the CAB approach is that it utilises the as-built programme as the base programme and considers events in the framework of the actual timing and sequence in which they occurred, as opposed to the as-planned sequence. It is possible to carry out the CAB when no as-planned programme exists. Additionally, there is the incentive on the analyst to identify as many delay events as possible, to avoid residual unknown delays from remaining in the CAB after collapsing. The CAB considers both EDE and CDE and attempts to represent when the project would have completed if these delays had not been experienced. Any events not considered in the CAB analysis will remain in the CAB after collapsing. If these delays cannot be demonstrated to be EDE, they are treated as CDE.

While the approach is fairly simple to understand, and may appear attractive, its main weakness is the need to create as-built logic and replicate the actual performance start and finish dates with calculated early start dates, using CPM methodology. The logic used to prepare this analysis is usually static, in the as-built state, both before and after collapsing. This overlooks the fact that the contractor will have altered logic and worked out of sequence, projecting different delays than those that can be determined from as-built logic alone. In effect, extracting the delays will cause the critical path to shift, but the logic will remain static.

In short, there are more circumstances in which the CAB approach will not be applicable than those in which it is appropriate. It is suggested that the CAB is only appropriate on projects which can be represented primarily as a linear sequence of events (tunnels, roads, bridges, earthworks, etc.). This would assist in mitigating the biggest weakness related to the creation of subjective as-built logic. The strengths and weaknesses of the CAB technique are summarised in Table 4.11.

Table 4.11 Strengths and weaknesses of the collapsed as-built technique.

Strengths	**Weaknesses**
• Relies on as-built programme • Based on simple, easy to understand principles • Can isolate impact of EDE from CDE (when iterative applications are applied) • Only relies on as-built • Does not require progress updates • Does not require a baseline programme	• Reconstructing sufficiently detailed as-built is laborious • Constructing as-built logic is subjective • Does not calculate delay based on contractor's contemporaneous intentions, 'at the time' • Unable to distinguish pacing activities from critical delays • Can identify as-built periods of compensable delay • Cannot identify as-built (contemporaneous) critical path • Requires many subjective assumptions when recreating the CAB as-built model for analysis, in content and level of detail, as well as logic and durations of the as-built activities

The SCL protocol states that:

> '4.15 Collapsed as-built is also an analysis simple to perform although it is often more laborious and subjective because of the inherent difficulty of establishing accurate as-built logic from records.'

Clients and counsel who employ experts who attempt the CAB technique must be fully aware of the risks inherent in the approach.

4.2.5 As-built based methods of analysis

What has been described thus far can be referred to as modelled techniques which rely on computer simulations of CPM schedules to calculate precise answers based on a given set of rules or assumptions. The theoretical nature of analysis increases with the complexity of the sequences, the length of the project duration, and the number of activities included in the CPM models.

On the other side of the spectrum, the basic methods of analysis include as-built based analytical techniques which do not rely on calculated CPM models. These are referred to as 'observational' in the AACEI FAS. On projects where the effects of acceleration (or attempted acceleration) or early completion programmes are at issue, it advisable to apply both a deterministic technique and also an analytical technique which relies solely on as-built data. This provides a tribunal with a range of opinions, based on different assumptions. To prove acceleration, for instance, it is often helpful to demonstrate what the delay 'would have been' if it were not for the acceleration. This will require a method which calculates a theoretical impact, as well as one which demonstrates what actually happened, to establish entitlement.

There are many approaches which can be used when quantifying the impact of events when relying on as-built data. The FAS identifies four observational method implementation protocols (MIPs), as listed below:

- Observational/Static/Gross (MIP 3.1)
- Observational/Static/Periodic (MIP 3.2)
- Observational/Dynamic/Contemporaneous As-Is (MIP 3.3)
- Observational/Dynamic/Contemporaneous Split (MIP 3.4)

The SCL Protocol only refers to the as-planned versus as-built analysis, with no distinction between the dynamic, periodic, as-is or split options. When one breaks down the terms used in the FAS titles, each one makes sense and the precision of each classification is helpful when distinguishing between the various methods applied in practice. Many of these techniques are discussed in this chapter together with their more common names and optional derivatives. Assumptions which the analyst must make when carrying out any of these methods are also introduced.

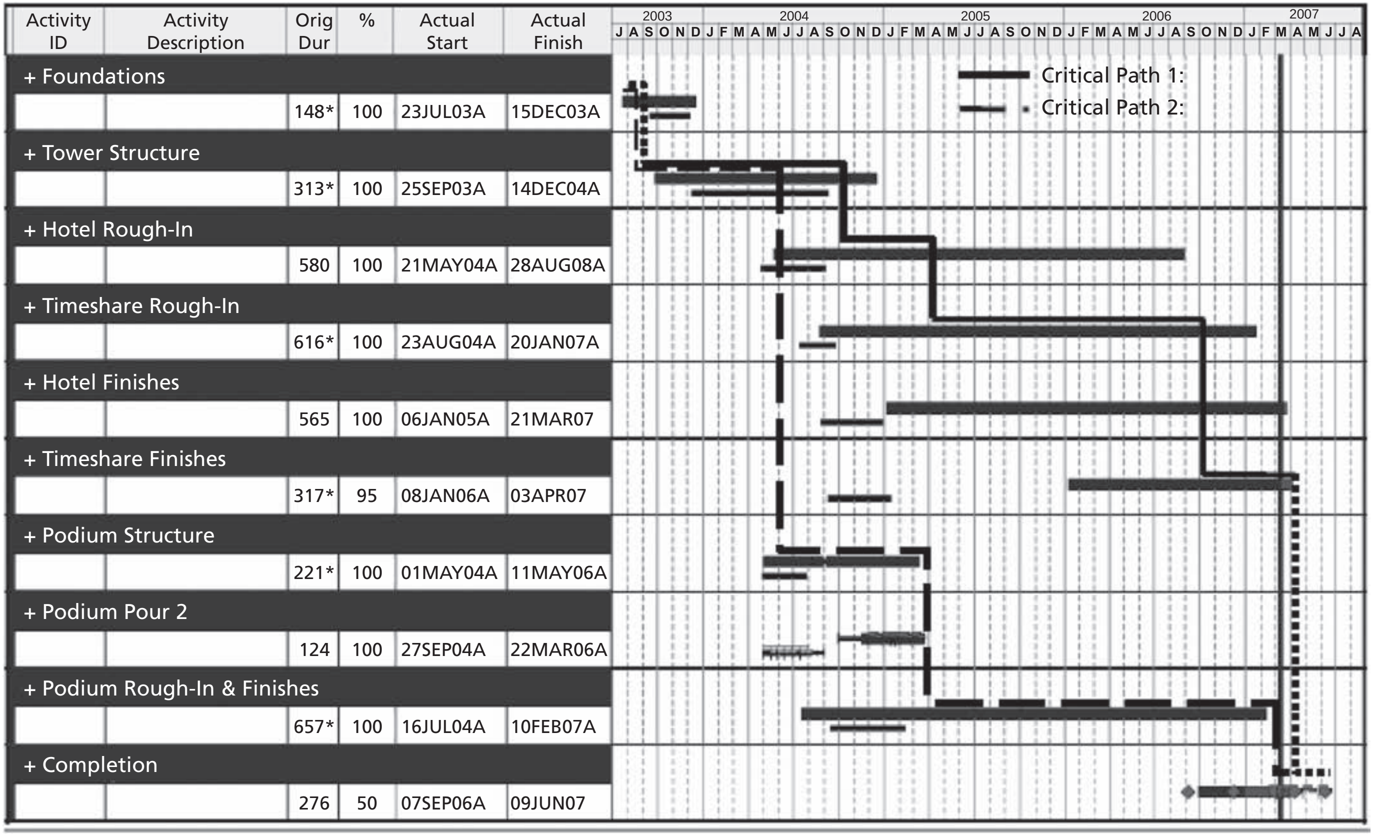
Identifying the critical path from time to time can be difficult without monthly progress updates or records. Defining an as-built critical path when performing an as-planned versus as-built analysis usually requires the input of a programming expert, using professional judgement and skill based on industry experience. The approach first requires the analyst to develop an objective and transparent method of deriving the critical path through the as-built programme. This may be supported by a chronology and an explanation of each shift of the critical path from one activity, or group of activities, to another. It is typical for more than one single critical path to be identified on large scale projects with work ongoing in several independent geographical locations. Concurrent delays are then evaluated by reference to events identified along these parallel critical paths. A sample illustration of a project with more than one single critical path is provided in Figure 4.7.

In Figure 4.7 both planned and as-built bars are represented, along with an as-built critical path through the timeshares, as well as an as-built critical path through the podium structure on the same project. It was determined that there were concurrent critical paths through these two areas of the building. If delays along one path were not experienced, or are removed from the analysis, delays along the other critical path would remain. It is possible that the delays along both of these paths were the liability of the employer. Alternatively, all of the delays along critical path 2 might have been down to a CDE. In reality, there is usually a mixture of liability, and allocation of delay periods along each path is required. When a contractor is able to demonstrate extension of time entitlement along more than a single path to completion, this could be described as 'concurrent entitlement'.

4.2.6 Total time assessments (observational/static/gross)

In its simplest form, an as-planned versus as-built analysis compares the planned duration with the actual duration of a project and asserts the difference as being both excusable and compensable. This is, in effect, a global claim. When advancing a global time claim (total time), a similar burden of proof must be met as that required for a total cost claim. The approach must demonstrate that:

- the as-planned 'baseline' schedule was reasonable;
- the contractor's performance was reasonably efficient;
- the contractor did not contribute to critical delay;
- the difference between the as-planned and as-built durations is entirely attributable to excusable events; and
- the complexity of the project makes it impossible or highly impractical to account for the time impacts of the other party/parties in any other way.



Activity ID	Activity Description	Orig Dur	%	Actual Start	Actual Finish
+ Foundations					
		148*	100	23JUL03A	15DEC03A
+ Tower Structure					
		313*	100	25SEP03A	14DEC04A
+ Hotel Rough-In					
		580	100	21MAY04A	28AUG08A
+ Timeshare Rough-In					
		616*	100	23AUG04A	20JAN07A
+ Hotel Finishes					
		565	100	06JAN05A	21MAR07
+ Timeshare Finishes					
		317*	95	08JAN06A	03APR07
+ Podium Structure					
		221*	100	01MAY04A	11MAY06A
+ Podium Pour 2					
		124	100	27SEP04A	22MAR06A
+ Podium Rough-In & Finishes					
		657*	100	16JUL04A	10FEB07A
+ Completion					
		276	50	07SEP06A	09JUN07

Figure 4.7 Multiple critical paths.

This is referred to as the Observational/Static/Gross method in the RP-FSA.

The process of carrying out an as-planned versus as-built programme analysis is as follows:

- Establish a contractually compliant as-planned programme for analysis. It is not essential that this programme indicates float or identifies critical paths.
- Establish a properly reconstructed as-built programme, to the same or higher, level of detail as the as-planned programme.
- Add into the as-built programme potential delay events which represent varied or additional work, key milestones (which may not have been included in the as-planned programme), and significant events which assist in demonstrating the chronology leading up to delays relied upon.
- Deduce at least one as-built critical path (ABCP) through the as-built programme. This is potentially the most subjective area of the as-planned versus as-built analysis. Unless monthly CPM updates were kept and relied upon throughout the project, or the critical path through the works is otherwise obvious and capable of being represented on a summary level programme, with activities grouped into a few bars, it is likely that the ABCP will be challenged in whole or part. In order to deduce an as-built critical path the analyst will have to:
    - From time to time, review correspondence, and weekly or monthly reports, to determine where the contractor's focus/effort was concentrated.
    - Apply experience to the type of construction and logical dependencies between tasks to interpret the required sequences followed.
    - From time to time, review plant and labour returns to determine where key plant or trades were utilised.
    - Review as-built start and finish dates between inherently dependent activities (see 'hard logic' in Chapter 2, Figure 2.3). The normal convention is to interpret the critical path as having shifted to a successor activity once the successor commences. (The predecessor is no longer critical once the successor is able to commence, even if the predecessor is not 100% complete.) If this convention is not followed, proper explanations should be provided.
    - Trace additional critical paths through the works, testing conclusions to eliminate unlikely critical paths, or to determine if there was more than one reliable critical path competing for dominance through to completion.

A properly reconstructed as-built programme is one which identifies all original scope, as well as all additional scope, to a level of detail which is suitable for analysing the discrete nature of each task and any delays experienced. The as-built should be comprehensive and must contain both critical and non-critical activities. It should be based on, and corroborated with, as many project records as necessary to identify and eliminate any erroneous or conflicting sources of information. If as-built bars contain extended periods of inactivity, the analyst should consider adding a new as-built activity for the individual periods of activity to avoid long extended as-built bars.

The method used to derive the as-built critical path should be recorded and all assumptions expressly stated so that the resulting as-built critical path is transparent and correctable if further evidence is identified which alters or enhances the as-built programme. At this stage, the analyst has the option of quantifying delays by way of an 'activity level' variance model or an 'earned value' variance model. An activity level variance model summarises the losses and gains experienced against the individual activities on the as-built critical path. The earned value variance model compares from time to time the progress achieved in resource dependent tasks (e.g. quantum of brick placed, number of electrical terminations tested, amount of concrete poured, tonnage of structural steel erected). Both are methods which are not dependent on assigning liability but assist in quantifying the delay to the project from time to time.

An activity level variance model would simply require the analyst to identify activity level variances (e.g. late commencement, extended durations, late finish dates and periods of inactivity) for all events along the as-built critical path. The steps for preparing an earned value model are as follows:

- create an as-built critical path liability table, listing all events along the as-built critical path and the actual start and finish date for each event, indicating when each event was on the as-built critical path;
- compare the equivalent planned duration for the amount of work actually accomplished during the length of time in which each activity was critical (i.e. if only four days of work was accomplished in a 10 day period, there would have been a critical delay of six days calculated in this 10 day period);
- determine the cause, or causes, of delay which could explain all or a portion of the shortfall for each event, and assign liability for each delay accordingly;
- summarise delays caused by both EDE and CDE;
- if more than one as-built critical path was identified, repeat the process for each ABCP identified; and
- compare the periods of delay assigned to each party and identify any concurrent delays.

The sum of the EDE caused delays will usually represent the contractor's extension of time entitlement. The sum of the EDE, less any concurrent CDE will usually represent the contractor's entitlement to prolongation costs.

If the method of deriving the as-built critical path is logical, systematic and objective, this method of analysis has many strengths over the deterministic techniques referred to above. Deterministic techniques sometimes present an all or nothing scenario which succeeds or fails by the assumptions relied on to construct the CPM models. Analytical techniques, such as the ABAP technique,

Table 4.12 As-built critical path summary table.

Activity ID	Description	Actual Start	Actual Finish
A-001	Mobilise	6-Jan-06	6-Jan-06
A-002	Advanced Works/Site Clearing	7-Jan-06	11-Jan-06
A-003	Install Pipe 00010-10200	12-Jan-06	12-Feb-06
X-012	Pipe Repair	13-Feb-06	24-May-06
A-006	Test Pipe	25-May-06	30-May-06
X-042	Repair Leak	31-May-06	2-Jun-06
A-020	East End Connection	3-Jun-06	8-Jun-06
X-045	Install Additional Manhole	9-Jun-06	15-Jun-06
A-024	Back-Fill Pipe	9-Jun-06	16-Jun-06
X-050	Instructed Additional Backfill	17-Jun-06	27-Jun-06
A-030	Final Acceptance/Handover	28-Jun-06	28-Jun-06

are inherently correctable because they rely on the available factual matrix and simple mathematical variance calculations based on start dates, finish dates and duration variances.

When assessing delays by reference to variances between activities (activity level variance[15]) the analyst must first identify the events which make up the as-built critical path. A typical 'as-planned versus as-built' as-built critical path summary table would set out the information as illustrated in Table 4.12.

This table simply indicates which activities were actually critical from commencement to completion; including both original contract work (activity IDs with prefix 'A') as well as additional scope added during the course of the works (activity IDs with prefix 'X'). This activity level as-built critical path does not attempt to determine the extent of delay, or liability for delay.

There are many ways to reconcile, rationalise and calculate variances once an ABCP is established. For the sample ABCP listed above, the variances can be calculated by reference to start and finish variances, or duration variances for the events identified along the ABCP. For additional scope, the duration of the added scope is a duration variance, and should be added to the finish variance. Also, to calculate the start and finish variance, the formula must take into account all previous 'activity level variance' (ALV) to isolate any delay, or recovery, experienced by each activity.

Table 4.13 can be used to demonstrate both critical delay and achieved recovery of previous delay, regardless of whether this was achieved through acceleration, or simply through mitigation of delay by, for example, working out of sequence. From the results example, shown in Table 4.13, the following can be deduced:

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[15] AACEI, RP-FSA, page 27.

Table 4.13 Activity level variance table.

Act. ID	Planned Start	Planned Finish	Actual Start	Actual Finish	Start var. (less prev. ALV)	Finish var. (less prev. ALV)	ALV	Cum. ALV
A-001	1-Jan-06	2-Jan-06	6-Jan-06	10-Jan-06	5	3	8	8
A-002	2-Jan-06	7-Jan-06	7-Jan-06	11-Jan-06	(3)	(1)	(4)	4
A-003	7-Jan-06	7-Feb-06	12-Jan-06	12-Feb-06	1	–	1	5
X-012			13-Feb-06	24-May-06	N/A	100	100	105
A-006	7-Feb-06	12-Feb-06	25-May-06	30-May-06	2	–	2	107
X-042			31-May-06	2-Jun-06	N/A	2	2	109
A-020	12-Feb-06	17-Feb-06	3-Jun-06	8-Jun-06	2	–	2	111
X-045			9-Jun-06	15-Jun-06	N/A	15	15	126
A-024	17-Feb-06	28-Feb-06	9-Jun-06	16-Jun-06	(14)	(4)	(18)	108
X-050			17-Jun-06	27-Jun-06	N/A	10	10	118
A-030	28-Feb-06	28-Feb-06	28-Jun-06	28-Jun-06	2	–	2	120

1. Activity A-001 commenced five days later than planned and took three days longer to complete. Activity A-001 experienced an ALV of eight days. Upon the completion of Activity A-001, the project was eight days behind programme.
2. Activity A-002 commenced five calendar days late. However, this was three days earlier than it should have commenced, when the previous ALV of eight days is taken into account.
3. Activity A-002 finished four days later than planned. However, this was one day earlier than it should have completed, when the previous ALV of five calendar days is taken into account (8 plus –3).
4. The cumulative ALV, upon completion of Activity A-002, reduced from eight days to 4 days – indicating recovery of four days of critical delay.
5. Activity A-003 commenced five calendar days later than planned, which is only one day of the start ALV when the previous ALV of four calendar days is taken into account. Activity A-003 finished five calendar days later than planned, therefore no further delay was experienced when the previous ALV of five days is taken into account (4 + 1).
6. Activity X-012 is an additional activity with an actual duration of 100 calendar days. This is entered into the summary table as a finish level variance, which is also treated as a duration variance for the purposes of this example. This applies to all of the 'X' activities, (X-012, X-042, X-050). (No liability is assigned to this variance as the purpose of the ABCP ALV reconciliation table is simply to identify the loss, or gain, experienced along the ABCP, and how much of that loss/gain is attributable to each discrete activity. Assigning liability for delay is the final step in the process.)
7. Activity A-006 'Test Pipe' started 107 calendar days later than planned. This is an ALV start variance of only two days when the previous ALV of 105 days is taken into account. Activity A-006 finished 107 calendar days later than planned. This indicates that there was no further delay experienced when Activity A-006's start variance of two days added to the pre-existing ALV of 105 days is taken into account.
8. Activity A-020 'East End Connection' commenced 111 days later than planned and finished 111 days later than planned. This is a start variance of only two days when the pre-existing ALV of 109 days is considered.
9. Activity A-024 'Back-Fill Pipe' commenced 112 days later than planned but only finished 108 days later than planned. This is a start variance of negative 14 (–14) days and a finish variance of a negative four (–4) days, when pre-existing ALV is considered. This indicates that there was a total recovery of 18 days along the critical path experienced.
10. The final activity on this as-built critical path is Activity A-030 'Final Acceptance/Handover'. This task was accomplished 120 days later than planned.

One should bear in mind that the above is only a summary of ALV to the ABCP. While there may be other critical paths through the same project which would warrant similar analysis, to identify the effect of concurrent delays for instance, it is widely accepted that any delay to a critical activity is a delay to the critical path of the project's overall duration. Many delay analysts assess and explain only the delays along the 'dominant' path, being the longest path through the project to completion. Whether concurrent delay is relevant to the delay analysis will often require contractual, legal and technical arguments. Concurrent delay is discussed further in Chapter 5.

If a 'project level variance' analysis were carried out, the analyst would have assessed a total delay of 120 days. However, the activity level variance analysis indicates that there was actually 142 days of critical delay, and 22 days of recovery accomplished.

Not only is it possible to determine periods of recovery, it is possible to show that the activity 'Final Acceptance/Handover' was dependent upon multiple sequences of unrelated events, in addition to the pipeline analysed. By identifying multiple critical paths through the same project, it is possible to determine concurrent periods of both culpable and excusable delay when each of these ABCPs are analysed side by side. Caution should be applied to ensure that each ABCP was truly competing for critical status throughout the project. The example in Table 4.13 provides one method of assessing critical delay by reference to planned and actual events which were critical in both the as-planned and as-built state. This method is said to be static because it relies on a static as-planned baseline schedule. The critical path and activity float values change dynamically in properly prepared progress updates, which may incorporate revisions to activity durations and the relationships between activities, as well as updating the status of each activity.

Events which appear critical in the as-built state, simply due to their proximity to the actual completion date, may be activities which had extensive float but were simply carried out at the last minute, as a result of pacing or preferential sequencing. Pacing and preferential sequencing are terms which are not well understood, or accepted, by many construction professionals and are often overlooked when asserting concurrent or culpable delays. Events which appear to be critical due to 'pacing' may be treated either as concurrent culpable contractor delay or simply as events which did not have any influence on the actual completion date. Demonstrating the presence of pacing can only be done with contemporaneous documents. Establishing or mounting a defence against the relevance of pacing will require similar analyses of the relevant facts and contract provisions as those relevant to concurrent delay. Pacing events will be considered further in Chapter 5.

The as-built critical path analysis is usually easily adjusted when required and is consistent with, and readily supported by, the available factual matrix. The SCL Protocol provides support for this method of deriving an as-built critical path from the contemporaneous evidence, and not just the CPM programme, when it recognises that the critical path is deduced rather than calculated:

> 'The critical path analysis or method is the process of **deducing the critical activities in a programme by tracing the logical sequence of tasks that directly affect the date of project completion**. It is a methodology or management technique that determines a project's critical path. The resulting programme may be depicted in a number of different forms, including a Gantt or bar chart, line-of-balance diagram, pure logic diagram, time-scaled logic diagram or as a time-chainage diagram, depending on the nature of the works represented in the programme.'[16] (emphasis added)

It should be emphasised that critical path analysis is the process of 'deducing' the critical path, not simply calculating it with programming software. In addition, tracing the logical sequences is a method that does not require detailed CPM diagrams in every case. Many projects are linear, sequential, and are made up of an indisputable critical sequence of events, both as-planned and as-built.

Both the SCL Protocol and the AACEI agree that establishing an as-built critical path is a prerequisite to demonstrating compensation for delay. The SCL protocol states that:

> '1.10.5 The loss and/or expense flowing from an employer Delay cannot usually be distinguished from that flowing from contractor Delay without the following:
>
> 1.10.5.1 an as-planned programme showing how the contractor reasonably intended to carry out the work and the as-planned critical path;
> 1.10.5.2 an as-built programme demonstrating the work and sequence actually carried out and the as-built critical path;
> 1.10.5.3 the identification of activities and periods of time that were not part of the original scope;
> 1.10.5.4 the identification of those activities and periods of time that were not part of the original scope and that are also at the contractor's risk as to cost; and
> 1.10.5.5 the identification of costs attributable to the two preceding sub-sections.'

The AACEI also sets out guidelines for identifying excusable and compensable delays:

> '1. Excusable & Compensable Delay (ECD): Each incremental delay along the as-built critical path should be independently quantified and the cause of the delay identified. Then, determine the sum of the individual delays that were the responsibility of the employer, and delayed the completion date of the project and were not concurrent with delays the responsibility of the contractor is excusable and compensable.'[17]

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[16] SCL Protocol, page 55.

[17] Ibid, p. 36.

It is usual for the analyst to identify both culpable (contractor caused) delay, as well as excusable and compensable periods of delay when applying the as-built versus as-planned methodology. Establishing liability for these periods will be driven by the facts. However, the as-planned versus as-built methodology is a very efficient method isolating which activities are relevant to the factual matrix, thereby reducing the scope of the dispute and factual investigation required.

The as-planned versus as-built is most effective when an ABCP is ascertainable and delays to critical activities are identified, and supported with contemporaneous project records. However, when a contractor claims delay entitlement based on a total time comparison (i.e. project level variances) using the as-planned versus as-built approach in support of a full excusable and compensable extension of time, the bar has been set quite high for establishing the requisite burden of proof. Basically, the contractor must be able to show:

- the original as-planned programme was reasonable;
- the contractor did not contribute to critical delay in any way;
- all delay events identified along the as-built critical path entitled the contractor to both time and money;
- there is no other way to demonstrate cause–effect; and
- the contractor has complied with relevant contractual obligations (notice provided, all requested information provided in support of delay claim, mitigation attempted, works carried out with diligence, etc.).

The defence taken by most respondents faced with an as-planned versus as-built delay analysis will focus on the above parameters. It is usually not difficult to identify culpable events not taken into account by the claimant's analysis, as well as changes to the programme logic implemented during the course of the works, when attempting to undermine reliance on the as-planned programme for use in assessing critical delay.

In addition to a valid as-planned and accurate as-built, the as-planned versus as-built approach requires the application of a fair amount of deduction as well as a reliable and comprehensive factual matrix. If applied correctly, the as-planned versus as-built approach can be one of the most convincing and reliable methods of delay analysis, without the need for any modelled methods of calculating delay. The strengths and weaknesses of as-planned versus as-built technique are summarised in Table 4.14.

4.2.7 As-planned versus as-built windows analysis

The as-planned versus as-built windows analysis is another analytical approach, referred to in the AACEI RP-FSA as '3.2 Observational/Static/Periodic'. This approach is addressed in the SCL Protocol simply as the 'As-Planned versus As-Built approach'. This method follows a similar approach as set out above

Table 4.14 Strengths and weaknesses of the as-planned versus as-built technique.

Strengths	Weaknesses
• Intuitive and easy to understand • Conclusions are readily supported by as-built records • Does not require frequently updated progress schedules. • Does not require logical relationships or float to be expressly provided in as-planned programme • Can identify concurrency in the period work was actually carried out • Can identify critical delay in the period in which the work was actually carried out, and the period in which the costs were actually being incurred	• As-built sequence must relate to as-planned sequence for activity level variance method • Requires analyst to deduce the as-built critical path absent monthly progress updates • As-Built programme required • Constructing proper as-built programme could be resource intense and expensive

for the APAB approach, with the basic difference being that the delay variances, which can be measured at the project level or activity level, are summarised at the end of each 'window' selected by the analyst. The beginning and end of each 'window' is usually defined by:

- key milestone events which occurred during the course of the works;
- periods when the contractor's intentions, logic or methodology changed (e.g. attempted acceleration or changed conditions);
- periods when snapshots of progress were recorded contemporaneously, allowing earned value analysis calculations within each window; or
- key changes, suspensions or delays having been experienced.

Using the critical path activities listed in Table 4.12 as an example, and re-analysing the delays using a 'windows' based approach, might result in the following as-built critical path windows:

Window Ref.	Description	Actual Start	Actual Finish
CP-1.001	Install Pipe	6-Jan-06	12-Feb-06
CP-1.002	Test Pipe	13-Feb-06	30-May-06
CP-1.003	Handover	31-May-06	28-Jun-06

The level of detail and the commencement of each successive window are at the analyst's discretion. This method could also be referred to as a 'watershed' analysis. Each 'watershed' is simply a reference to a new window, signifying the commencement, or completion, of a significant event which provides a convenient point from which to assess delay.

The investigation of the facts should be no less intensive whether using a windows or watershed based approach. However, when irregular windows are selected, caution should be used to ensure that windows are not selected to otherwise hide the impact of certain events. Even when frequent progress updates are available, additional windows can be selected to add transparency to the status of the project at the commencement or completion of significant delay events which might not coincide with the date of a progress update. These intermediate windows will require the analyst to create an intermediate base programme.

An example of a reconciliation of the delays for this ABCP represented as window level variances is shown in Table 4.15.

The premise of this approach is that the entire 'window level variance' (WLV) entitles the contractor to excusable or compensable delay. The tests for the project level variance listed above are applicable in this case, by reference to each WLV. However, a modified, and more appropriate approach using this technique, is to identify both contractor and employer delays which contributed to each WLV, and which may require a composite analysis using both ALVs and the WLV to apportion responsibility for delay in each window. To allow apportionment of the delay in each window, the WLV analysis requires one additional step, which is illustrated in Table 4.16.

Table 4.15 Window level variance reconciliation table.

Window Ref.	Planned Start	Planned Finish	Actual Start	Actual Finish	Start var. (less prev. WLV)	Finish var. (less prev. WLV)	WLV
CP1-001	1-Jan-06	7-Feb-06	6-Jan-06	12-Feb-06	5	–	5
CP1-002	8-Feb-06	12-Feb-06	13-Feb-06	30-May-06	–	102	102
CP1-003	13-Feb-06	28-Feb-06	31-May-06	28-Jun-06	–	13	13

Table 4.16 Liability assessment.

Window Ref. CP	Description	WLV	CDE	EDE	Liability Assessment
CP1-001	Install Pipe	5		**5**	Delayed Site Access (5 days)
CP1-002	Test Pipe	102	**82**	**20**	Pipe Repair (80 days), Late Instruction (20 days), Plant Breakdown (2 days)
CP1-003	Handover	13		**13**	Additional Back-fill (10 days), Additional Manhole (3 days)

Depending on the level of detail of each window, it is less likely that the windows based approach will be useful in identifying concurrent delay because the actual over-run is not assigned to particular activities. The main drawback is that the costs associated with the delay in each window would require an average prolongation rate for each window in order for any compensation for prolongation to be awarded. With shorter discrete windows (weekly or bi-weekly) the overhead rate in each window would be less theoretical, and the time-related damages would be more representative of the actual loss experienced due to each identified delay event. The longer the window, the more theoretical the average overhead rate would be and the more difficult it would be to isolate damages incurred as a direct result of the event relied upon.

The strengths and weaknesses of this method are similar to those for the ABAP approach. One of the main differences is that this method has the ability to isolate and analyse periods when the contractor changed its intentions at some time after the issue of an as-planned schedule, thus it can explain the influence of delaying or disrupting factors in ‘windows of time’. Both the ‘activity level variances’ method and ‘windows level variances’ can demonstrate periods of achieved acceleration, as measured against the as-planned intentions. The benefits of this approach are decreased when:

- regular/frequent progress updates are available;
- the duration of the windows are very large;
- the contract scope or actual sequence of works is altered dramatically; or
- the contractor failed to follow the as-planned sequence.

The two as-built/static methods described above rely on comparison and rationalisation of two static models, the as-planned and the as-built programmes. When progress updates are relied on, the analysis will be able to take into account the dynamic nature of the critical path, actual progress achieved, and the contractor’s changed intentions from time to time. These are discussed next.

4.2.8 Contemporaneous windows analysis

A technique which relies on the analysis of contemporaneous progress information is considered to be dynamic because it considers the dynamic nature of the critical path. The as-built critical path of a programme shifts from time to time for many reasons, including:

- Variations from planned (or remaining) durations due to actual progress
- Variations from planned (or remaining) durations due to delay events
- Changes to planned (or remaining) durations due to added or deleted work scope

- Out of Sequence working due to a variety of reasons (e.g. changed intentions, varied scope, late design information, unforeseen conditions, plant breakdowns, access restrictions)
- Changed logical relationships due to a variety of reasons (see above)

Any changes made to the programme to reflect the actual progress achieved and the contractor's intentions for completing the remaining scope will have an effect on the total float of each activity in the programme and, most likely, the location of the critical path from month to month. Identifying the 'driving' activities from month to month using an objective and systematic method that is not subject to interpretation or assessment reduces the possibility of the approach being challenged. When the underlying data is not altered, and used in its contemporaneous condition, this is said to be an 'as-is' analysis. One variation to this theme is to use either forensically created progress updates, or to modify, augment or correct the existing progress schedules to correct any inherent errors in the data. Caution should be used when attempting to create a progress update forensically or when attempting to correct a contemporaneous record of progress.

Following the publication of the SCL Protocol many construction contracts now require contemporaneous progress programmes to be updated regularly and frequently, usually on a monthly basis. If such updates are not available, the 'contemporaneous windows analysis' may not be appropriate. If, however, there is an accepted baseline programme and detailed progress data available, which would allow the analyst to create 'what-if' contemporaneous programmes, such an analysis could be representative of what the contractor may have reported, particularly if progress is assessed and entered into the CPM programme at monthly intervals. Such an analysis is unlikely to provide a true representation of what each monthly update would have contained, due to the subjective nature of the assessment of progress achieved and remaining durations for each activity in the programme.

Additionally, contractors have the prerogative to change their intentions from time to time and it is difficult to replicate these changed intentions in forensically created progress programmes. The AACEI provides guidelines for creating progress updates forensically, which does not necessarily endorse the approach as much as it serves to highlight the subjective nature of the process. The section is entitled '2.3. Schedule Updates: Validation, Rectification, and Reconstruction (SVP 2.3)' and should be followed when contemporaneous schedule updates are not available, or when the analyst elects to rely on extensively modified 'updates' or programmes which are completely recreated.

When the method of analysis requires the recreation of a baseline programme the process should be carried out as transparently as possible to allow corrections to be made when further information regarding the baseline comes to light. Whether intentional or not, there is a risk that delay analysts will use the opportunity to create baselines which enhance the position of each respective client. As the name suggests, 'contemporaneous windows analysis' should, so far as possible, rely on contemporaneous progress evidence.

This method is considered to be both 'observational' and at the same time 'dynamic'. The method is observational because it does not require or rely on a base CPM model which calculates delay based on the addition or extraction of EDE or CDE. The approach relies on the rationalisation of changes and variances which are observed in the contemporaneous programme updates.

Some employers prefer this method of delay analysis because it uses contractor information, and relies on an as-built critical path to demonstrate the actual effect of delays. Equally some contractors do not like this approach because it can hide the impact of concurrent delays or events, such as design activities, which are not adequately modelled in the as-planned CMP or progress updates.

The basic process of identifying the as-built critical path, and the activities which experienced critical delays along that path, is contained in Table 4.17.

Whenever dealing with float, it must be remembered that float is a relative measure of delay rather than an absolute measure of delay. The amount of loss or gain in float calculated each month may not appear to correspond exactly with the number of calendar days the project completion slipped or gained in that same period. This is due to constraints such as working-day calendar assignments, imposed 'must finish by' dates, imposed 'zero total float', and so on. The number of calendar days the project loses, or gains, between each update is an absolute measure, measured in calendar days against a milestone completion date.

The strengths and weaknesses of the contemporaneous windows analysis technique are summarised in Table 4.18.

This method is the preferred method by the authors when contemporaneous updates are available. Performing 'float mapping' exercises on recreated or modified contemporaneous programmes should be avoided. A case study is provided in Chapter 6 which contains a detailed application of this methodology, along with a further explanation of its strengths and weaknesses.

4.2.9 Month-to-month update analysis

A similar method to the 'contemporaneous windows analysis' is the 'month-to-month update analysis'. This is a method which discretely determines the loss/gain experienced due to both progress achieved/not achieved and programming revisions made by the contractor. This method identifies and isolates any programming revisions made by the contractor from update to update to determine the additional loss or gain achieved by those revisions. This method is referred to as the 'Observational/ Dynamic/Contemporaneous Split' in the AACEI RP-FSA. The terms 'observational', 'dynamic', and 'contemporaneous' are familiar to the reader by now. The added term 'split' refers to a process described in the

Table 4.17 Identifying the as-built critical path.

1. Identify the contractor's as-planned CPM programme.
2. Identify all contemporaneous progress updates through to completion.
3. Determine the most critical activities in each month by identifying the activities with the least amount of positive total float or the greatest amount of negative total float. (This may require replacing float and date constraints with appropriate logical relationships and can be done manually, or by using the 'longest path' or 'critical path' filter options available in most commercially available software.)
4. Determine the activities along the longest path which are either in progress or planned to commence in the period being analysed. These are deemed to be the 'driving' activities.
5. Keep a record of the float values for all of the driving activities in a 'float map' (a technique described in detail in the case study in Chapter 6) which tracks the gain and loss of float against each driving activity through all of the available contemporaneous progress records.
6. Group all related driving activities in the float map and identify concurrent as-built critical paths by reference to sequences of unrelated activities which were competing for dominance on the driving contemporaneous critical path from time to time.
7. Identify the tasks which were sub-critical but predecessors to 'driving' critical activities along each path when concurrent as-built critical paths were dominant in that period.
8. Document the planned project completion date in each monthly update. (When concurrent critical paths were critical to 'sections' defined by the contract then each sectional completion date should be monitored and documented.)
9. Identify and record the loss or gain achieved in each monthly update by reference to the projected project completion date.
10. Align the driving activities identified in the float map exercise with the loss/gain achieved each month.
11. Investigate the cause of delay to the driving activity in each period where a measurable loss or gain is identified.
12. Assign or apportion responsibility for the loss or gain measured in each window by reference to the driving activity and causative events documented in the contemporaneous records.

Table 4.18 Strengths and weaknesses of contemporaneous windows analysis technique.

Strengths	Weaknesses
• Relies on readily available contemporaneous progress programmes • Relies on shifting critical path • Allows identification of multiple critical paths. • Intuitive and easy to understand • Conclusions are readily supported by as-built records • Can identify concurrency in the period work was actually carried out • Can identify both loss and gains achieved between progress updates • Can identify critical delay in the period in which the work was actually carried out, and the period in which the costs were actually being incurred	• Properly updated progress programmes required • Activity start, finish and float constraints may create gaps in the as-built critical path and require rationalisation when they affect the critical path • Early programmes may contain logical errors which were corrected in later contractor prepared updates • Requires reasonable level of planning expertise

RP-FSA as 'bifurcating'.[18] This approach allows the isolation of any gains (mitigation) or losses (delays) due solely due to progress achieved, as opposed to any gains or losses due to revisions to the schedule. These other revisions, unrelated to the progress achieved, might include:

- increased or decreased activity durations;
- amended, added or deleted logical relationships;
- amended, added or deleted constraints;
- increased or decreased leads or lags; or
- added or deleted activities.

When deriving the as-built critical path, it is important to ensure that the float values of the activities which are assessed as driving are directly related to the chain of events on the longest path to completion. Constraints such as 'zero total float', 'must start', or 'must finish' dates will have the effect of inhibiting the programme from calculating a true float path when those constraints fall on

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[18] Bifurcation (also known as half-stepping or two-stepping) is a procedure to segregate progress reporting from various non-progress revisions inherent in the updating process. This should not be considered a revision or modification of the update schedules but rather a procedure that examines selected data, namely logic changes, which are inherent in the updates of the record. For a step-by-step implementation of the bifurcation process please refer to MIP 3.4.

either the path with the least float or the longest path to completion. It may be necessary to remove any manually imposed date or float constraints to allow the programme to calculate a true float path, thus allowing the analyst to derive the driving activities at the beginning of each window being analysed.

This method of analysis is very effective when a contractor is seeking to demonstrate 'acceleration' and needs to demonstrate what the 'likely' effect of a delay event would have been, as opposed to the 'actual' effect. If acceleration measures or mitigation was attempted by way of altering logical relationships, increasing the overlap of future events and so on, the actual effect will be decreased. By demonstrating both what the delay was by reference to the progress update, as well as what the delay would have been, the contractor has a credible method of demonstrating achieved acceleration by reference to both the as-built schedule and contemporaneous progress programmes.

The basic process is as follows:

1. Identify the contractor's as-planned CPM programme.
2. Identify all contemporaneous CPM progress updates to completion.
3. Export the progress achieved each month, against each activity into a spreadsheet, data-base, comma separated value (CSV) or ASCII text file. This will include only progress data, including percent complete, actual start, actual finish, and remaining durations.
4. Identify the periods requiring a 'half-step' update to evaluate loss/gain experienced due to 'progress only' (month 'n').
5. Import the progress achieved in month 'n' into the immediately preceding update programme (month n – 1);
6. Recalculate month n – 1 programme with the data date corresponding to month n. This is the 'month-to-month' progress-only update. Save the programme with an appropriate unique file name.
7. If subsequent programmes contain logic or duration revisions which were not agreed to, or are somehow suspect, the programme which received the progress data for month 'n' may also need to receive the progress data for month 'n' + 1, and so on. If so, repeat the process:
   - import cumulative progress as of month n + 1 into the programme n – 1;
   - re-calculate the programme with the data date corresponding to month n+1, save the file, and repeat the process as many times as necessary.
8. Tabulate the loss/gain to the project completion from each subsequent month-to-month update programme.
9. Tabulate the additional loss/gain in the corresponding contemporaneous programme update with the same data date. This loss/gain is the amount of delay that was not related to progress, but rather due to changes in sequences, durations made by the contractor on the programme.
10. Rationalise the additional loss/gain by researching and identifying the changes in logic/duration along the critical path which caused the additional loss/gain. (This can be done by way of manual review of the electronic programmes

or by using commercially available scheduling comparison software such as 'Claim Digger™[19] or PrimaPlan Project investigator™.)

11. For the month-to-month programmes, determine which activities were on the 'longest path' which were either in-progress, or planned to commence in the period being analysed. These are determined to be 'driving' activities in the month-to-month update programme.
12. Compare and rationalise the variances of the float values for all of the driving activities in a 'float map' which tracks the gain/loss of float solely due to lack of progress in each driving activity through all of the available contemporaneous progress records.
13. Group all related driving activities in the float map and identify concurrent as-built critical paths by reference to sequences of unrelated activities which were competing for dominance on the driving contemporaneous critical path from time to time.
14. Identify the tasks which were sub-critical but predecessors to 'driving' critical activities along each path when concurrent as-built critical paths were dominant in that period.
15. Document the planned project completion date in each monthly update. (When concurrent critical paths were critical to 'sections' defined by the contract then each sectional completion date should be monitored and documented.)
16. Identify the loss/gain achieved in each monthly update by reference to the projected project completion date.
17. Align the driving activities identified in the float map exercise with the loss/gain achieved to the completion date each month.
18. Investigate the cause of delay to the driving activity in each period that a measurable loss/gain is identified.
19. Assign or apportion responsibility for the loss/gain measured in each window by reference to the driving activity and causative events documented in the contemporaneous records.
20. Assign or apportion responsibility for the additional loss/gain reported due to changes to logic or duration noted above in step 10 above.

There are automated methods provided in some commonly available planning software for performing the above operations. The skill level and familiarity of the analyst with these functions will determine the effort required to perform this method of analysis.

There are many uses for the approach. For example, an employer's representative may reject a contractor's programme updates, and the contractor's subsequent claim for delay and acceleration damages, on the basis that the number and nature of the changes made to the base programme make the programme unsuitable for the task of imposing delays. To meet this criticism, the contractor could choose to rely on a programme analysis which uses the actual progress

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[19] Primavera™ has integrated Claim Digger™ into version 5.

Table 4.19 Summary of delay identified using the month-to-month technique.

Contemp CPM Prog. Reference	Delay as reported in CPM Updates	Month-to-Month Programme Reference	Delay Calculated Month-to-Month Programmes (cal. days)	Month-to-Month Cumulative Gain/Loss	Gain/(Loss) experienced through revisions
A	B	C	D	E	F (D – B)
UP10	393	**UP10**	393	0	0
UP11	403	1002	424	31	21
UP12	430	1003	454	30	24
UP13	431	1004	466	12	35
UP14	431	1005	473	7	42
UP15	513	**UP15**	515	42	2
UP16	513	1507	518	3	5
UP17	513	1508	521	3	8
UP18	513	1509	564	43	51
UP19	612	1510	543	–21	(69)
UP20	612	1511	571	28	(41)
UP21	514	1512	603	32	89
UP22	514	1513	630	27	116
UP23	514	1514	597	–33	83
UP24	528	1515	590	–7	62
UP25	556	1516	567	–23	11

achieved and projects the delay in each window using the most recently accepted programme as a '*consistent baseline*'. While not a perfect solution, it is one which may address such criticism from employers. The most common use of this approach, by contractors, is to demonstrate the amount of acceleration attempted, or achieved, through re-sequencing or adding resources to a project.

Table 4.19 was prepared using the above procedure and summarises the delay calculated in the month-to-month progress updates alongside the projected completion date reported by the contractor at the time. This analysis determines what delay would have been reported in each window if a 'consistent baseline' had been used as the basis for the window analysis. Contemporaneous programme updates UP10 and UP15 were accepted by the employer's representative. These were used as the 'base' programme for the 'month-to-month' calculations in columns C and D.

The month-to-month update analysis indicates that the contractor reduced the delay that would have been reported in all but two contemporaneous updates, UP19, and UP20. In these two programmes, the delay in the recalculated 'month-to-month', by importing progress from UP19 and UP20 into the UP15 base programme, was actually less than the delay projected at the time. This indicates that no acceleration was attempted in UP19 or UP20, and there were other logic, scope or duration alterations in these two programmes which caused delay beyond what would have been projected had the logic and scope remained in accordance with UP15.

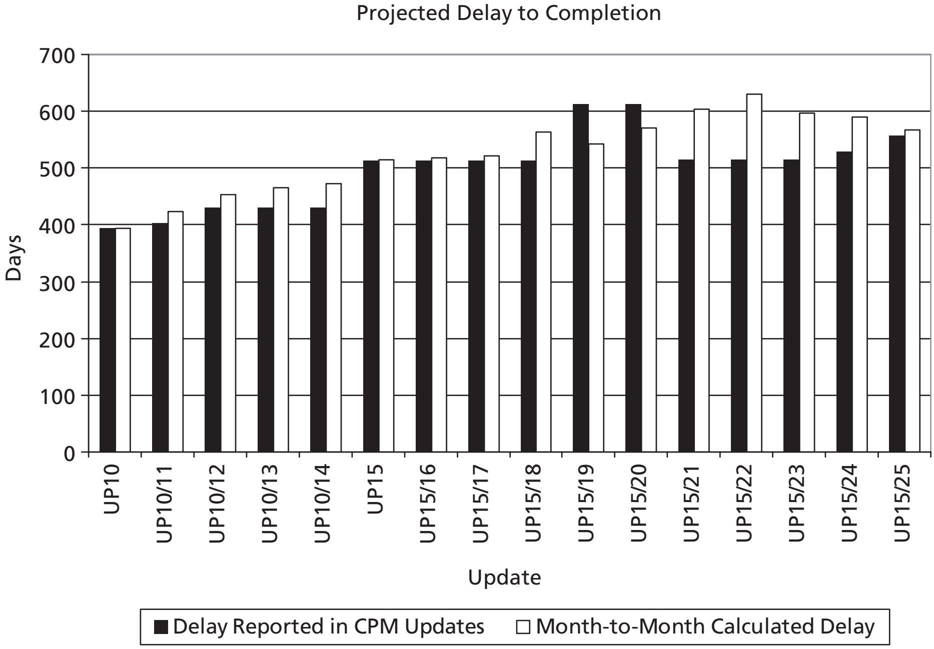

Figure 4.8 Month-to-month update analysis.

Column F in Table 4.19 indicates the number of days which were gained, or lost, due to the revisions or sequence alterations made to each of the contemporaneous progress updates. This data has been converted to bar chart format at Figure 4.8 to assist clarity.

The white bars in Figure 4.8 were created by importing contemporaneous progress data into UP10 and UP15. These calculations indicate what delay would have been projected if the contractor had not attempted mitigation measures and acceleration through re-sequencing and other methods as represented in the logic and durations of the contemporaneous progress updates. The black bars indicate the delay that was actually calculated, at the time. It was argued that projected delay represented by the black bars was reduced due to attempted acceleration measures.

Each of the loss and gains reported above could easily be researched and allocated to either an EDE or CDE. Normally, the contractor would gain the benefit of any recovered time to be set against culpable delays. However, the allocation of liability will depend on the relevant facts.

This is clearly a theoretical conclusion because the programme logic was not static. It was altered dynamically by the contractor, whether appropriate, accepted or not. However, the delay that is determined using the month-to-month update programmes, and contemporaneous progress (actual start, finish, remaining duration) is helpful in determining what the reported delay might have been if not for the re-sequencing that was instigated by the contractor. In the face of excusable delay events, this is good evidence to support the position that the contractor both attempted and achieved some mitigation.

Whether this could be classified as acceleration depends on the measures and means by which delay was mitigated from month to month.

These results demonstrate that the schedule alterations made 'month-to-month' to the programmes were not designed to increase, or exaggerate, the reported delay at the time. However, caution should be applied to ensure the schedule alterations were not made to sequester a culpable delay event by means of unrealistic logic or duration revisions.

It is good practice for a contractor, or consultant, tasked with the requirement to keep and maintain CPM programmes, to issue a transparent record of all programming revisions made on a monthly basis to avoid allegations of deliberate schedule manipulation. The strengths and weaknesses of this approach are set out in Table 4.20.

Table 4.20 Strengths and weaknesses of the month-to-month update analysis technique.

Strengths	**Weaknesses**
• Relies on readily available contemporaneous progress programmes • Relies on dynamic critical path • Allows identification of multiple critical paths • Allows delays to progress to be isolated from delays due to preferential logic and duration changes or corrections • Intuitive and easy to understand • Conclusions are readily supported by as-built records • Can identify concurrency in the period work was actually carried out • Can identify both loss and gains achieved between progress updates • Can identify critical delay to specific activities in the period in which the work was actually carried out, and the period in which the costs were actually being incurred • As a 'cause based' approach, it is objective, and relies on programmes already available to both parties • The programme analysis is relatively straightforward and easy to perform • Does not require creation of an as-built	• Updated progress programmes are required • Actual start, finish and percent complete for each activity must be available in each period requiring a month-to-month update • Activity start, finish and float constraints may need to be replaced with appropriate logical relationships when deducing the as-built critical path and driving activities • Logic and duration changes made by the contractor may not be possible to rationalise in forensic circumstances • The base update-to-update programmes may not reflect the contractor's intentions at the time of each identified delay event

Of all of the methods described above, the IAP, TIA and CAB were 'cause' based approaches. These methods firstly identify all of the relevant delay events (both CDE and EDE) and rely on the models to calculate the 'effect'. When applying these techniques, it is important to gather all relevant project documents, contractual provisions, and relevant progress records and to identify all of the events which are going to be added or extracted from the relevant programme.

The as-built methods were all 'effect' based approaches. These methods start with the delay 'effect' and then identify the most proximate event, be it CDE or EDE, that most likely caused that delay.

4.3 Selection criteria and guidance

On many of today's larger international engineering and construction projects, the contracts specifies which method of analysis will be used to measure the impact of change to the programme during the course of the works. When the contract is silent on the method, or when these requirements are not followed, the terms of the contract must be the first factor to consider when choosing which method of analysis will be applied forensically.

If the contract terms state that the extension of time entitlement must be established by measuring delays to the 'planned completion' date rather than the 'contract completion' date, then a method which relies on contemporaneous programme projections is necessary. This is because the 'planned' date changes from time to time; progress achieved and the impact of any critical delays experienced must be measured by relation to the 'planned' completion date.

If the contract terms state that the extension of time entitlement must be established by events which 'have caused delay' to completion, then a form of retrospective analysis relying on an as-built programme of some sort is likely to be most appropriate so that the delay will have a basis in fact, rather than prospective CPM calculations.

If the contract requires that extension of time entitlement can be established based on the 'likely delay' to completion caused by an event, then methods of prospective analysis, which project 'what-if' scenarios of how the works might have been delayed, may be used.

Before selecting the method of analysis, it is necessary to review the contract and identify what question(s) the analyst must address, for example: what was the actual delay to completion, as a matter of fact, and what is the likely delay to completion?

The questions identified will influence whether the delay analysis method starts with identifying the 'cause' and attempting to assess the 'effect' on contract completion, or whether to start with the 'effect' (i.e. the actual over-run or delay) and assess the most proximate 'cause'. When seeking to justify acceleration, it is sometimes recommended that more than one method of delay analysis is applied, using the same factual matrix to answer both questions. A prospective method of delay analysis will assist in demonstrating what the delay 'would have been' if not for attempted acceleration, while a forensic method of analysis will assist in demonstrating what true delay was experienced, as a matter of fact. Demonstrating delay periods, as a matter of fact, assists in demonstrating, or linking, actual delay related damages for the same periods of delay.

The lack of guidance regarding delay analysis methodologies has to an extent hampered advancements in the fields of change management and dispute resolution. It has, for example, resulted in delay analysis becoming an end in itself in large disputes. However, this situation has changed in recent years with the publication in the UK of the SCL Protocol. A similar guide has also appeared in the US in the form of the Recommended Practice No. 29R-03 *Forensic Schedule Analysis* provided by the Association for the Advancement of Cost Engineering International.

Delay and disruption analysis is one of the most researched, controversial and featured topics at international forums and conferences on construction world-wide. The guidance and recommendations contained within these two documents are considered briefly below.

4.3.1 The SCL Delay and Disruption Protocol

Firstly, in the UK, the Society of Construction Law published its Delay and Disruption Protocol in October 2002. The aim of the SCL Protocol is stated as being to:

> 'provide useful guidance on some of the common issues that arise on construction contracts, where one party wishes to recover from another an extension of time and/or compensation for the additional time spent and the resources used to complete the project. The purpose of the Protocol is to provide a means by which the parties can resolve these matters and avoid unnecessary disputes.'[20]

Regarding its use, it states:

> 'The protocol exists to provide Guidance to all parties to the construction process when dealing with time/delay matters. It recognises that transparency of information and methodology is central to both dispute prevention and dispute resolution.'

The focus of the SCL Protocol is on dispute avoidance by providing recommendations for managing programmes that are capable of being used for managing, and predicting, the impact of change during the course of a project. The SCL Protocol recognises that the application of common sense and reality checks are required when applying delay analysis techniques.

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[20] Ibid, page 3, Introduction.

The SCL Protocol has effected a sea-change in the way delay analysis is undertaken in the UK and everywhere UK based contractors, consultants or law firms conduct business around the globe. It has successfully raised awareness of the problematic issues regarding delay analysis and compensation for delay related damages. The SCL Protocol achieved judicial recognition in the UK Courts[21] when resolving complex construction disputes regarding delay and disruption.

The SCL Protocol sets out 21 core statements of principle, four Sections of Guidance Notes which explain the authors' position on the points of principle, guidelines on 'Preparing and maintaining programmes and records', guidelines on 'Dealing with extensions of time during the course of the project' and guidelines on 'Dealing with disputed extension of time issues after completion of the project'. The protocol also provides useful definitions and a glossary of terms. A 'Model Specification Clause' for the provision and management of programmes on construction projects, 'Model Records Clauses' and 'Graphics Illustrating Points' are also included.

The 21 points of principle addressed in the SCL Protocol are listed in Table 4.21.

Table 4.21 The SCL Protocol points of principle.

1. Programme and records.
2. Purpose of extension of time (EOT).
3. Entitlement to EOT.
4. Procedure for granting EOT.
5. Effect of delay.
6. Incremental review of EOT.
7. Float as it relates to time.
8. Float as it relates to compensation.
9. Concurrent delay – its effect on entitlement to EOT.
10. Concurrent delay – its effect on entitlement to compensation for prolongation.
11. Identification of float and concurrency.
12. After the event delay analysis.
13. Mitigation of delay and mitigation of loss.
14. Link between EOT and compensation.
15. Valuation of variations.
16. Basis of calculation of compensation for prolongation.
17. Relevance of tender allowances.
18. Period for evaluation of compensation.
19. Global claims.
20. Acceleration.
21. Disruption.

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[21] *Mirant Asia-Pacific Construction (Hong Kong) Limited* v. *Ove Arup And Partners International Limited*, His Honour Judge Toulmin CMG,QC, [2007] EWHC 918 (TCC).

A number of the SCL Protocol recommendations were well received, in particular the establishment and management of a detailed construction programme and the need for transparency when auditing the baseline programme including identification of any subsequent changes to that baseline. Some guidance was controversial; for example the SCL Protocol's support[22] for the time impact analysis methodology was met with some trepidation. The SCL Protocol states: 'This technique is the preferred technique to resolve complex disputes related to delay and compensation for delay'. The general concern expressed about this view was that it was too prescriptive, and did not place equal reliance on more accurate methods of as-built analysis

4.3.2 The core statements of principle

The following is a brief summary on each of the SCL Protocol points of principle.

1. Programme and records

It is recommended that the contractor should prepare and the contract administrator agree a baseline programme. This programme should be updated to reflect actual progress and any extensions of time granted. It is also recommended that the parties should agree on the type of records that should be kept to identify the cause and extent of delays. Model specifications are provided for the preparation, submission, updating and revising of construction programmes as well as a model records specification. Penalties and sanctions are offered to deal with failure to comply with the programme provisions, including:

- reducing interim payments by 25% until the contractor submits a programme initially or updates the accepted programme (at which point the 25% is released);
- liquidated damages to cover the owners added cost of hiring outside consultants if the contractor fails to submit or update a programme;
- default for a material breach due to the failure to submit a programme or update it.

2. Purpose of extension of time

It states that the benefit of an extension of time for a contractor is solely to relieve the contractor of liability for damages (e.g. LDs) for delay to the contract completion date. The benefit for the employer is twofold. First it maintains the right to establish a new contract completion date, thus preventing time for

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[22] The SCL Protocol, Section 4, Paragraph 3.2.13, page 45.

completion of the works becoming ‘at large’. Also it preserves the employer’s right to deduct damages from the contractor.

3. Entitlement to extensions of time

Applications and awards of extensions of time should be dealt with ‘at the time’ the event occurs. This requires both parties to accept a risk transfer mechanism and negotiations for time and money, at the time, to be signed off by both parties as *‘full accord and final settlement for all related damages, direct or indirect’.* The protocol discourages either party playing the ‘wait and see’ game, as delays rarely go away by themselves and the later an application is left, the more difficult it will be to assess its impact accurately.

4. Procedure for granting extension of time

The SCL Protocol recommends that extensions of time are awarded close to the time a delay event occurs, e.g. prospectively, to avoid the ‘wait and see’ position frequently adopted by contract administrators. This position is often endured by contractors under the erroneous expression that it will assist their likely recovery position later. The underlying principle is that an extension of time should be based on ‘entitlement’ not need.

5. Effect of delay

The SCL Protocol suggests that the risk of the potential effect of an event can be transferred to the contractor (via a prospective extension of time) before the impact of that event is actually known. This is simply an agreement to revisit the original ‘bargain’ struck between the parties each time the work is varied.

6. Incremental review of extensions of time

To address the concern that, based purely on a prospective delay analysis, more time might be granted than a proper as-built analysis would later justify, the SCL Protocol suggests that extensions of time could be awarded incrementally based on the known impact from time to time.

7. Float as it relates to time

This point touches on a hotly debated issue, namely who owns the float in a contract programme. This topic is reviewed in detail in Chapter 5. On this point the SCL Protocol endorses the usual contractual position that an extension of time will only be granted where float on the critical path(s) has been reduced to below zero and thus the contract completion date is delayed. This view assumes that the contract does not indicate that one party or the other ‘owns’ the float.

8. Float as it relates to money

To balance the SCL Protocol's stance on ownership of float, the protocol suggests that contractors are entitled to direct time related costs (not overheads) for periods of delay which deteriorate float. This could be interpreted to apply only when a contractor is working to an 'early completion' programme (i.e. when 'terminal float' exists along the critical path). An accurate, approved and transparent programme, updated from time to time, is essential for this to work in practice. Chapter 5 discusses the topic of a contractor's right to early completion in detail.

9. Concurrent delay – its effect on entitlement to extension of time

Not only did the SCL Protocol tackle the issue of float, it also took on another major or controversial issue namely, 'concurrent delay'. The UK courts tend toward the 'dominant' cause approach, but the SCL Protocol has recommended the more traditional US approach in which employer risk events entitle a contractor to an extension of time when concurrent delays are present. The protocol also addresses the financial aspect of concurrent delay (see 10 below).

10. Concurrent delay – its effect on entitlement to compensation for prolongation

The protocol provides a clear definition of 'concurrent delay' making the term interchangeable with 'concurrent effect'. This is a more accurate description of the common scenario, as true concurrent delays are rare and often contested. The general principle for 'compensable' delay used in the US applies. A contractor can only recover costs which directly result from a compensable event. If those costs cannot be discretely isolated from any non-compensable causes (i.e. the costs would have been incurred in any event), the contractor is not entitled to any recovery of time related costs.

Although there is a recent movement towards 'dominant' delay arguments in the UK on professional negligence cases, the SCL Protocol is consistent with general English law which requires a claimant to link the loss flowing from the defendant's wrongful act. If it can be shown that the loss would have been incurred in any case, due to a contractor risk event, then no loss has been suffered due to the employer risk event. The SCL Protocol recommends record keeping and accounting for supervision and overheads to allow a contractor to discretely track compensable costs and non-compensable costs.

This is consistent with the attempt to encourage the parties to deal with extension of time applications as close as possible to the delay event. The 'dominant cause' approach, a retrospective view, encourages the 'wait and see' attitude, which is frowned upon in the SCL Protocol. If all recommendations in the SCL Protocol are followed, a forensic 'dominant cause' approach should not be required. The problematic issues associated with concurrency are more fully dealt with in Chapter 5.

11. Identification of float and concurrency

As a practical point, the identification of float and concurrency contemporaneously are only possible if all programming management provisions are complied with (i.e. a programme which is approved and properly updated).

12. After the event delay analysis

A further somewhat controversial aspect of the SCL Protocol is the suggestion that a trier of fact should place himself in the shoes of the contract administrator 'at the time', to determine what extension of time should have been granted at that point, without the benefit of hindsight. For this approach to work practically, reliable programmes would have to be available for any form of prospective delay analysis to be applied. Many delay analyst consultants might see this as an invitation prospectively to create a programme from which delays can be impacted. Many would say that a contractor should not benefit from a prospective analysis when they failed to provide to the project consultants/CA contemporaneous programmes which would have allowed such an analysis to take place at the time. Reconstructed programmes, created solely to measure the impact of change 'after the event' should be treated with scepticism and applied with caution.

13. Mitigation of delay and mitigation of loss

It is suggested that 'mitigation' as a contractual obligation should be read as 'reasonable steps to minimise loss' but not 'unreasonable steps that result in a greater loss'. There is some subjectivity in the term 'reasonable', and specific contract provisions may increase the obligation to mitigate beyond what is suggested in the SCL Protocol.

14. Link between extension of time and compensation

Entitlement to additional time does not automatically provide an equal entitlement to additional money. It is unfortunate that many hold contractors to the same burden of proof for time as they do for money. The protocol recognises that there are different tests for time and money.

15. Valuation of variations

The SCL Protocol suggests that when negotiating variations, the parties, where possible, should agree the direct costs, along with time related costs (and revisions to the programme) as full accord for a change. This is consistent with many US Change Order provisions, which require full and final settlement prior to implementing a Change Order. Some argue that applying such a principle in the UK would require a sea-change in the way contracts are administered, although the NEC3 has moved in this direction to some extent.

16. Basis of calculation of compensation for prolongation

The SCL Protocol recognises that the recovery of additional compensation for delay is based on causal links from delay events to the actual cost incurred. The time related costs must be 'work actually done, time actually taken up or loss and/or expense actually suffered'. Where possible, the SCL Protocol suggests the option of pre-agreeing a fixed daily rate for delay (similar to a pre-agreed rate of liquidated damages).

17. Relevance of tender allowances

It is said that bid allowances, or tender allowances, have little relevance. Bids are often 'unbalanced' and not reflective of the actual cost incurred when delay damages are experienced.

18. Period for evaluation of compensation

A key phrase used throughout the SCL Protocol is 'at the time'. Delay events should be analysed at the time they occur, and the costs associated with that delay should be assessed relative to the work that was ongoing 'at the time' the delay event occurred (rather than during the extended contract performance period).

19. Global claims

Global claims are discouraged in the SCL Protocol, while the application of discrete 'cause–effect' based methods are encouraged. Global claims are discussed further in Chapter 5.

20. Acceleration

It is recommended that, prior to implementing acceleration, payment entitlement mechanisms should be agreed to avoid constructive acceleration disputes. When acceleration is agreed to have been the result of an employer risk event, the basis of payment should also be agreed where possible.

21. Disruption

It is universally accepted that good record keeping is essential in demonstrating losses experienced due to disruption. The protocol recognises that entitlement to compensation for disruption can be established even if no critical delay has been experienced (and no extension of time granted). Establishing a causal link from an employer risk event to actual loss is the hurdle and the protocol suggests that the best way of identifying disruption is by using the 'measured mile' technique. The issue of disruption and the use of techniques such as the 'measured mile' are dealt with in Chapter 3.

Summary

In summary, while the SCL Protocol has its critics, it provides useful general guidance for those involved with delay and disruption analysis. In particular, it is careful to counsel the use of common sense when dealing with delay and disruption as this extract shows:

> 'Although the programme should be the primary tool for guiding the CA in his determination of extension of time, it should be used in conjunction with the contemporary evidence to ensure that the resulting extension of time is fair and reasonable. It will also be necessary for the parties to apply common sense and experience to the process to ensure that all relevant factors are taken into account, and that any anomalous results generated by the programme analysis are managed properly.'

The 'process' is where the SCL Protocol and the RP-FSA complement one another. The recommendations outlined in the SCL Protocol are reviewed alongside the RP-FSA in the sections below.

4.3.3 Recommended Practice No. 29R-03 *Forensic Schedule Analysis*

Recently the Association for the Advancement of Cost Engineering International (AACEI) published relevant guidance, similar to the SCL Protocol, in the form of its 'Recommended Practice' No. 29R-03 - *Forensic Schedule Analysis*[23] (RP-FSA) which was issued on 1 July 2007 and officially launched on 15 July 2007. The RP-FSA is primarily focused on the terminology and the application of forensic analysis and is a much more technical document. However, it acknowledges that the SCL Protocol had a '*wider scope*'.[24] The stated purpose of the AACEI's Recommended Practice guide is '*to provide a unifying technical reference for the forensic application of critical path method (CPM) scheduling*' and to '*reduce the degree of subjectivity involved in the current state of the art*'. Whereas the SCL Protocol provides guidance to contract administrator and forensic analysts alike, the RP-FSA has an expressed emphasis on '*minimising procedural subjectivity*' in forensic scheduling. The RP-FSA is not intended to be a primer on critical path methods or forensic scheduling techniques and assumes the reader has both advanced, hands-on knowledge of critical path method principles and analysis, as well as a working knowledge and experience in claims and contractual disputes regarding delay and time related compensation issues.

While there are many very well researched and articulate technical papers available on the various methods of delay analysis, articulating their strengths

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[23] Association for the Advancement of Cost Engineering International – Recommended Practice No. 29R-03 *Forensic Schedule Analysis*.

[24] AACEI RP-FSA 29R-03, footnote/acknowledgement, page 9.

and weaknesses and practical concerns regarding their application in a real life environment, the above two texts (the SCL Protocol and the RP-FSA) are the most recent and comprehensive technical works available. The RP-FSA notes that:

> 'The only other similar protocol known at this time is the 'Delay & Disruption Protocol' issued in October 2002 by the Society of Construction Law of the United Kingdom. The SCL Protocol has a wider scope than the RP-FSA'

The structure of the RP-FSA is similar to that of the SCL Protocol, with the exception that it does not provide guidance on how parties should manage programmes contemporaneously, but rather focuses on the techniques of delay analysis and the application of those techniques in forensic analysis environments. Its structure is set out below:

- Organisation and Scope
- Source Validation
- Method Implementation
- Analysis Evaluation
- Choosing a Method

Some of these are addressed below, and compared with the SCL Protocol where relevant.

Organisation and scope

Here the RP-FSA provides background as to its purpose, scope, focus, classification of delay analysis techniques, as well as some explanatory notes regarding underlying assumptions, fundamentals and principles relevant to forensic scheduling analysis.

Basic 'premise and assumptions' of the RP-FSA are provided to set the stage for its recommended practices. These include statements which distinguish forensic scheduling from project planning and scheduling, and assumes that the RP-FSA will '*be used by practitioners to foster consistency of practice and in the spirit of logical and intellectual honesty*'. These assumptions also recognise that '*All methods are subject to manipulation. They all involve judgment calls by the analyst whether in preparation or in interpretation*'. Most importantly the RP-FSA recognises that no forensic schedule analysis method is exact and that proof of entitlement to additional time (EOT) does not automatically establish proof to compensation for delay damages. This has its own standard of proof, which must have a basis in fact.

Helpful guidance provided under the 'Scope and Focus' states that it:

> 'is not intended to be a prescriptive document that can be applied without exception. The recommended protocols will aid the practitioner in creating a competent work

> product. Some cases require additional steps and some require less. Thus a departure from the recommended protocols should not be automatically treated as an error or a deficiency as long as such departure is based on a conscious and sound application of schedule analysis principles.'

While the RP-FSA does not currently have authority or judicial recognition, delay analysts who may be called to give expert evidence would be advised to familiarise themselves with the section on Taxonomy and Nomenclature, provided in the RP-FSA to avoid pitfalls of applying the wrong technique or applying the correct technique contrary to the RP-FSA recommendations.

The 'Taxonomy and Nomenclature' for 'retrospective' methods of delay analysis comprises five layers in its hierarchical breakdown:

- Timing (Retrospective);
- Basic Methods (Observational or Modelled);
- Specific Methods (Static, Dynamic, Additive or Subtractive);
- Basic Implementation (see Figure 4.9); and
- Specific Implementation (see Figure 4.9).

Layer 1: Timing (retrospective)

Prospective analysis methods are performed during the project, in 'real time', and are not the subject of the RP-FSA. The RP-FSA states that retrospective delay analysis is performed after the event has occurred and the impacts are known. Even when the RP-FSA discusses the approach of 'additive' modelling, this is under the assumption that it is being carried out in a forensic, retrospective, environment. Contrary to the SCL Protocol, the RP-FSA does not deal with prospective methods of delay analysis (i.e. during the course of the works).

Layer 2: Basic methods (observational or modelled)

Observation may imply a passive method of analysis, but only in the sense that it does not require the analyst to actually quantify the delay through programming simulations by 'impacting' or 'subtracting' events to or from a programme. The process of deduction from comparing programmes is required when applying observational techniques. Modelled techniques require 'intervention' (some would say 'manipulation' by another name) by the analyst to arrive at 'before' and 'after' states using 'what if' programme simulations when quantifying the effect of delays.

Layer 3: Specific methods (static, dynamic, additive or subtractive)

These are somewhat self explanatory. 'Static' logic observations are based on comparisons of fixed programmes in either their as-planned, as-updated or

Taxonomy	1	RETROSPECTIVE												
	2	OBSERVATIONAL							MODELLED					
	3	Static Logic			Dynamic Logic				Additive				Subtractive	
	4	3.1 Gross	3.2 Periodic		Contemporaneous Updates (3.3 As-Is or 3.4 Split)		3.5 Modified/ Reconstructed Updates		3.6 Single Base[2]		3.7 Multi Base[1]		3.8 Single Simulation	
	5		Fixed Periods	Variable Windows	All Periods	Grouped Periods	Fixed Periods	Variable Windows	Global Insertion	Stepped Insertion	Fixed Periods	Variable Windows or Grouped	Global Extraction	Stepped Extraction
Common Names		As-Planned vs As-Built	Window Analysis		Contemporaneous Period Analysis, Time Impact Analysis, Window Analysis	Contemporaneous Period Analysis, Time Impact Analysis, Window Analysis	Contemporaneous Period Analysis, Time Impact Analysis	Window Analysis, Time Impact Analysis	Impacted As-Planned, What-If	Time Impact Analysis, Impacted As-Planned	Time Impact Analysis	Window Analysis, Impacted As-Planned	Collapsed As-Built	Time Impact Analysis, Collapsed As-Built

Figure 4.9 Taxonomy and nomenclature for retrospective methods of delay analysis.

as-built states, so long as those programmes consist of the same set of activities and logic, unamended between each state. 'Dynamic' logic observation requires the analysis of logic changes between each state, or each update, and quantifying the effect of the logic change before considering the impact of delay events. Static Observation is very much a fact based method of analysis, with conclusions readily supportable by contemporaneous documents. 'Additive' methods of modelling encompass any form of delay analysis which involves recalculating a base programme with additional events, constraints or logic representing a delay event. 'Subtractive' methods are all of those methods involving the removal of delay events from an as-built model to determine when completion would otherwise have occurred 'but for' that event. Additive and subtractive modelling are by necessity, somewhat theoretical, in that they produce 'what if' scenarios of the likely impact of events.

Layer 4 (Basic implementation) and Layer 5 (Specific implementation)

These detailed Implementation Protocols require an understanding of each specific method of delay analysis available and provide guidance to enable the analyst to answer the following questions:

- Will I analyse the entire programme at once (gross) or will I break the project into smaller windows for analysis (periodic)?
- Will I use the available programmes ('as-is') or will I use available progress data to update an existing programme prior to analysis ('split')?
- Will I correct, or alter, the existing programme ('modified') or will I use available data to 'recreate' a programme for analysis?
- Will I use only one programme 'single base' (e.g. as-built, or as-planned) or many updated and intermediate programmes ('multi-base') for analysing the impact of events?
- Will I use regular monthly or weekly updates ('fixed periods') or key events ('variable periods') to determine windows of time for analysis?
- Will I consider all events at once, 'Global (Insertion or Extraction)' or will I consider the impact of events individually, 'Stepped (Insertion or Extraction)' to determine their impact to completion?

The answers to each of these questions will largely be dependent on the factors listed in Table 4.22.

'Underlying Fundamentals' and 'General Principles' are provided and recognise that visibility of the critical path is required throughout the project and is dependent on properly updated programmes and that delays can affect critical or non-critical works. One principle which is strikingly similar to the SCL Protocol's main theme is:

> 'when quantifying project delay, schedule analysts must evaluate the impact of potential causes of delay within the context of the schedule at the time when the circumstances happen.'

Many of the 'general rules' in this section are also very similar to the SCL Protocol's guidance. The most relevant are set out below.

Float ownership. Float is a shared commodity (the project owns the float on a first come-first served basis). The RP-FSA clarifies later that 'Network Float' is a shared resource but that 'Project Float' is '*owned solely by the contractor*'. Delays to early completion programmes would result in contractors being able to recover additional time related overheads prior to the contractual date for completion. This is a fundamental difference to the SCL Protocol, which defines float as '*the time by which a group of activities may be shifted in time without causing delay to a contract completion date*'. While the SCL Protocol recommends compensation for direct (not overhead) costs in periods of float, it does not go as far as recommending that float is 'owned' by either party. This, however, does not address the argument that, if contractors 'own the float' they should be put back in the position they were in before the employer risk event caused float deterioration, and therefore an extension of time is required to restore the 'Project Float' as if it is truly owned by the contractor. This issue reflects one of the fundamental differences between US case law[25] and UK case law[26] on the subject of early completion programmes.

Critical path changes. These happen from time to time and the programme in place at the time is preferred to the original baseline or other out of date programmes.

Delays must affect the critical path. As a precursor to compensation for delay damages, delays to '*completion*' must be demonstrated. A full read of the RP-FSA indicates '*completion*' is referring to scheduled completion, and not contractual completion. When the RP-FSA defines 'Critical', however, it is referencing the 'longest path' whether that path is to the 'Contractual' completion date or the 'Scheduled' completion date. This definition takes on a fundamental departure from the SCL Protocol. The RP-FSA states that 'Network Float' is a shared resource but that 'Project Float' is '*owned solely by the contractor*'. (See **Float ownership** above.)

The RP-FSA views on float contrast with the SCL Protocol. However, the RP-FSA does not advise as to the compensation for non-critical delay. For a delay to be 'compensable' and 'excusable' delays must be critical to the 'completion date'. Where the 'completion date' is earlier than the contractual date for completion, there will be 'total float' to the longest path. The period between the scheduled and contractual completion date must be discretely identified as 'terminal float' or 'project float' and preserved for the RP-FSA to work practically.

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[25] *Metropolitan Paving Co* v. *United States* 325 F2d 241 (Ct. Cl. 1963).

[26] *Glenlion Construction Ltd* v. *The Guinness Trust* (1987) 39 BLR 89.

Source validation

The RP-FSA then provides for 'Source Validation' of the 'baseline' programme, whether contemporaneous or forensically recreated, the 'as-built' schedule, and intermediate 'schedule updates'. These schedules form the foundation for the various scheduling analysis techniques, and the reliability of each approach is dependent on the reliability of the base model used to quantify the impact of delay events. The 'source validation' protocols provided are intended to maximise the reliability of the schedules to achieve a faithful reflection of the facts as they existed at the time, and as reflected in contract documents and witness statements. The RP-FSA recognises that '*Whether that reflection is an accurate model of reality is almost always a matter of debateable opinion*'.

These protocols define how a 'baseline' should be validated to ensure:

- it is contractually compliant;
- it is 'reasonable' for project controls purposes;
- all alterations are documented and auditable;
- it is capable of modelling the impact of change using CPM techniques;
- any reconstructed programmes are a true reflection of contemporaneous programmes; and
- any programmes converted from one software to another are faithful reflections of the original baseline.

There is a protocol for constructing as-built programmes: identifying which sources are required, which activities should be included, and the level of accuracy which is acceptable. It is stated that 'significant' activities should be accurate to within one working day, and all others within five working days. It is concluded that the as-built programme should correlate with the as-planned 'baseline' programme for comparison purposes.

The process of validating, or recreating as-built programmes is also described in some detail. The RP-FSA explains how to create an updated schedule from a baseline, and alternatively how to 'de-status' (i.e. remove progress from) an as-built programme backwards, to a desired data date.

4.3.4 Which technique to use under given circumstances

Determining which technique is the most appropriate is the most subjective task and, even when agreement is reached between the parties, often the application of the same 'technique' varies to such an extent that neither party is willing to accept the other's conclusions. These issues have been addressed in both the SCL Protocol and the RP-FSA. Both provide guidance on the factors which assist in selecting which techniques are appropriate under given circumstances. These are summarised in Table 4.22.

Not surprisingly, the factors contained within each document are similar. However, the AACEI provides two additional factors (forum and legal/pro-

Table 4.22 Factors for choosing an appropriate delay analysis technique.

SCL Protocol	AACEI RP-FSA
• the relevant conditions of contract • the nature of the causative events • the value of the dispute • the time available • the records available • the programme information available • the programmer's skill level and familiarity with the project	• contractual requirements • purpose of analysis • source data availability and reliability • size of the dispute • complexity of the dispute • budget for forensic schedule analysis • time allowed for forensic schedule analysis • expertise of the forensic schedule analyst and resources available • forum for resolution and audience • legal or procedural requirements • past history/methods and what method the other side is using

cedural requirements) based on US case law and the experience and familiarity of US Courts with the available techniques and software. The SCL Protocol is expressly geared towards identifying the most appropriate method of analysis and '*is not intended to be a statement of law*'. Indeed, the SCL Protocol states that:

> 'Because Judges only come to consider concurrency issues after the delays have occurred and disputes have arisen, current English law focuses on 'after the event' analysis, of cause and effect of the different delays, and/or which of a number of delays is the dominant one. The SCL Protocol takes a different approach, consistent with its objective of encouraging parties to deal with extension of time applications as close in time as possible to the delay event that gives rise to the application and discouraging the "wait and see" approach.'[27]

4.4 Summary

In summary, delays can be categorized in many ways and the circumstances and factual analysis are more important to tribunals than the method of delay analysis applied to quantify or apportion delay. Delays can be excusable, non-excusable, compensable and non-compensable. They can also be critical, non-critical or concurrent. Delays can be identified as dominant, sub-critical or simply not relevant when it is determined that those delays were as a result of expressed pacing by a party.

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[27] SCL Protocol, Guidance Section 1, 1.4.11.

The purpose of delay analysis is to establish entitlement, causation and damages. There are a few tests which must be satisfied for a delay to be considered for relief from liquidated damages or compensation in respect of delay related damages. Firstly, the delay must be shown to be critical, by reference to a reliable critical path analysis. Secondly, the party claiming damages must be able to demonstrate that they were not responsible for any delays which were concurrent with those critical delays being relied upon. Lastly, the critical delays relied upon must be found to be excusable and compensable events under the contract.

Excusable, compensable delays are delays which are beyond the control of the contractor. being the responsibility of the owner, and which, according to the contract documents, entitle the contractor to both a time extension and recovery of delay related damages. The test for additional time under the contract is usually less restrictive than the test for recovering delay damages for the same events.

Excusable, non-compensable delays are delays which are beyond the control of both the owner and the contractor where the contractor is entitled to a time extension but no damages. These include acts of God, strikes, labour disputes and weather related delays.

Non-excusable delays are delays which are the responsibility of the contractor. These are events for which the contractor is not entitled to either a time extension or recovery of delay damages. These include failure to deliver materials in a timely manner, low productivity, failure of a subcontractor to perform, defective work, equipment breakdowns and delays related to under-resourcing critical tasks on the project.

The starting point of satisfying these tests is establishing a basis for measuring delay, and identifying relevant events, both culpable (self inflicted) and excusable. Delays are caused by many conditions and factors. Employer controlled factors include finance issues and non-payment for completed work, interference with performance of the contract, slow decision making and inadequate constructability/feasibility planning resulting in an unrealistic original contract duration.

Contractor controlled factors include inadequate or incompetent site management, inadequate experience in the given type of construction, mistakes during construction, improper means and methods, improper equipment selection, inadequate planning and resourcing of activities, subcontractor (trade) coordination and subcontractor (trade) payment issues.

Professional team controlled issues include poor contract management, poor coordination of information (e.g. RFIs, drawings), late preparation and approval of drawings and submittals, long waiting time for approvals or tests/inspections, improper contract packaging/delivery strategy, late identification and resolution of drawing or specification errors and omissions, poorly prepared contract documents, over-inspection.

There are many other factors such as materials, suppliers, labour availability and skill level, weather, local regulatory issues, coordination with adjacent property owners and access/logistic restrictions, to name a few. In the authors' experience, the events which have the highest correlation to resulting in the award of time extension are:

- designer controlled issues (changes/corrections);
- weather related delays;
- differing site conditions;
- late delivery of owner furnished materials/equipment; and
- instructed additional works.

These often act in concert and it is often difficult to isolate a discrete cause–effect relationship from each of the above listed factors to a precise effect on the critical path.

Chapter 5

Problematic Issues

5.1 Introduction

In previous chapters the methodologies of construction programming, and the techniques available for the identification and analysis of delay events have been explained. In this chapter a number of problematic issues which arise in connection with both programming and delay analysis are considered. The main issues reviewed are float and its implications in delay claims, concurrency, the requirement for programmes to be approved, and onerous specifications. Other topics reviewed, and which are associated with programming in the context of delay analysis, include acceleration and delay mitigation, pacing, contractors' entitlement to early completion and the assessment of disruption damages.

5.2 Float and delay claims

The concept of float in planning and programming was introduced in Chapter 2. It is a topic which gives rise to much debate as to its definition, usage and implications when assessing delay and disruption impacts. In this chapter, float is defined in more detail, including its usage, measurement and ownership.

5.2.1 General definitions – what is 'float'?

Float in programming terms is the time difference between a sequence of activities and the critical path. Where float is present an activity may be started later than its early start date, yet not prolong the project. There are several types of float. In Chapter 2 the most commonly referred to float type, namely 'total float', was defined as 'the amount of time by which a task may be delayed or lengthened without impacting upon the calculated earliest finish of the project completion date'. Also the closely related term 'free float' was defined as 'the amount of time which a task may be delayed or lengthened without impacting upon the early start date of any of its successor activities' (see Figure 5.1).

When contractual arguments ensue regarding float ownership, they are invariably referring to 'terminal or end float', which only exists when planned

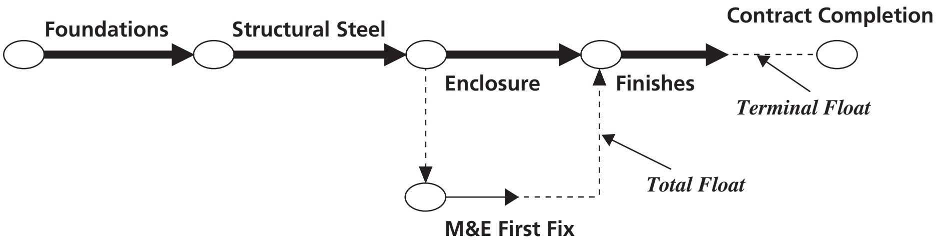

Figure 5.1 Float definitions.

completion is earlier than the date for contract completion. Terminal or end float is the period by which the finish of the longest path through a programme can be delayed, brought forward or extended without affecting the completion date. It is sometimes called 'finish float'. Figure 5.1 illustrates Terminal Float and Free Float.

Float can be expressed as a positive or negative value. Positive float is the period an activity can slip before it will affect the completion date. Negative float is a measure of how much 'behind schedule' an activity is at a given point in time. When the earliest date an activity can take place is after the latest date by which the activity should have taken place so as not to cause delay to completion, the total float of the activity will be negative.

Negative float will also occur when activities are constrained by an intermediate 'key date'. Float is a relative value. It determines which activities are more critical than others. The precise numerical value is not as important as the absolute delay calculated when measuring the planned completion date to the projected completion date. Total float monitoring techniques are used by planners and project managers to act as an early warning of potential programme delays to critical and non-critical activities alike. Other forms of float including independent and interfering float are defined and explained briefly in Chapter 2, Section 2.3.3.

5.2.2 How float is used

Float is used in a number of ways; primarily to identify which activities in a programme are critical and which have 'slack' periods. Where float is identified on non-critical activities it can be used for levelling or smoothing resources, that is using positive float to minimise sharp changes in resource usage, to 'smooth' or 'flatten' the shape of a resource profile. It does this by allowing less critical works to be delayed (within their float period) to allow continuity of work for a specialist or expensive resource (crane, earth movers) or trade contractor.

Float is an integral part of critical path method programming and delay analysis as explained in Chapters 2 and 4. It is a relative quantifiable value which can and should be treated as a resource, like money. It is a finite resource, which can be used to:

- identify slippage that is occurring to an activity, sequence of activities and/or overall programme of activities;
- identify critical paths;
- allow re-sequencing of activities to mitigate pre-existing delay; and
- allow re-sequencing of activities to reduce or avoid disruption due to stacking of trades, discontinuity of work, or avoid working in adverse weather or seasonal conditions.

Although float is treated as a contingency period, in addition to any time risk allowance included in project duration, substantial depletion of float decreases the probability of completion on time. This can be seen most acutely in the Case Study in Chapter 6. When contractors are deemed to 'own the float' an excusable event will not deteriorate float, because the same amount of float that existed before the excusable event should be restored by way of an extension to the date for completion.

Float can be built into a contractor's programme as a contingency to reduce the risk that delays will impact completion, and increase the likelihood of completing on time. Such float may be built into the duration of activities, as a 'time risk allowance', by simply extending the estimated duration that is required to carry out the scope included in an activity. A 'time risk allowance' may also be included by introducing additional activities at the end of a programme such as an extended cleaning or snagging activity, or an activity expressly titled 'contractor's contingency'. Use of float in this way can disguise the fact that float exists in a programme. Many US forms of contract restrict contractors from sequestering float in this way while others expressly encourage the inclusion of time risk allowances, such as NEC3.

A more subtle manipulation of float is the use of constraints to sequester an activity's float by requiring that activity, or group of activities, to be carried out as late as possible, effectively using up the available float (see Figure 5.2).

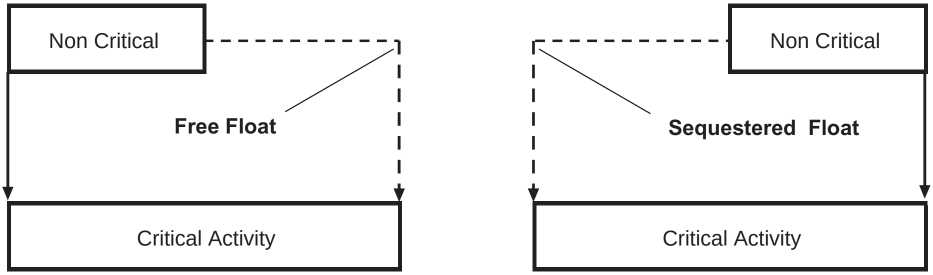

Figure 5.2 Positioning of float.

A number of points arise from sequestering float in this way. Firstly, the early start and finish dates for the non-critical activity are shifted to equal its late start and late finish dates, which in turn could make the activity appear to be critical. Secondly, succeeding activities could also be affected if the non-critical activity is delayed beyond the original amount of float available. Finally, this type of float manipulation adds to the confusion when attempting to isolate the critical path activities because it will not be apparent from a hard-copy printout of the programme or activity data and may only be discovered by interrogating the electronic programme in its native software format.

Extending activity periods and thereby reducing float periods is a risky strategy which can lead to confusion and ultimately dispute over the reasonableness of the programme. For example, when a claim for delay exists, contractors will be required to demonstrate and defend the original durations of activities comprising critical paths being relied on. Further, if a contractor were to attempt to sequester float by adding 20% to every activity duration, that same float would soon emerge when those activities were performed in accordance with their natural durations. However, when attempting to use time-risk allowances in this way, Parkinson's Law should be heeded, e.g. 'work expands so as to fill the time available for its completion'. The use of extended durations to include time-risk allowances is likely to encourage the use of the entire activity duration by the site foreman, resulting in slower outputs, and so defeating the purpose of the contingency in the first place. It will also be more difficult to establish a 'measured mile' or 'un-impacted', or 'efficient progress' and will mask the true impact of excusable, or culpable, delay events which are smoothed over by the skewed activity durations.

Float should therefore not be used for specific contingency purposes. Where contractors have an ambition to complete a scope of works earlier or want to make allowance for risk work items where the time requirements are not fully known about at the time, then they should declare these estimated contingency periods at the outset to protect them and keep them apart from the pattern of float movement within the programme during the lifecycle of the project's contract period. They can then be represented on the programme as expressed 'contingency' or 'risk allowance' periods for groups of related tasks, or included as a predecessor to each respective milestone date.

Employers can seek to influence contractors' design of construction programmes by placing limitations on the number of activities in a programme that may be critical or near critical. For example, there could be a requirement that a submitted programme must have no more than 25% of activities as critical and that no more than 40% of activities are to have float of less than seven days. The following requirement was taken from an actual clause in a recent contract in the UK, drafted for an NEC2 form of contract:

> 'No more than fifty percent (50%) of the activities shall be critical or near critical, subject to the Project Manager's approval. Near critical is defined as float in the range of one (1) to fourteen (14) days.'

While this may give employers a degree of comfort, in risk reduction terms, it is likely to have a cost implication as contractors may have to increase their resources or alter their intended methodology to meet these conditions. It is a matter of debate as to what impact such clauses actually achieve when set against the dynamic and often complex nature of the programme during the course of a project with critical paths changing and float ebbing and flowing on activities. On many projects it is impossible to maintain a position where less than 50% of the works are critical or near critical and such provisions can only be taken to apply to the baseline, or else the definition of near critical would require amending for each subsequent programme submitted for approval. For instance, the clause could be altered to state:

> 'No more than fifty percent (50%) of the activities shall be critical or near critical, subject to the Project Manager's approval. Near critical is defined to be float of between one (1) and fourteen (14) days on the most critical path to completion from time to time.'

Even then, maintaining such a position would be difficult once the majority of the works have slipped to, or beyond, their latest allowable event dates.

Programmers are able to manipulate float to enhance the likelihood of gaining an extension to the time for completion by the use of various float suppression techniques, for example:

- **Preferential logic:** Elective sequencing whereby the critical path is arranged to either pass through or avoid activities more susceptible to delay caused by the employer.
- **Excessive lead/lags:** The use of these logic restraints reduces the flexibility of the programme to react dynamically to change by linking the entire programme as a large inflexible mass of work, bound up with inter-related logic, not all of which is usually necessary or followed on-site.
- **Excessive use of date constraints:** These effectively break the linear flow of the critical path, often creating gaps, or periods of inactivity between the early finish of a successor activity and the early start of a successor,the latter of which is held out to be a date in the future due to a date constraint, such as 'start no earlier than'. The use of date constraints makes identifying the longest path to completion and the use of float mapping techniques more difficult.
- **Zero total or free float constraints:** These constraints simply hide any available float by over-riding the backward and forward pass calculations, requiring the early dates of activites to match the late dates.
- **Extended activity durations:** This is the simplest form of float sequestering technique, and is discussed in detail above.

In the US and other international locations where large EPC contractors use CPM specifications which have evolved over the past 20 years, the use of such techniques to consume or sequester float and influence the critical path is frowned upon, and under certain contracts, expressly forbidden. For example, a typical float suppression clause is provided below.

> 'FLOAT. Use of float suppression techniques, such as; preferential sequencing (arranging critical path through activities more susceptible to government caused delay), special lead/lag logic restraints, zero total or free float constraints, extended activity times, or imposing constraint dates other than as required by the contract, shall be cause for rejection of the project schedule or its updates. The use of Resource Levelling (or similar software features) used for the purpose of artificially adjusting activity durations to consume float and influence the critical path is expressly prohibited.'[1]

5.2.3 Float loss and the impact

Activities with float are by definition non-critical and therefore do not determine the critical path or the project duration. However, if activity float is used up then the critical path will change and previously non-critical activities become critical. If non-critical activities do not start at the earliest date then float is used up. This reduces a contractor's contingency time cushion and increases the probability of critical delay to the project. Many factors can contribute to float loss, for example:

- out of sequence and/or inefficient working;
- poor management of resources;
- shortage of resources;
- inappropriate plant selections;
- underestimated scope of work;
- over-estimated outputs and crew efficiency factors;
- omission of key tasks (drawing review time, permit approvals, etc.);
- over-optimistic lead-in times;
- variations or changes in the scope of works;
- additional works; and
- poor workmanship leading to extended remedial periods.

While float reduction does not result in critical delay to a project it can cause financial loss due to the extended need for discrete task related resources (e.g. tower cranes, generators, compressors, scaffold rental). Thus any delay analysis should deal with both those delay events which are identified as being critical together with those that cause float deterioration.

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[1] UFGS-01321N (February 2002), DIVISION 01 – General Requirements Section 01321N Network Analysis Schedules (NAS).

5.2.4 Measurement of float loss

An analysis of construction delays includes a review of the master construction programme. This may comprise several versions from tender, through baseline to various updated or revised versions. One particular area of analysis that can be undertaken is the performance of the contractor as evidenced by the changing state of activities within the programme as the works progressed. This can be undertaken in particular by tracking periodic slippage and measurement of float deterioration. This may be useful in identifying the slippage and thus status of a programme prior to the impact of an excusable delay event. Where the construction programme has been updated on a regular periodic basis (e.g. monthly) the remaining float in the programme can be recorded. This is then compared with the previous update to measure:

- the decrease in total float on an activity by activity basis; and
- the change in criticality of activities.

This approach is the basis of many forms of contemporaneous 'windows' analyses. However, there are many variations on the same theme. Another approach is to view the float deterioration for the project as a whole. The float values of all of the activities can be allocated, analysed and categorised according to various thresholds of float loss, to allow simple statistical analysis of the project as a whole, as illustrated in the example in Table 5.1.

Table 5.1 shows that by the end of a 12 month project all activities were showing negative float and that negative float was increasing. The 'critical path' can be expressed as the 'most' critical path in these later updates, or it could be said that every path to completion which is in a state of negative float is relevant on a simple 'but for' test. That is, 'but for' the most critical path (–35) the project would be 20 days behind schedule (–20). If it could be shown that

Table 5.1 Project float deterioration summary.

Programme Baseline & Updates	75% of all uncompleted activities had float less than the values shown below (days)	50% of all uncompleted activities had float less than the values shown below (days)	25% of all uncompleted activities had float less than the values shown below (days)
05-Jan	30	15	0
05-Apr	30	10	0
05-Jul	20	10	0
05-Oct	5	–5	–20
05-Dec	–15	–20	–35

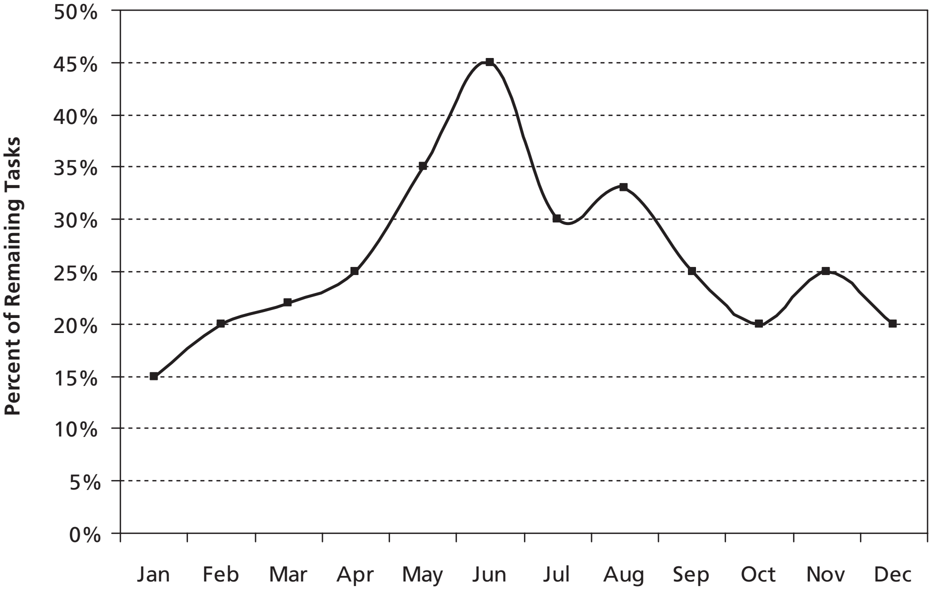

Figure 5.3 Critical activity profile.

the employer was responsible for the 35 day delay, and the contractor was responsible for the 20 day delay, it may be found that the contractor's entitlement to compensable delay is reduced from 35 days to 21 days. However, it is just as likely that it will be found that the employer's delay was the dominant delay, and that the concurrent sub-critical delay caused by the contractor is not relevant when apportioning damages. There is case law supporting both of these findings and the ultimate decision will turn on the facts of the case, not the method of delay analysis.

As one measure of contingency, the pattern of criticality can be reviewed by identifying the number of tasks in a programme which are critical, as a proportion of the total remaining (uncompleted) activities. An illustrated example is shown in Figure 5.3.

From the above graph it is observed that only 15% of all activities in the programme were critical in January. This percentage steadily increased until June, when 45% of all remaining activities were critical. The definition of 'critical' can be set to either all activities on the longest path, or alternatively, all activities with a float value less than zero. Programme software also allows users to specify a user-defined 'critical float' value. While the above chart does not provide an indication of how far behind programme the critical path is, it does provide an indication of how much contingency exists in the programme generally. The higher the percentage of activities that are critical, the more difficult it will be to accelerate the project.

Along with the various charts and tables introduced in Chapter 4 and the Chapter 6 Case Studies, these charting techniques can assist an analyst to focus on and identify periods in which critical delays and sub-critical delays were experienced. Such techniques should be used with caution and with periodic reality checks against other corroborating evidence. The use of any form of trending analysis is only indicative and must be supported by contemporaneous evidence that the delay existed and was known to the parties. If a trend is found to be based on anomalous data, the observations and findings will be of limited value.

5.2.5 Who owns the float?

The issue of who owns the float in a construction programme has been the subject of much debate for many years, the implication being that the owner of the float has exclusive use of it. Currently three conflicting viewpoints hold sway; namely that float is owned by the contractor, the employer or by the 'project'.

The contractor

Firstly, there is the argument that the contactor owns the float. This is based largely on the premise that the contractor prepares the programme including the sequencing of operations to maximise the use of the resources to be employed, all to meet an often fixed timescale and quantum. Contractors, under these fairly common circumstances, are assuming a substantial degree of risk. It follows therefore that the programme is theirs to use, manage and control. This, for example, includes being able to re-sequence activities to enable an accelerated target to be met, resulting in cost savings to the contractor and often a benefit to the employers. As the contractors have undertaken the risk of completing to a fixed deadline it also follows that if delay occurs, other than excusable, then again they can re-sequence operations to minimise the impact by using up float on non-critical activities where possible.

Those in the contractors' camp on the issue of float ownership will also point out that if employers were to be exclusively entitled to the float, and in turn use it up in the course of the project contract works, if contractors then incur non-excusable delay they will have no opportunity to recover the lost time through re-sequencing and using float, and thus would be likely to incur damages. It is believed by the authors that the final review, allowed under most standard forms, is intended to take this situation into account. Determining what is fair and reasonable must take into account whether the contractors truly allowed for their own potential delays and whether that contingency was taken up by other unforeseen events, which would otherwise have entitled the contractor to additional time.

One form of construction contract, namely the NEC3[2] family of contracts, endorses the view that float belongs to the contractor. Clause 63.3 states that:

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[2] NEC3 – Engineering and Construction Contract (previously the New Engineering Contract), Thomas Telford, 2006.

> ‘any delay to the completion date is assessed as the length of time that, due to the compensation event, planned completion is later than planned completion shown on the accepted programme . . .’

The fact that delays to the completion date are measured relative to delays to the ‘planned completion date’ leaves no doubt that contractors own the float in an unamended NEC3 contract. When the date for ‘planned completion’ is earlier than the contractual completion, there is clearly ‘terminal float’ in the programme. Extending the contractual completion date by the extent the ‘planned completion’ is delayed effectively restores the same amount of terminal float that existed before the excusable event occurred. This is consistent with the philosophy that contractors should be put back in the position they were in before the employer’s risk event occurred.

If, therefore, contractors have terminal float in their programme, this is retained when an excusable event occurs. This clause now also has a new addition which relates to key dates and states that a delay to a key date is assessed as the length of time the planned date for meeting a key date is later than the date shown on the accepted programme due to a compensation event. Again, it is the accepted programme that fixes the basis of acceptance. It may be argued that under this form not all float contained in the programme is exclusively for a contractor’s use. In any event, float is likely to be used up in re-programming the works, which may work to the employer’s benefit when the date for ‘planned completion’ would otherwise be later than the contract completion date. Project managers are likely to refuse to accept programmes which project a planned date for completion beyond the contractual date for completion.

The employer

An assertion that employers own the float may be based on the belief that, as the owners of the project, they have ‘bought’ the float. Thus if a contract period of 24 months has been agreed, and a contractor has priced the on-site costs (preliminaries) based on this contract period, then effectively the employer is entitled to make use of the entire contract period, so long as any added or changed work does not extend any of the contractor’s work beyond the contractual date for completion.

There is, however, a fundamental flaw in this view. If it were correct that employers ‘owned’ the float then they would surely be entitled to have some say in how much float was required in a programme, and how it was to be managed and utilised, so that their entitlement to use such float was preserved. As float is essentially a by product of the planning process, that is the difference between start and finish dates, this would amount to an intolerable amount of interference with a contractor’s programming activity, or conversely would shift a substantial part of the risk from the contractor to the employer with regard to completion of the works within the contract period. It thus follows that where an employer causes the consummation of float, even if it does not affect the finish date, there is likely to be an entitlement to recover direct time-related costs which arise solely as a result of the delay to progress, as measured by deteriorated float.

The project owns the float (or 'first come-first served')

There is a growing school of thought which supports the view that when the contract is silent on float ownership neither contractor nor employer owns the float. The float should be treated as a shared commodity, and accordingly is available for use by whoever needs it, on a first come-first served basis. In the event that in using the float the other party suffers financially then recompense can be made retrospectively. This view is widely promoted in the US and supported by the SCL Protocol.[3]

Conventional wisdom

It is difficult to say where the argument of float ownership will go in the future. In the 1960s and 1970s, before the widespread use of critical path method analysis, there was support for the argument that contractors owned the float. These arguments were based on simple bar charts indicating an intention to complete earlier than the contract completion date rather than any complex critical path analysis. In the 1980s and 1990s there was support for the argument that it was a shared resource. The case which addressed the concept of float most directly was *Ascon* v. *McAlpine*[4] in which the issue was analysed in paragraphs 91 to 93:

> '. . . McAlpine's argument seems to be that it is entitled to the 'benefit' or 'value' of this float and can therefore use it at its option to 'cancel' or reduce delays for which it or other subcontractors would be responsible in preference to those chargeable to Ascon.
>
> 92. In my judgment that argument is misconceived. The float is certainly of value to the main contractor in the sense that delays of up to that total amount, however caused, can be accommodated without involving him in liability for liquidated damages to the employer or, if he calculates its own prolongation costs from the contractual completion date (as McAlpine has here) rather than from the earlier date which might have been achieved, in any such costs. He cannot, however, while accepting that benefit as against the employer, claim against subcontractors as if it did not exist. That is self-evident if total delays as against sub-programmes do not exceed the float. The main contractor, not having suffered any loss of the above kind,

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[3] SCL Delay and Disruption Protocol, The Society of Construction Law, October 2002.

[4] *Ascon Contracting Ltd* v. *Alfred McAlpine Construction Isle of Man Ltd* [1999] 66 Con LR 119 (QB, TCC).

> cannot recover from sub-contractors the hypothetical loss he would have suffered had the float not existed, and that will be so whether the delay is wholly the fault of one sub-contractor, or wholly that of the main contractor himself, or spread in varying degrees between several sub-contractors and the main contractor. No doubt those different situations can be described, in a sense, as ones in which the 'benefit' of the float has accrued to the defaulting party or parties, but no-one could suppose that the main contractor has, or should have, any power to alter the result so as to shift that 'benefit'. The issues in any claim against a sub-contractor remain simply breach, loss and causation.
>
> 93. I do not see why that analysis should not still hold good if the constituent delays more than use up the float, so that completion is late. Six subcontractors, each responsible for a week's delay, will have caused no loss if there is a six weeks' float. They are equally at fault, and equally share in the 'benefit'. If the float is only five weeks, so that completion is a week late, the same principle should operate; they are equally at fault, should equally share in the reduced 'benefit' and therefore equally in responsibility for the one week's loss. The allocation should not be in the gift of the main contractor'

This decision supported the view that float was a shared commodity but instead of the 'first come-first served' basis, it introduced an apportionment based on a shared contribution. This approach is consistent with the SCL Protocol's recommendation, when considering float as it relates to extentions of time, that:

> 'Unless there is express provision to the contrary in the contract, where there is remaining float in the programme at the time of an Employer Risk Event, an EOT should only be granted to the extent that the Employer Delay is predicted to reduce to below zero the total float on the activity paths affected by the Employer Delay.'[5]

While this may hold true as today's conventional wisdom, the fact that the NEC3 form of contract is the preferred contract, which will be used widely by the Olympic Delivery Authority (ODA) on the Olympic Games sites in London in 2012, it is more than likely that the conventional wisdom will shift towards the view that 'contractors' own the float, due to the unique formula for calculating time extensions under that form of contract.

5.3 Concurrency

One of the most problematic issues which arise in the analysis of construction delay impacts is that of concurrency as it relates to delay and compensation for prolongation. This uncertainty as to how concurrent delay should be managed causes difficulty to contract administrators, in particular in their task

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[5] Ibid, Section 1.3.1, page 13.

of assessing extensions of time and compensation events during the course of a project. Not only does a contract administrator have to identify the causative events, and their effect, but he will have to grapple with the thorny matter of identifying and apportioning liability and attempting to isolate the costs that were experienced as a direct result of the contribution of one party, or the other, to the overall delay. This task is made all the more difficult because the liability for causative events will lie partially with both the employer and the contractor, and possibly there are also events that are considered to be 'neutral' under the contract. Neutral events entitle a contractor to additional time, but not compensation. An example of a neutral event is a delay resulting from a 'force majeure' happening.

These issues impact both on the level of extensions of time that might or might not be granted, and also on the amount of compensation, for example loss and/or expense, that might be due. The more complex the project the more likely it is that this issue will arise and much will turn on the quality of planning or programming, and on the record keeping. Not only will there often be several delay events running in parallel, but there may be parallel critical paths to contend with, and also periods of acceleration and/or mitigation to take into account. The terms and conditions of the prevailing contract will also have an influence on the analytical approach used.

Case law on the subject is of little assistance to site based staff, who must grapple with technical analysis to avoid criticism of arriving at an intuitive or 'impressionistic' assessment. Much of the recent case law emphasises the application of 'common sense' in assessing liability or apportioning responsibility for delays and prolongation when concurrent or shared responsibility has been established. While applying common sense is clearly a common goal, it does not, and should not, relieve any of the parties from fulfilling their obligation under the contract to demonstrate the cause–effect relationship, from a compensable event to the resulting financial loss or damage.

5.3.1 Definitions

There is no universally accepted definition of 'concurrent' delay. It could be said to be simply two or more events which cause delay running side by side. The most acceptable and salient definition of concurrent delay stated recently is 'a period of project over-run which is caused by two or more effective causes of delay which are of equal causative potency'.[6] This latest definition could also be said to apply to the 'concurrent effect' of those effective causes, rather than the actual period in which they occurred. Both are relevant when assessing:

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[6] *Concurrent Delay*, John Marrin QC, February 2002. A paper given at a meeting of the Society of Construction Law on February 5th 2002.

- the delay caused by two or more effective causes; and
- the actual damages experienced as a direct result of either of those causes.

The particular relevance of this issue applies when at least one of the concurrent delay events is at the risk of the contractor. True concurrent delay, where the events run together at exactly the same time is a rare occurrence. Causes of delay more commonly tend to overlap, and in this sense 'concurrent delay' applies only to the period of overlap.

While considering the meaning of concurrency, it is worth briefly reviewing the various definitions applied to delay terms. A great deal has been written on delay analysis in the USA which has led to the introduction of US terminology alongside, and sometimes in preference to, existing UK terminology. For example the Society of Construction Law used many US terms in its publication 'SCL Delay and Disruption Protocol'. These definitions are looked at in Chapter 4, Section 4.1.3.

5.3.2 Delay analysis and concurrency

There are essentially two parts to time delay analysis; firstly the assessment of the effect on progress sustained by a delay event which may lead to a time extension, and secondly the assessment of the financial compensation.

In the first instance a contract administrator has to consider whether a claimed relevant delay event had a deleterious effect on the progress of the works. For example, did it merely slow down progress of the works or did it bring the works to a standstill? If the answer is 'yes' in either case, the next step is to consider how much the progress of the works was affected. If there were no concurrency issues present then the next step would ordinarily be to apply the result of the assessment of the amount of delay caused by the relevant delay event and award an extension of time for the same amount, that is extend the contract period for completion of the works.

Where concurrent delays are present the contract administrator has to identify from as-built data the incidence of the delays, the window in which the concurrency falls, whether the delays have affected the existing completion date, and the liability for each delay. There are a number of alternative approaches advocated for dealing with the analysis of concurrent delay which vary in application as to whether one is considering time and damages or compensation. The more commonly recognised of these approaches are:

- the first-in-line;
- the dominant cause approach; and
- the apportionment approach.

Selection of the appropriate approach will depend upon the circumstances, including contract conditions, the prevailing case law, and to some extent the preference of the delay analyst. The chosen method and subsequent analysis will also have to deal with the possibility of delay arising in various combinations. For example:

- reimbursable/non-reimbursable;
- reimbursable/culpable delay; or
- non-reimbursable/culpable delay.

There are pros and cons in applying these various techniques which are explained below. The underlying principle which has long been applied to concurrent delay theory is that neither the employer nor the contractor can recover damages from one another when they contribute to the delay. An appendage to that is that contractors may be able to recover the amount of damages which can be discretely attributed to an excusable event caused by the employer. The bulk of the US case law on this topic concludes that contractors are entitled to time, but not time related damages, when concurrent delays are present. The UK case law is less clear or consistent on the topic of concurrent delay, owing to the various methods of apportioning liability when concurrent delays are shown to be present. The various techniques are discussed briefly below.

The first-in-line approach

The first-in-line approach is one in which the first occurring event of two overlapping events is identified as the one which has caused a critical delay. A drawback of the first-in-line approach is that the results do not reflect the impact of culpable delay.

The dominant cause approach

The dominant cause approach is a test used to establish as a question of fact the dominant cause of a loss suffered. In the case of construction delay analysis this approach is applied to identify which of a number of competing delay events is the most dominant or predominant. It was an approach that was given early support by the courts,[7] but subsequently rejected in a later construction case[8] that went to appeal. In fact, the dominant cause approach is relevant to recovery of damages and not relief from damages. There is still support for the dominant cause approach in recent history, and it cannot be ruled out as an available argument, depending on the facts and circumstances of the evidence.

The apportionment approach

The method of apportioning concurrent delay is important in situations where both excusable and non-excusable delays have been experienced, such as the

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[7] *Leyland Shipping Co. Ltd* v. *Norwich Union Fire Insurance Society Ltd* [1918] AC 350 at p.370 (H.L.).

[8] *H. Fairweather & Co Ltd* v. *London Borough of Wandsworth* (1987) 39 BLR 112.

occurrence of exceptionally inclement weather and contractor-caused delay. It is even more important and controversial in situations in which each party is responsible for at least one of the concurrent delay(s). This situation is also applicable to claims downstream where a main contractor needs to identify liability for delay amongst a group of subcontractors.

The recent case of *City Inn* v. *Shepherd Construction*[9] considered concurrency and provided a pragmatic and workable guide to assessing concurrent delay. The case concerned a dispute over a contractor's extension of time against an employer's entitlement to withhold liquidated damages. One of the many time related issues dealt with in some detail was that of concurrent delay. It was held that where concurrent delay is shown to be present:

> 'between a relevant event and a contractor default, in the sense that both existed simultaneously, regardless of which started first, it may be appropriate to apportion responsibility for the delay between the two causes; obviously, however, the basis for such apportionment must be fair and reasonable.'

While the case provided some credence to both the dominant cause approach and the *Malmaison*[10] approach to apportioning concurrent delay, in the event, the judge made his own assessment of what he determined to be fair and reasonable, based on the magnitude and significance of each culpable and excusable delay event. The same case was also helpful in supporting the view in the SCL Protocol that there is a different test for time and money (i.e. entitlement to additional prolongation does not automatically follow entitlement to additional time). However, the judge ultimately apportioned the monetary award on the same basis of apportionment as the additional time awarded.

In this approach only concurrent delays identified as having caused critical delay are considered. Once concurrent delays have been identified, one of which is at the employer's risk and one the contractor's risk, then the liability can be apportioned by offsetting the contractor's delay against that caused by the employer. If the contractor's delay and the employer's delay can be so apportioned, time and/or money can be granted for the difference depending on whether the remaining period of delay is excusable, non-excusable, compensable, or non-compensable. For example, if none of the contractor's delay remains after the application of the employer's concurrent delay then time, but not money, may be granted, e.g. both the contractor and the employer equally contributed to the delay. Accordingly, the contractor is entitled to an extension of time but no delay damages, and no liquidated damages are applied.

Apportionment is a pragmatic approach that can effectively be used in analysis of extension of time entitlements, but which may be inconsistent with legal principles in certain situations.

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[9] *City Inn Limited* v. *Shepherd Construction Limited* [2006] CSOH 94.

[10] *Henry Boot Construction (UK) Ltd* v. *Malmaison Hotel (Manchester) Ltd* (1999) 70 Con LR 32.

5.3.3 SCL delay and disruption protocol

The SCL Protocol position on analysing concurrent delay sets out examples of outcome depending on whether time or money is being considered.

With regard to time the SCL Protocol suggests:

- determine the status of the programme and available float at the date of delay event; and
- determine the impact of employer risk event to the contractor's plan at the time, regardless of concurrent delays operating at the time.

Importantly, the SCL Protocol states that contractor caused concurrent delay should not reduce an entitlement to an extension of time.

With regard to money the Protocol raises a number of points as follows:

- entitlement to an extension of time does not automatically equal an entitlement to money;
- when concurrent delays are present, a contractor is generally due time but not money; and
- there are distinct tests for time and money.

The SCL Protocol does state, however, that where costs are suffered due to an employer delay, if these can be distinguished from the costs which the contractor incurred due to culpable delays, these may be recovered.

5.3.4 Delay scenarios

A number of examples of true concurrent delay are illustrated in Figures 5.4 to 5.6. Figure 5.4 shows an example of equal concurrent delay on a series of critical path activities. The top two bars represent the as-planned critical path. The lower bars indicate the as-built progress interrupted by two equal delay periods.

In Figure 5.4 a contractor might argue for a one month extension of time and one month of prolongation costs. The employer might argue that there is no entitlement to an extension of time or any prolongation costs. The SCL Protocol advises one month extension of time entitlement, no prolongation costs, but payment of costs arising directly as a result of the employer's delay event.

In Figure 5.5 the employer's delay is one month greater than the contractor's delay.

In the scenario depicted in Figure 5.5 a contractor might argue for a two months extension of time and two months of prolongation costs. The employer in this situation might concede that there is an entitlement to one month's extension of time and one month of prolongation costs. The SCL Protocol advises a two month extension of time entitlement, one month of prolongation costs, and payment of costs arising directly as a result of the employer's delay event.

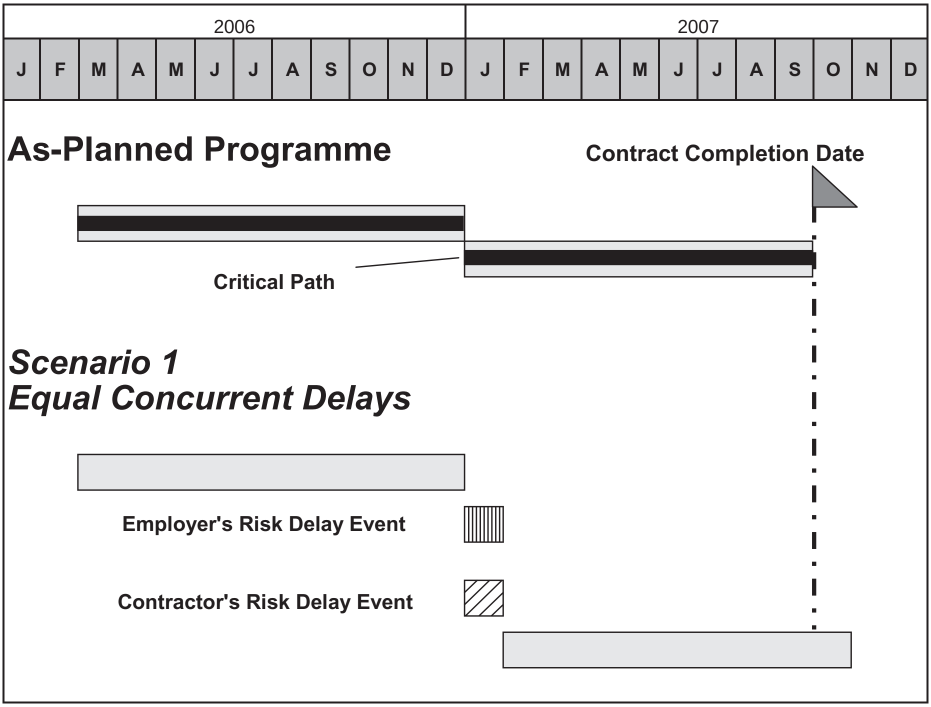

Figure 5.4 Equal concurrent delay.

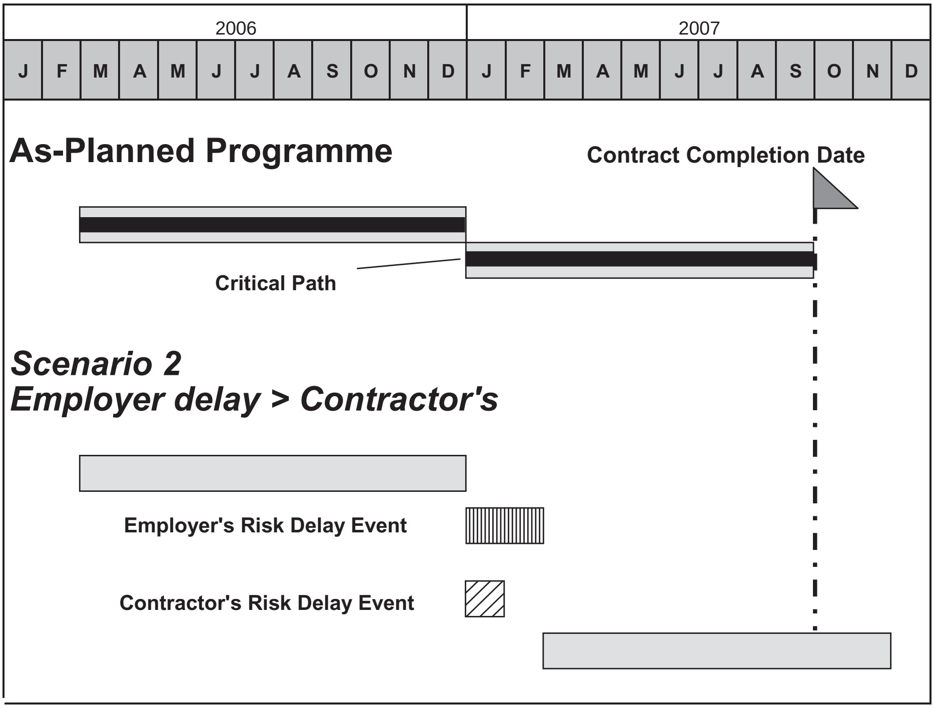

Figure 5.5 Concurrent delay scenario 2.

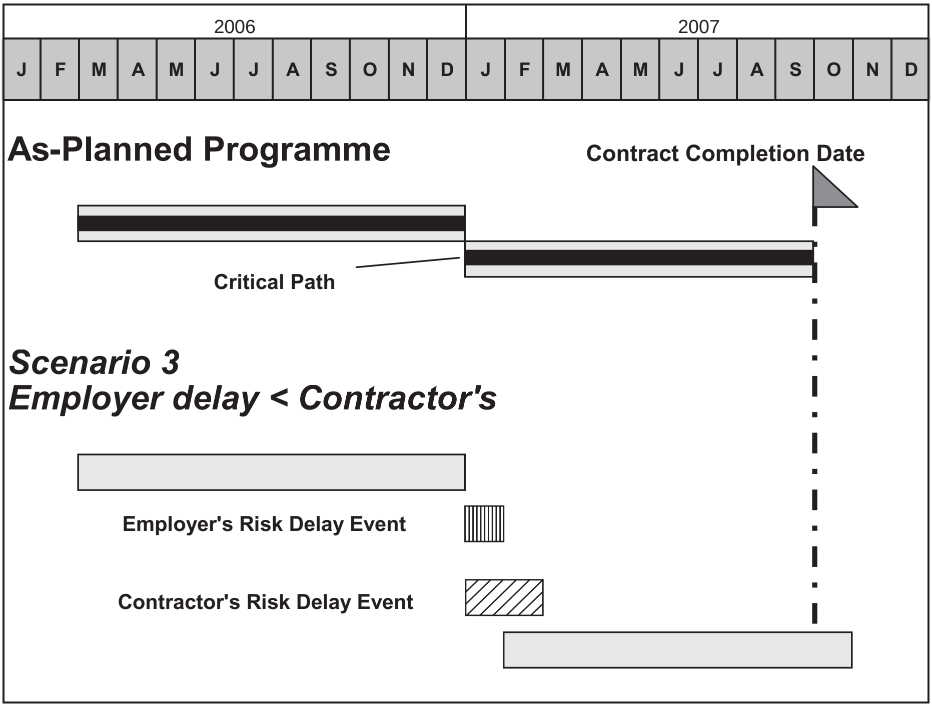

Figure 5.6 Concurrent delay scenario 3.

The scenario in Figure 5.6 reverses the position with the contractor's delay event being greater than the employer's.

In Figure 5.6 a contractor might argue for a one month extension of time and one month of prolongation costs, whereas the employer might argue that there is neither entitlement to an extension of time nor any prolongation costs. The SCL Protocol advises one month extension of time entitlement, no prolongation costs, but payment of costs arising directly as a result of the employer's delay event.

5.3.5 Common questions

Question: Where two concurrent causes of delay occur, one of which is a relevant event, and the other is not, is the contractor entitled to an extension of time?

The situation described in the question is illustrated in Figure 5.4 above. This issue was considered by the courts in the well-known *Malmaison*[11] case where

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[11] *Henry Boot Construction (UK)* v. *Malmaison Hotel (Manchester)* (1999).

it was recorded that if there are two concurrent causes of delay, one of which is a relevant event and the other is not, then the contractor is entitled to an extension of time for the period of delay caused by the relevant event notwithstanding the concurrent effect of the other event.

The example quoted in the *Malmaison* case was that if a week's production was lost because of exceptionally inclement weather (an RE – relevant event), and also because the contractor suffered a labour shortage (not an RE), and if the failure to work during that week was likely to delay the works beyond the completion date by one week, then if he considers it fair and reasonable to do so, the contract administrator is required to grant an extension of time of one week. He cannot refuse to do so on the grounds that the delay would have occurred in any event by reason of the shortage of labour.

The *Malmaison* approach was subsequently supported by a subsequent case, *Royal Brompton Hospital*,[12] in which it was stated that if the contractor:

> 'was delayed in completing the works . . . by relevant events, within the meaning of that term in the Standard form . . . it would be entitled to extensions of time by reason of the occurrence of the relevant events notwithstanding its own defaults.'

The above in fact echoes issues and views that were aired in an earlier case, *Fairweather* v. *Wandsworth*[13] which considered and criticised the 'dominant cause' approach based on the merits of the evidence in that case.

Question: Is a contractor entitled to an extension of time if variations are instructed during a period of 'culpable delay', that is after the contract completion date has passed?

The issue of whether a contract administrator can grant an extension of time in a period of culpable delay was reviewed in the case: *Balfour Beatty* v. *Chestermount*.[14] In this case, which dealt with the provisions of JCT80, the judge held that the architect had the power to grant an extension of time after the original completion date had passed.

The principle of quantifying the issue was also dealt with in the above case, that is whether an extension, if granted, should be given on a 'gross' or 'net' basis. The gross approach would include for the contractor's delay prior to the variation, and the net basis being the time required for the variation itself, which is then added onto the last revised completion date (i.e. the 'dot-on'

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[12] *Royal Brompton Hospital NHS Trust* v. *Hammond and Others (No 7)* [2001].

[13] *H. Fairweather and Co Ltd* v. *London Borough of Wandsworth* (1987).

[14] *Balfour Beatty Building Ltd* v. *Chestermount Properties Ltd* (1993).

principle). The approach considered correct in *Balfour* was the net method, but words of caution were added. Contract administrators must exercise care when considering questions of delay causation post completion date and have regard to whether an adjustment to the completion date is fair and reasonable in all the circumstances.

5.3.6 Experience and common sense

The authors' experience suggests that various approaches adopted by contract administrators from time to time lead to a state almost of 'paralysis by analysis', with illogical results which hinder the ability to make fair entitlement assessments. There is fortunately increasing evidence that contract administrators are more accepting of the principle that overlapping or concurrent delays (where for example one of the delays is an ERE and the other a CRE) entitle the contractor to an extension of time.

But then difficulty arises in addressing the all important issue of what proportion of compensation, if any, should be paid to the contractor. The approaches referred to above, together with measures suggested below, should go some way to providing delay analysts with a logical approach to tackling this difficult area.

There are measures that can be taken at the outset of a project which will generally assist in the analysis of delays, whether contemporaneously or retrospectively, and which will ease the problematic issue raised by the existence of concurrency in relation to construction delays. These mainly comprise the preparation and implementation of effective project controls in line with industry best practice guidance such as that contained in the SCL Protocol**.** These would include:

- preparation of a CPM (critical path method) based master programme;
- preparation of detailed method statements;
- updating/saving revisions to the master programme; and
- monitoring and recording progress.

The effective implementation of these and similar measures is that an accurate as-built programme will be produced which will assist enormously in the analysis and assessment of the effect of delay events whether concurrent or otherwise.

The trend in the courts is consistent with *Chitty on Contracts* (29th Edition), which states:

> 'The courts avoided laying down any formal test for causation; they have relied on common sense to guide decisions as to whether a breach of contract is a sufficiently substantial cause of the Claimant's loss. The answer to whether the breach was the cause of the loss, or merely the occasion for loss must in the end depend on the court's common sense in interpreting the facts.'

The court's common sense in interpreting the facts will prevail, regardless of the method of delay analysis undertaken, or method of apportionment applied by contractors or employers.

5.3.7 The concept of pacing

When concurrent culpable delays are identified by the employer, contractors often argue that they were simply 'pacing the work'. Likewise, when designers are late with information and shop drawing approvals, they often argue that the works were already in a state of delay, and their late response caused no further delay to the works. They responded just-in-time, and there was no reason to hurry up and wait. Both the employers and contractors can argue that their delays were not relevant because they were simply pacing their work with pre-existing delays. Both of these scenarios are sometimes valid and both have limited support from various cases in the US and UK jurisdictions.

The argument of pacing is based on the premise that it (either party) was aware that more critical delays were occurring elsewhere and it elected to simply pace its own work progress with the more critical (or dominant) delay. Thus, this assisted in avoiding unnecessary costs associated with the alternative of speeding up, or working to a normal output programme, only to have to wait for the concurrently delayed works to catch up.

If either a contractor or the employers' professional team seek to rely on this argument then the following should be demonstrated by the relevant party:

- a knowledge of the more critical excusable delay;
- evidence of an express decision to pace its works;
- notification to the employer/contractor that its works would be paced so as not to cause further delay and/or disruption to the works; and
- the ability to reinstate normal outputs if the pre-existing delay was mitigated or avoided.

A helpful recent US case addressed both concurrency and pacing, where it was found that:

> 'The general rule is that, where both parties contribute to the delay neither can recover damages, unless there is in the proof a clear apportionment of the delay and expenses attributable to each party. Courts will deny recovery where the delays are concurrent and the contractor has not established its delay apart from that attributable to the government.'[15]

A further US case addresses 'pacing' and concludes that when contractor caused delays are merely being paced, concurrently with employer risk events, then contractors sometimes do so at their own peril:

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[15] Coffey Construction Company Inc. VABCA No 3361, 93-2 BCA 25, 788 (1993).

> 'Conversely, it does not appear from the record that but for the government-caused delays, appellant could have completed the work by December 13. It is concluded, therefore, that despite the delays caused by the government, the record establishes that from the time scheduled for commencement of the project, appellant was at least concurrently responsible for the delay in the progress of the work. Appellant must bear the responsibility for the consequence for his search for a less costly source of water and the manner in which he chose to sequence and perform the work.'[16]

According to this case, contractors are not entitled to compensable delay when the result was merely to consume float.

Proving the above elements can only be done with contemporaneous records. Pacing arguments are most often made at the end of a project, when an as-built programme analysis reveals that activities which were not affected by any employer instructed variations or other excusable events appear to have been delayed. When pacing is argued with hindsight, it should be treated with both caution and scepticism, especially when the assertion is unsupported by contemporaneous records.

5.4 Programme approvals and onerous specifications

Many of the major building and civil engineering forms of contract require the contractor to prepare and submit a construction programme. However, under most standard forms of contract the programme is not a contract document. Thus while it may be a breach of condition not to produce a programme, it is rarely a requirement for a contractor to proceed exactly to the programme other than meeting key contractual dates that are shown on the programme, i.e. sectional completion dates.

5.4.1 Programme requirements, format and compliance

The content and standard of construction programming data that employers have required to be submitted by contractors in the past has varied quite considerably. However, in more recent times, with the advances in computer generated output and a growing awareness of the nature of construction planning, employers have been requesting ever increasingly detailed and sophisticated programmes from contractors. The requirement to provide programming data does not now end with the initial submission of a compliant programme, but on most medium to large projects there is an ongoing obligation to provide refreshed programme data.

The obligation for planning, programming and construction of the project works lies generally with the contractor. The content and status of a

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[16] John Murphy Construction Company, AGBCA, No 418 79-1 BCA 13,836 (1979).

contractor's construction programme depends on the conditions of contract governing the particular works and varies depending upon the form of contract. Most British standard forms of construction contract do not dictate specific detailed programming requirements, other than requiring a programme indicating the contractor's intended sequence, showing start dates, completion dates and, if applicable, sectional completion dates.

However, some contract conditions are amended with regard to programming requirements, for example, to require a contractor to indicate on the programme key dates by which information is required by reference to the activities affected. Increasingly on larger projects there is a requirement from employers for contractors to maintain a critical path programme during the lifecycle of the project and provide periodic programme data updates (usually monthly) in such a form as to allow the employer's consultants to monitor and track contractor's progress using a 'shadow' programme.

In the USA, particularly on government forms of contract, it is a more common practice to require quite detailed and sophisticated programme requirements, for example provision of:

- a preliminary network diagram which indicates work activities for the first 60 days;
- a detailed network diagram which shows the order, interdependence, and sequence of construction, procurement, and submission activities, which might also show, for example, milestones, government activities affecting progress, activity durations of 30 days maximum, and differentiation of construction areas;
- time scaled summary network diagrams;
- a detailed activity report which would include activity identification numbers, description, duration, early/late start and finish dates, manpower, float and value; and
- the programme updating requirements.

An example of US standard clause, converted for use on an NEC form of contract is provided in the Appendix (p. 259) ('contractors programming submittals'). This programming requirement was used in 1997 on a £100 m NEC2 project with a fixed completion date on an international sports stadium complex. The project was completed on time, and without recourse to adjudication, arbitration or litigation. According to the client, this was due, in large part, to the project controls and programme monitoring procedures put in place by the project manager, including diligent application and enforcement of these requirements.

Examples of typical programming requirement conditions contained in unamended standard forms of construction and engineering contracts are reproduced below to illustrate the diversity of the emphasis placed on the programmes function and use. In the JCT standard building form, 2005 Edition, the obligations on the contractor are relatively light. Under the heading *Construction information and contractor's master programme* the contract provides:

> '2.9.1.2 . . . the Contractor shall without charge provide the Architect/Contract Administrator with 2 copies of his master programme for the execution of the Works and, within 14 days of any decision by the Architect/Contract Administrator under clause 2.28.1 or of agreement of any Pre-agreed Adjustment, with 2 copies of an amendment or revision of that programme to take account of that decision or agreement.'

In the ICE Conditions of Contract, 7th Edition (1999) commonly used for civil engineering works the programming requirements are contained within Clause 14, '*Programme to be furnished*'. Under this form the contractor is required to go further than the JCT in producing a construction methodology which should be consistent with the construction programme. Clause 14(1) states:

> '(a) Within 21 days after the award of the Contract the Contractor shall submit to the Engineer for his acceptance a programme showing the order in which he proposes to carry out the Works having regard to the provisions of Clause 42(1).
>
> (b) At the same time the Contractor shall also provide in writing for the information of the Engineer a general description of the arrangements and methods of construction which the Contractor proposes to adopt for the carrying out of the Works.
>
> (c) Should the Engineer reject any programme under sub-clause (2) (b) of this Clause the Contractor shall within 21 days of such rejection submit a revised programme.'

In accordance with the ICE 7th Edition, the Engineer then has 21 days after receipt of the programme to:

- accept the programme in writing; or
- reject the programme in writing with reasons; or
- request that the contractor supply further information to clarify or substantiate the programme or to satisfy the Engineer as to its reasonableness having regard to the contractor's obligations under the contract.

If none of the above actions is taken within the 21 day period then the Engineer will be deemed to have accepted the programme as submitted. This is consistent with the NEC3 terms.

Further provisions with time scales are included in Clause 14 in connection with the provision by the contractor of further information. There is also a provision for the Engineer to require a contractor to produce a revised programme showing any modifications to the original programme as may be necessary to ensure completion of the works (or any section) within the time for completion as originally defined (Clause 43) or extended (Clause 44).

The form used by the British Government for the procurement of building, civil engineering and major works, namely the GC/Works/1 (1998) adopts an approach more in line with the JCT and it is much less onerous than the ICE.

In Condition 1 'the programme' is defined as '*the programme submitted prior to acceptance of the tender and agreed at that time by the Employer, as it may be amended from time to time*'.

The main requirements are contained in Condition 33:

> '(1) The Contractor warrants that the Programme shows the sequence in which the Contractor proposes to execute the Works, details of any temporary work, method of work, labour and plant proposed to be employed, and events, which, in his opinion, are critical to the satisfactory completion of the Works; that the Programme is achievable, conforms with the requirements of the Contract, permits effective monitoring of progress, and allows reasonable periods of time for the provision of information required from the Employer; and that the Programme is based on a period for the execution of the Works to the Date or Dates for Completion.'

In addition the contractor is able to offer suggestions for amendment to the programme to the 'project manager' (PM):

> '(2) . . . the Contractor may at any time submit for the PM's agreement proposals for the amendment of the Programme. The agreement of the PM to any proposal for the amendment of the Programme shall not relieve the Contractor of any liability which he has under the Contract. In particular, without limitation, the submission by the Contractor of any proposal for the amendment of the Programme showing a period for the execution of the Works extending beyond the Date or any of the Dates for Completion shall not constitute a notice from the Contractor requesting an extension of time for the completion of the Works or of any Section; and the agreement of the PM to any such amendment shall not constitute, or be evidence of, or in support of, any extension of time for the completion of the Works or of any Section.'

In the New Engineering Contract (NEC3, June 2005) core clause 11.2 (14) states:

> '(1) The Accepted Programme is the programme identified in the Contract Data or is the latest programme accepted by the *Project Manager*. The latest programme accepted by the *Project Manager* supersedes previous Accepted Programmes.'

Under Clause 31.1, if a programme is not identified in the Contract Data, the contractor has to submit a first programme to the Project Manager for acceptance within the period stated in the Contract Data. The constituent parts of the programme are quite detailed under this form of contract, as set out in Clause 31.2. The contractor is expected to show on each programme which it submits for acceptance the following:

- the starting date, access dates, key dates and completion date;
- the planned completion;
- the order and timing of the operations which the contractor plans to do in order to provide the works;

- the order and timing of the work of the employer and others as last agreed with them by the contractor or, if not so agreed, as stated in the works information;
- the dates when the contractor plans to meet each condition stated for the key dates and to complete other work needed to allow the employer and others to do their work;
- the provisions for:
    - float,
    - time risk allowances,
    - health and safety requirements, and
    - the procedures set out in this contract;
- the dates when in order to provide the project works in accordance with its programme, the contractor will need:
    - access to a part of the site if later than its access date,
    - acceptances,
    - plant and materials and other things to be provided by the employer, and
    - information from others;
- for each operation a statement of how the contractor plans to do the work identifying the principal equipment and other resources which it plans to use; and
- other information which the project works information requires the contractor to show on a programme submitted for acceptance.

The contract also stipulates arrangements and time scales for the programme to be accepted (Clause 31.3) and subsequently revised (Clause 32). The programme requirements are not particularly onerous and would generally comply with good construction planning practice. Failure to comply with the NEC programme requirements results in:

> 'one quarter of the Price for Work Done To Date is retained in assessments of amounts due, until the Contractor has submitted a first programme to the *Project Manager* for acceptance showing the information which this contract requires.'[17]

A common amendment to the above clause is to apply this sanction on any programme which is submitted for acceptance, and not only the first programme.

In the USA the early historical development and usage of programming and scheduling methodologies has resulted in quite detailed and onerous obligations being placed on contractors for the provision of construction programmes/schedules. An example of a programme submittal and compliance requirement is contained within the widely used American domestic form, the

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[17] NEC3 (2005), Clause 50.3.

CMAA[18] contract. It initially sets out in Article 2, ‘Performance of the Work’; the following obligations on the contractor:

> ‘2.1.2 To prepare and submit to the CM the contractor’s construction schedule for the Work in accordance with the requirements of the Contract Documents. The Owner and CM make no representation or warranty that the Contractor shall be able to complete the Work in accordance with the contractor’s construction schedule or that other contractors shall perform in accordance with their construction schedules
>
> 2.1.3 To modify the approved schedule or any part thereof in terms of order, sequence or duration only in compliance with the Contract Documents and to promote the timely prosecution of the entire Project; . . .’

Article 8 then lists out in some 14 clauses further requirements which the contractor ‘shall’ submit within seven days. These include:

- A preliminary schedule that conforms to the milestone dates set out in the Master Schedule (8.2.3.1);
- A preliminary schedule of submittals (8.2.3.2); and
- A schedule of values for all of the Work (8.2.3.3, 8.2.3.4).

There are other strict requirements:

- The contractor must convene a conference with the designer and construction manager, within 10 days after the date of the contract and before work commencement, to discuss the work schedule, procedures for handling shop drawings, samples and other submittals and for processing applications for payment (8.2.4).
- The contractor must submit to the construction manager the ‘contractor’s construction schedule’ before submission of the first application for payment. The construction schedule or programme has to be prepared in a critical path method (CPM) network format, and comply with several requests, e.g. activity durations of no more than 20 days (8.2.5).
- The contractor shall revise and resubmit the construction schedule following the schedule review and no progress payments shall be processed or paid until the contractor’s construction schedule has been ‘properly prepared and submitted’.
- The contractor shall submit monthly schedule reports to the construction manager with all pre-defined information including or incorporating:
  - the current status of the ‘Work’;
  - all change orders; and
  - proposed adjustments in the contractor’s construction schedule;

indicating any revised sequence of the ‘Work’ as may be necessary.

Acceptance of any proposed adjustments is at the sole discretion of the construction manager and any proposed adjustments ‘*shall be for the benefit of the Project and its completion . . .*’.

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[18] The Construction Management Association of America, Inc.

The above clauses are provided to assist in illustrating the gap between the requirements of various forms of British and US forms of construction contract, and indicate the historical rise of the programming requirements in the US which are being increasingly adopted internationally, together with an increased planning burden. In the US most, if not all, construction cases accept CPM methods for determining entitlement and liability for delay. This may be due to the quality, abundance, or sophistication of programming information available contemporaneously on many projects in the US, which contain provisions similar to those set out above.

5.4.2 Approval or acceptance of construction programme

The main purposes for detailed scheduling clauses being imposed is to provide the employer with a degree of confidence or assurance that the contractor has an achievable programme and plan for the construction works. It also provides a measurable standard of the contractor's progress, and enables monitoring of progress.

Whether a programme is required to be 'approved' or 'accepted' depends upon the form of contract. Under the JCT family of contract forms the contractor's obligations[19] are limited to providing copies of the master programme to the architect/contract administrator *'as soon as possible after execution of the Contract, if not previously provided'*.

The contractor is also required to provide a revised programme within 14 days of the issue of an extension of time under condition 2.28.1. There is no requirement for the programme to be approved, nor any imposed constraint on how the contractor formulates its programme.

Under the NEC3 form, the project manger is required to review programme submissions within two calendar weeks. However, there is no limit on how often a contractor can submit revised programmes. This provision could potentially increase the effort required by the project manager's team significantly. It could be argued that under the NEC3 no response by the project manager could be deemed acceptance. The NEC3, like its predecessor, limits the reasons which a project manager can rely on for not accepting the programme which include:

- the plans it shows are not practicable;
- the information required under the contract is not shown;
- the contractor's plans are not realistically represented;
- it does not comply with the works information.

Each of these reasons will contain a degree of subjectivity, and accordingly provide conditions for a dispute to form in respect of issues, including the

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[19] Condition 2.9

content of the contractor's programme and whether the contractor's planned intentions are realistic. Into this mix is added the potential for 25% of the amount due being withheld on one hand and the ability of the contractor to propose early completion programmes on the other. The amount due is the total cumulative amount due, before accounting for amounts previously paid and this therefore becomes a more significant incentive later in the project.

The SCL Protocol provides helpful guidance on this issue where it states that:

> 'Acceptance by the CA merely constitutes an acknowledgement by the CA that the Accepted Programme represents a contractually compliant, realistic and achievable depiction of the Contractor's intended sequence and timing of construction of the works. Acceptance does not turn the Contractor's programme into a contract document, or mandate that the works should be constructed exactly as set out in the Accepted Programme (if the programme is made a contract document, the Contractor may become entitled to a variation whenever it proves impossible to construct the Works in accordance with the programme). Nor does it amount to a warranty by the CA to the Employer that the programme will be achieved. The Protocol regards the agreement of the Accepted Programme as being very important. Disagreements over what constitutes the Accepted Programme should be resolved straight away and not be allowed to continue through the project.'[20]

Whichever form of contract is used it is important for the employer's representative to be proactive, and to act reasonably in reviewing and approving contractors' programmes.

5.5 *Acceleration and mitigation*

Two activities which can be problematic both during the course of a project and subsequently, while carrying out a delay analysis forensically, are acceleration and mitigation. There are a number of misconceptions as to what these activities comprise; also how and when they occur. The typical dilemma contractors face with the prospect of having to mitigate some delay is in deciding when it is appropriate or necessary to instigate such mitigation action, to what extent and at what cost. This is particularly difficult where contractors consider they have not received extensions of time that are considered due and are therefore in the difficult position of having to decide whether to undertake expensive mitigation measures, or wait until a proper assessment is made of their time claim. This often requires consideration of whether the risk of damages being applied outweighs the cost and later recovery of mitigation steps. Mitigating delay often involves some form of acceleration. Both mitigation and acceleration are discussed in more detail below.

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[20] Ibid, page 37 (2.2.1.4)

5.5.1 Mitigation

A contractor has a general duty to mitigate the actual or potential loss arising from delayed and/or disrupted contract works. In particular a contractor should do everything reasonably possible to ensure that non-productive labour and plant costs are minimised. Many of the standard forms of construction contract require a contractor to mitigate delay, that is take steps to reduce the effects of delay.

Care must be taken to identify the difference between actions to mitigate the cost effect of disrupted works and the use of acceleration measures to minimise the delay effects of disrupted works. A contractor is not required to incur cost in mitigation unless it chooses to, for example to recover culpable delay.

5.5.2 Acceleration

There are many reasons why a contractor falls behind programme necessitating consideration of acceleration measures. Many of these have been dealt with in previous chapters and include for example:

- slow release of design information, design changes;
- changed ground conditions;
- poor construction or project management of the works;
- changes or additional works instructed, but without any time extension; and
- employer's instructions to complete the whole or part of the works earlier than planned.

Whatever the reason, acceleration activity often results in additional cost. Acceleration is defined in the SCL Protocol as:

> 'The execution of the planned scope of work in a shorter time than anticipated or the execution of an increased scope of work within the originally planned duration.'

In practical terms this means reducing the time scale of the construction programme activities either on or off site to achieve an overall reduction in a project's duration, or that of a particular works section. The need for acceleration from an employer's viewpoint can arise for a number of reasons; for example being locked into a delivery date for sub-lets, or to meet a particular peak shopping period. Accordingly employers may also be faced with difficult decisions where they must weigh up the costs of acceleration against the income stream to be derived from a completed building.

Acceleration measures affect work patterns and efficiency as was illustrated in Chapter 4. Acceleration can in fact disrupt works, with stacking of trades, congestion on site, reduced productivity and an increase in defects. Acceleration may be achieved by extending working hours, increasing manpower, altering shifts and providing additional plant. One major problematic area is how to measure acceleration and recover the costs. It is clearly imprudent for contractors to embark on a range of expensive accelerative measures unless they have a pre-agreed method of reimbursement.

In a situation where contractors are of the view that excusable delay has occurred but the contract administrator disagrees and refuses to award an extension of time, they are faced with a difficult problem. If the contractors feel confident of their position then they complete the works in whatever time it reasonably takes, and argue their case that liquidated damages should not have been retained as a result of the delay caused. They can also seek to recover additional costs incurred directly as a result of the accelerative measures. However, being alive to the potential high risk associated with such an action (where the employers are in the driving position), the contractors may feel that they have in practical terms been forced to accelerate the works and seek recovery of costs incurred once the original completion date has been achieved. This situation is sometimes termed 'constructive acceleration' a concept or doctrine more widely referred to in the US. Constructive acceleration is said to have occurred when the employer fails to recognise a contractor's entitlement to additional time, and as a direct result, the contractor is 'forced' to accelerate its progress in order to avoid suffering liquidated damages or other financial consequences for finishing later than the date for completion.

A big problem facing employers in an acceleration situation is how the costs will be established. Clearly, while it is prudent to agree a fixed price at the outset, this is not always possible as acceleration can be something of an unknown quantity and a degree of flexibility should therefore be anticipated. The costs of acceleration may be varied depending on the approach adopted by the contractors and their success at implementing the measures. What employers will need to avoid is becoming hostage to a 'blank cheque' situation.

In order to accelerate, contractors need to consider the following factors:

- agreement on the nature, scope and reimbursement plan for the accelerative measures;
- the option of accepting deduction of damages rather than incurring accelerative costs;
- how to obtain support of their own management and labour;
- how to obtain support of sub-contractors and suppliers as to delivery;
- how to obtain support from the employer's professional team, e.g. designers, project managers and consultants;
- monitoring quality standards (which will likely slip during a period of sustained acceleration);
- the ability to secure additional labour of suitable quality and supervisory management; and
- changes to the construction programmes.

In certain circumstance a contractor has to manage the employer's expectation that the contractor will proceed with the acceleration measures before all the cost reimbursement details are sorted out. Clearly, the magnitude of the acceleration required needs to be considered; but a contractor would be entertaining unnecessary risk in embarking on this course of action, except for a minor accelerative measure applied to a small section of a project works. It would be better to wait until a fully considered plan of action has been produced.

From the perspective of employers, they should have some methodology in place for monitoring and measuring the effectiveness of the operation; for example employers may want an 'early warning system' that indicates the acceleration measures are not working and accordingly have the option to instruct that the acceleration stops and the related costs cease.

Most of the standard UK forms of contract do not deal with acceleration, except where the contractor is at fault. In this case contractors are usually given the option of mitigating their delays by taking steps and incurring costs to overcome their delay. There is a move towards contracts giving contract administrators authority which allows them to instruct, by agreement, acceleration measures. For example, the NEC3[21] clause 36 moves in this direction, though it only gives the project manager an express right to obtain quotations from a contractor to accelerate the work and to subsequently agree to the implementation of acceleration measures. There is no authority for the project manager to instruct acceleration unilaterally.

5.5.3 Contractors' right to early completion

A further problematic area of concern for contractors and employers is when contractors proposes a programme which indicates an intention to finish a project earlier than the agreed contract completion date. In fact there is nothing to prevent a contractor planning to complete the works in a shorter time period than agreed, and in doing so inserting a period of float at the end of the programme (i.e. the period between a contractor's targeted early completion date and the contractual contract completion date). However, issuing such a programme cannot unilaterally change the contractual rights or obligations of the parties. In practical terms, by reference to current UK case law,[22] while contractors are entitled to complete early and the employers must not hinder them in this endeavour, there is no duty imposed on the employers to produce information early. In the US, where a contractor seeks to work to an early completion programme, the employer can either:

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[21] New Engineering Contract 2003.

[22] *Glenlion Construction Ltd* v. *The Guinness Trust* (1987) 39 BLR 89.

- accept the programme and the early completion date; or
- accept only the programme, but maintain the contract completion date, which effectively creates float to all activities equal to the amount of time between the early completion date and the contract completion date.

Under the first option, the liquidated damages clause could be amended to align with the earlier completion date, while prolongation costs would be recoverable for compensable delays which prevented early completion. This would have to be done by agreement, and through an express change to the contract conditions. If the second option is pursued, and the contract is silent on float ownership, any delays to the early completion will simply absorb float, and the traditional arguments regarding 'ownership of float' will be made by both the contractor and the employer (see Section 5.2).

Clearly, the benefits to a contractor in achieving an early completion are to make savings on time-related overhead costs, or avoidance of working through a seasonal bad weather period. The opportunity to finish earlier than anticipated may lead to cost reductions for materials, temporary works, direct and indirect labour, supervision, site expenses, head office overheads, bonds, insurance and finance (e.g. interest). Where a contractor proposes to finish earlier than the agreed contract completion date, and the conditions of contract allow, the following guidelines (based on US case law) and common sense, are suggested for both the set-up and record keeping:

- the contractors should indicate, seek approval, or advise the employers early on any plans for early completion;
- the contractors have the burden to prove that they intend to achieve an early finish and have the capabilities to do so;
- prolongation costs during the period of time leading up to the contract completion date will require proof that the contractors intended to finish early and that the employers were aware of it;
- the early completion programme must be reasonable;
- the programme should be periodically updated and reflect actual performance conditions and all delays as they occur;
- the contractors must demonstrate that they could have and would have finished early, but for employer delay;
- any delays to the eventual actual completion which occurred prior to the contract completion date must be excusable under the contract;
- notice should be given and detailed information required by the contract should be submitted in a timely manner.

The trend in most US standard contracts is to accept float as a shared resource, i.e. it is not for the sole benefit of either party. This effectively adopts the SCL Protocol approach to float and has resulted in an increased use of early completion programmes on contracts which allow contractors to benefit from delays to such programmes.

In summary, this issue concerns whether contractors can calculate and recover time-related damages from the early completion date. If they can demonstrate that they intended, attempted and could reasonably have achieved the early completion date, but for an employer-caused delay, it is generally accepted in the US that contractors can recover their time-related damages, when these tests are met.

In the UK the concept has been tested in the courts in the *Glenlion* v. *Guinness*[23] case where it was decided that there was no obligation for the employer to facilitate the early completion by the contractor in accordance with a programme that indicated that the works would be completed before the contract completion date. Notwithstanding, under most forms of standard contract, the contractor is entitled to submit a programme showing that the works will be complete in advance of the contract completion date.

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[23] *Glenlion Construction Ltd* v. *The Guinness Trust* (1987) 39 BLR 89.

Chapter 6

Effective Presentation of Delay Analysis

6.1 Introduction

In this chapter, various methods of delay analysis are demonstrated using a case study which is largely based on an actual assignment. The information available on the case study project is listed and the technique of identifying the as-built critical path is described in detail. The purpose of this chapter is to describe, step-by-step, how these techniques of delay analysis can be applied, and how the assumptions made by an analyst are fundamental to the reliability of the conclusions. It is important to note that the methodology demonstrated in this case study is not the only method, or only variant on the method demonstrated, for carrying out this type of delay analysis. Chapter 4 provides step-by-step procedures for the more commonly discussed methods of analysis: impacted as-planned; collapsed as-built; time impact analysis (TIA) and as-planned versus as-built. This case study was selected to provide a better understanding of a widely used method of delay analysis, contemporaneous update/windows analysis, which has not been discussed or demonstrated in detail in previous texts or protocols.

6.2 Case study – airport terminal expansion

This case study demonstrates the application of a contemporaneous update / windows analysis, in conjunction with time impact analysis conclusions. Other techniques and topics described in this case study are ‘float mapping’, ‘pacing’, ‘concurrent delay’, ‘dominant delay’ and a ‘month-to-month’ update analysis.

A joint venture consortium (JV) was contracted to carry out renovations to an existing terminal and modernise an existing Control Tower, as well as Runway Extension works to an existing international airport. The date for commencement was 1 October 2006, with a date for completion of 1 August 2007. In the event, the project was actually completed on 28 January 2008.

A disputed time extension claim was referred to arbitration and a tribunal appointed planning expert was appointed to provide an independent review and analysis that would either validate or refute the existing analyses performed by party appointed experts. The planning expert for the JV (the claimant) undertook a time impact analysis. The planning expert for the employer (the respondent) submitted a report which concluded that the JV had not proved its case and had not sufficiently demonstrated any causal link from the events relied upon to the losses that were being claimed. The employer's expert also concluded that:

- the JV failed to act on instructions to accelerate, and thus were not entitled to any recovery of any costs incurred while attempting to mitigate the employer delay events; and
- the JV would have finished late in any case, due to delays on the Runway Extension work, which were not varied or delayed in any way by the employer.

The information available on this case was as follows:

- submitted and approved baseline (as-planned) programme;
- contemporaneously updated CPM programmes;
- contemporaneously prepared as-built programme; and
- agreed employer risk events.

6.2.1 Initial analysis by party appointed planning experts

Although there was agreement between the experts as to which delay events were employer's risk events, and thus 'excusable' risk events, there was a large disagreement between the experts regarding which delays were on the critical path to completion from time to time, and which were relevant to the contractor's entitlement to both time and money. There was also a dispute over how much recovery was achieved by the mitigation schedules, and whether the employer delay events affected the critical path to the actual completion date in January 2008. The employer delay events were identified in the Terminal Building works and the Control Tower, as well as the Runway Extension works. The Runway Extension works were largely completed on time, so these were not considered in the time impact analysis by the claimant's planning expert.

The available programmes are listed in Table 6.1.

It is notable that the project was in delay from the first updated CPM programme dated 1 October 2006, which reported a 28 day delay at the time (i.e. –28 days of float). The agreed excusable risk events are listed in Table 6.2.

There were no particularised delay events identified by the employer's planning expert, therefore these were the only events considered in the tribunal appointed expert analysis. The time impact analysis carried out by the claimant's expert concluded that all of the risk events contributed to critical delay and demonstrated that the claimant was entitled to a full time extension when the impact of all events was considered cumulatively. However, certain excusable events were clearly unrelated, and in different areas of the project. The

Table 6.1 Available programmes.

Programme File Name	Data Date	Projected Completion Date	Total Float
1006	1-Oct-06	29-Aug-07	–28
1106	1-Nov-06	24-Aug-07	–23
1206	1-Dec-06	30-Sep-07	–60
0107	1-Jan-07	5-Oct-07	–65
0207	1-Feb-07	13-Oct-07	–73
0307	1-Mar-07	25-Oct-07	–85
0407	1-Apr-07	12-Sep-07	–42
0507	1-May-07	20-Sep-07	–50
0607	1-Jun-07	10-Oct-07	–70
0707	1-Jul-07	14-Oct-07	–74
0807	1-Aug-07	25-Oct-07	–85
0907	1-Sep-07	4-Nov-07	–95
1007	1-Oct-07	24-Dec-07	–145
1107	1-Nov-07	15-Jan-08	–167
1207	1-Dec-07	30-Nov-07	–121
0108	1-Jan-08	2-Dec-07	–123

Table 6.2 Excusable risk events.

Event	Description
A	Additional services below slab
B	Additional protection works to underground utilities
C	Shop drawing approval
D	Revised columns to Control Tower
E	Revised blockwork to Terminal Building
F	Revised curtain walling to Terminal Building
G	M&E revisions – 1st Fix 2nd Level Terminal Bldg
H	M&E revisions – 1st Fix 1st Level Terminal Bldg
I	M&E revisions – 1st Fix Ground Level Term Bldg
J	Terrazzo floor changes – Terminal Bldg
K	Revised curtain walling to Control Tower
L	Acoustic ceiling revision – Control Tower
M	Revised retail layout – Terminal Bldg

time impact analysis did not offer a linear critical path through the works, demonstrating how the impact of the unrelated events should be treated as additive critical delays. According to the results in the TIA, the critical path shifted from the Terminal Building to the Runway Works, and back again. The TIA did not provide a linked chain of events, from commencement to completion, which could be related to an as-built programme and the actual costs incurred. The conclusions of the time impact analysis are shown in Table 6.3.

Table 6.3 Conclusions of time analysis.

Event Rev	Description	Delay Duration (Cal. days)	Impacted Window
A	Additional services below slab	15	1106
B	Additional protection works to underground utilities	20	1206
C	Shop drawing approval	4	0307
D	Revised columns to Control Tower	33	0607
E	Revised blockwork to Terminal Building	12	0607
F	Revised Curtain Walling to Terminal Building	10	0707
G	M&E revisions – 1st Fix 2nd Level Terminal Building	46	0707
H	M&E revisions – 1st Fix 1st Level Terminal Building	20	0707
I	M&E revisions – 1st Fix Grnd Level Terminal Building	15	0807
J	Terrazzo floor changes – Terminal Building	20	0807
K	Revised curtain walling to Control Tower	14	1207
L	Acoustic ceiling revision – Control Tower	7	1207
M	Revised retail layout – Terminal Building	24	0108

The ‘impacted window’ in column four of Table 6.3 relates to the contemporaneous updates listed in Table 6.2. The duration of each delay event was determined by an analysis of the available facts and an agreed chronology for each delay event. For example, Table 6.4 summarises the calculation of the revised columns to the Control Tower, event D in Table 6.3.

Although the total delay from the planned finish of ‘strengthening columns’ (3 April 2007) to the actual finish of ‘strengthening columns’ (4 August 2007) is 123 calendar days, the planned finish of strengthening, at the time the revised work was instructed, was 2 July 2007 in programme 0607. Programme 0607 is dated June 2007, and was the prevailing programme in place when the ‘*Engineer issues revised details for column strengthening*’. Therefore, any delay to the commencement of column strengthening that occurred prior to 1 June 2007 was not due to the revised details.

Table 6.4 Event D, calculations to revised columns.

Key Dates	Description
1-Apr-07	Engineer advises revised loadings on Control Tower roof
3-Apr-07	Planned finish of strengthening columns in baseline programme
1-Jun-07	Engineer issues revised details for column strengthening
1-Jun-07	Planned commencement of strengthening in 0607 update programme
5-Jun-07	Strengthening able to commence
2-Jul-07	Planned finish of strengthening columns in 0607 update programme
4-Aug-07	Strengthening of columns completed
33 cal. days	Actual delay to strengthening columns (02-Jul-07 – 04-Aug-07)

The measurement of delay was based on the date the work was actually carried out and the most recently submitted programme at the time the revised work was instructed. This translated into a direct critical delay of 33 days (2 July 2007 to 4 August 2007) in the time impact analysis. While the discrete delay of 33 days is logical, as demonstrated from an analysis of the brief chronology provided above, it was not agreed that the event was on the critical path at the time.

The method of carrying out the time impact analysis by the previous expert was simply to 'set the clock to zero' by updating the status of the programme (e.g. by inserting progress data) for all activities in progress up to the date immediately prior to each delay event. This resulted in a base programme which was used as the basis for measuring the impact of each event. This process was performed for each event, independent of one another, with only one event analysed at a time, even when those events occurred in the same update period, in a similar fashion as described in Chapter 4 for time impact analysis.

This method was relied on by the claimant to prove its entitlement to an extension of time and presented before an arbitration tribunal of three arbitrators. It was agreed between the experts that this method provided a measure of the likely impact of delays from time to time, as measured against an updated version of the contractor's most recent contemporaneous programme, but it was argued by the employer's expert that this approach did not provide assistance in demonstrating compensable periods of delay to assist in pricing prolongation entitlement for each delay event.

Further submissions were made and an additional hearing was deemed necessary by the tribunal. A tribunal-appointed expert was agreed to by all parties to assist the arbitration tribunal in understanding the complex set of analyses before it, and to assist in deciding whether any entitlement for additional time or money could be demonstrated when considering only the facts and analyses relied upon by the parties' planning experts. This case study is focused on the tribunal appointed expert's approach and findings. This approach will be deemed 'the tribunal expert's approach'.

6.2.2 Using time impact analysis for prolongation

It is not universally accepted that the time impact analysis (TIA) method of delay analysis can be used for linking causation to the resulting prolongation. For example, the AACEI RP-FSA expressly states:

> 'An additive-modeled schedule by itself does not account for concurrent delays and is therefore unsuitable for determining compensability.'[1]

The problem with TIA is that it relies on the calculations of a prospective programme, and is therefore seen to be theoretical. Like the impacted as-planned programme, the conclusions may or may not hold true when viewed in retrospect and compared to the as-built programme and when evaluated against an as-built critical path. While these prospective methods may be deemed unsuitable on their own, when applied in conjunction with a comprehensive analysis of the facts and delays reported contemporaneously, the gap between causation and damages can be closed considerably. The responding party's expert did not provide a positive case in the form of an independent programme analysis, other than questioning the reliability of the contemporaneous programmes, and refuting the credibility of the TIA approach adopted by the claimant. The tribunal expert's approach focused on a comparative analysis of the TIA conclusions and the as-built critical path, as determined from contemporaneous progress records available to both party appointed experts.

6.2.3 Tribunal planning expert's contemporaneous approach

While the approach described here could be deemed simply a 'windows' analysis, or a contemporaneous update/windows analysis, it is, like most forms of analysis, a hybrid. The name of the analysis is not as important as understanding the raw materials that were considered in analysing the impact of each event. It relies on the best available evidence, and requires the application of both technical expertise in programming and also common sense to ensure that the conclusions have a basis in reality, and are consistent with the available facts.

Because it was important to rely on evidence which was relied upon by the party appointed experts, and facts that were already before the tribunal, the

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[1] Association for the Advancement of Cost Engineering International – Recommended Practice No. 29R-03 *Forensic Schedule Analysis*, page 66.

tribunal expert's intention was not to carry out an approach, *de novo*, but to provide assistance to the tribunal, in interpreting the evidence already presented by the party appointed planning experts.

The steps carried out comprised the following:

- an analysis of the contemporaneous programmes;
- analysis of the as-built programmes;
- identification of an as-built critical path, from commencement to completion;
- identification of concurrent as-built critical paths;
- determination of which of the employer delay events are relevant to actual delay (by reference to the as-built critical path(s)); and
- determining how much excusable critical delay resulted along each as-built critical path.

This approach assisted in determining:

- how much delay was reported in each window, contemporaneously;
- which activities were driving the critical path, in each window;
- whether concurrent (or near critical) paths existed through the project; and
- who was responsible for that critical, and near critical, delay.

Firstly, an analysis of the contemporaneous programmes was carried out to establish how much float deterioration was experienced contemporaneously. This project entailed the completion of three primary areas of work: Terminal Building Renovations, Runway Extension and Control Tower Modernisation. The completion of each of these areas of the project was to occur by the same date, 1 August 2007. All three areas finished late, independent of one another. Float deterioration curves (as measured by increasing negative float) were developed to indicate how far behind schedule each area slipped from month to month (Figure 6.1).

In the event, the Runway Extension works were completed 45 days behind programme, on 15 September 2007, while the Terminal Building was completed on 12 December 2007 (133 days late). The Control Tower was completed on 15 January 2008 (167 days late). The float deterioration timeline (Figure 6.1) indicates that the Terminal Building and Control Tower work were competing for dominance throughout the project.

While there may have been interaction between each scope, with regard to sharing of access, suppliers, management and trade contractor resources, these were largely independent, and completed at different times. This timeline, based purely on raw float values, indicates that the Terminal Building was initially in the most critical delay, in October and November of 2006. In December 2006, and January and February 2007, the Control Tower took over, with the greatest negative float values. The two areas continued to compete for dominance throughout the balance of the project until the Terminal Building

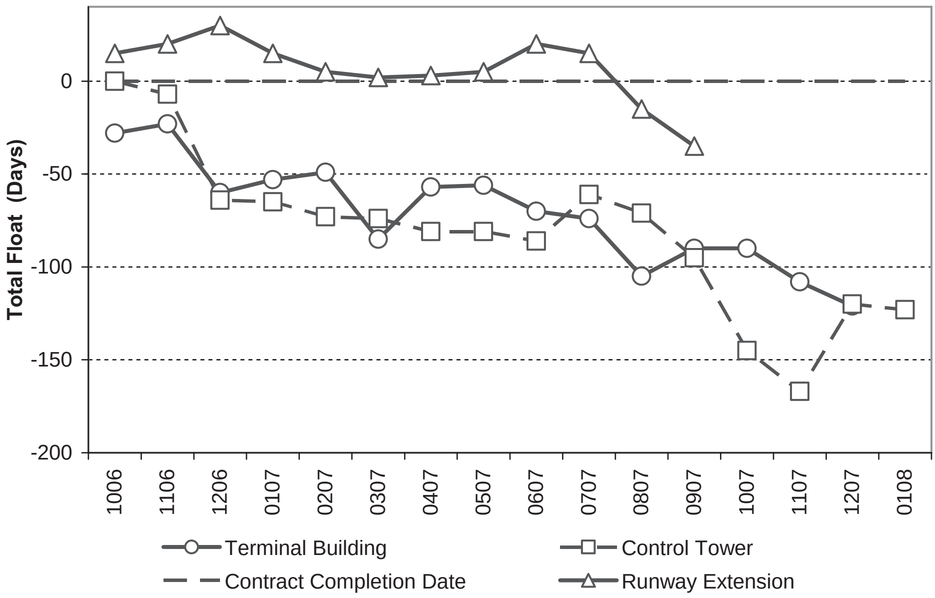


Figure 6.1 Float deterioration chart.

was completed in December 2007. Although it was not driving the critical path throughout the project, the last item of work completed was the Control Tower in January 2008.

This analysis raised two important issues:

- whether delays to the Runway Extension are relevant; when the balance of the work was completed so much later; and
- whether concurrent delays to the Terminal Building are relevant, when the ultimate task completed was the Control Tower.

When the 'dominant delay approach' to delay analysis is argued, concurrent delays are irrelevant, and the answer may be 'no', they are not relevant. However, when one looks at where the contractor was placing resources from time to time, it may be established that the Terminal Building was in fact critical, and was treated as critical at the time. This would explain why the contractor focused resources on reducing delays to the Terminal Building, resulting in the Control Tower work slipping beyond the date by which the Terminal Building was complete. Focusing only on the Control Tower would overlook all delays experienced at the Terminal Building, which was completed 133 days behind schedule.

To ensure that all available programming evidence was made available and was as transparent as possible, the tribunal appointed expert provided a range of opinion to assist the tribunal in addressing the two issues raised above.

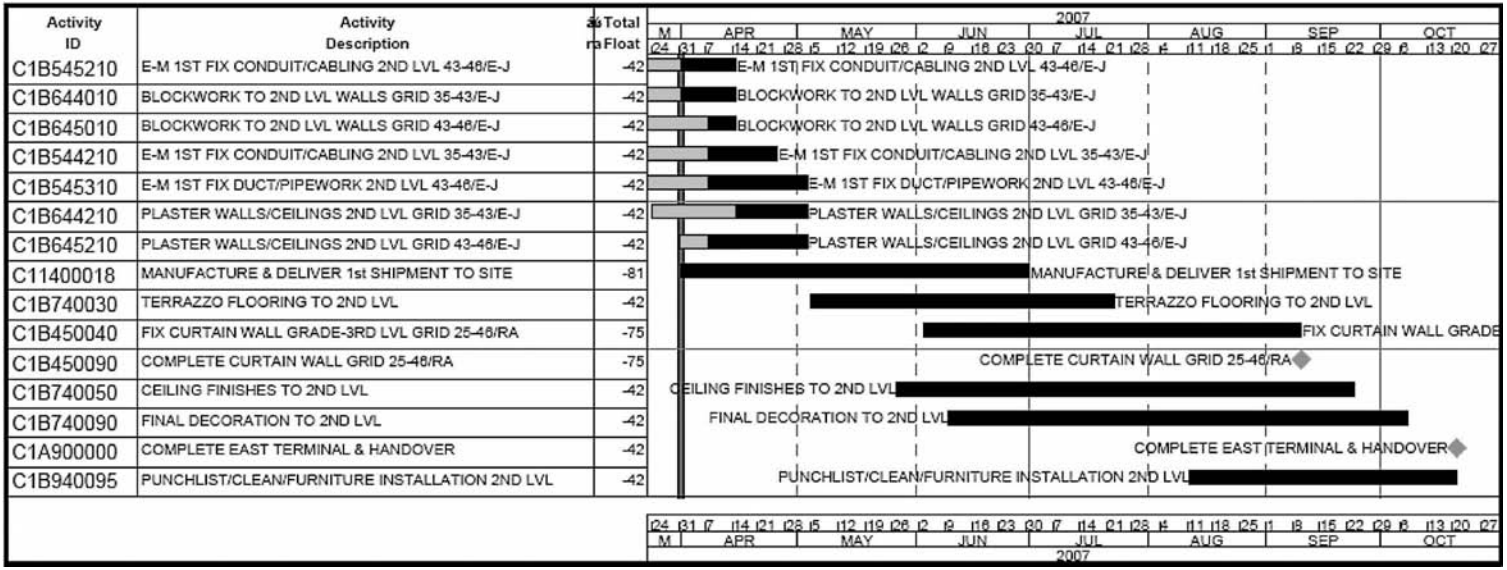
6.2.4 Runway Extension – are delays to the Runway Extension relevant?

To determine if the delayed Runway Extension was relevant the contemporaneous programmes, correspondence and monthly reports were reviewed. There was supporting evidence to show that the claimant did not cause any non-excusable delay events to the Runway Extension. This was established on the basis that the claimant was aware of the extent of delay being experienced to both the Terminal Building and Control Tower as early as March 2007. This is supported by the float deterioration analysis illustrated in Figure 6.2. There was evidence in the JV's files and monthly reports in which it expressly stated that it was going to alter the timing and sequence of the Runway work to coincide with more favourable weather conditions, but, in any event, well in advance of the completion of the Control Tower.

This approach is referred to as 'pacing' which is mentioned briefly in Chapter 5, Section 5.3.7. Pacing is determined by some to be just another form of concurrent delay. Pacing, however, is when an event is completed later than planned, in the knowledge of the existence of a more critical delay being experienced to works independent of the works being paced. Pacing can only be demonstrated when there is evidence of a conscious and contemporaneous decision to pace progress against the more critical delay to other works. There must also be an implied or expressed intention and ability to restore the works being paced, to avoid those delays causing critical delay to the work. Pacing is usually implemented to save money, but can be implemented for many reasons including:

- to perform work in more favourable weather conditions;
- to smooth or level resources;
- to avoid unnecessary acceleration to non-critical events;
- to allow designers more time to complete shop-drawing;
- to allow fabrication shops to expedite more critical components or assemblies;
- to reduce reliance of on-site storage or lay-down areas;
- to reduce reliance on vertical movement of trade/materials (lifts/cranes);
- to mitigate logistical challenges regarding access to site; and
- to allow management to focus on and resolve critical issues.

These are just a few. To implement pacing, outputs can be reduced, resulting in extended durations for tasks, or suspended altogether. The reasons must be clearly expressed, and the ability to restore outputs to normal conditions must be demonstrated. In the US, a contractor's right to pace the works in response to a more critical delay is an accepted concept. Thus, when accepted, the contractor is not being penalised for pacing the works to avoid unnecessary costs. Whether or not costs are recoverable in the period of pacing is an issue which is not clear in any jurisdiction.



Activity ID	Activity Description	Total Float
C1B545210	E-M 1ST FIX CONDUIT/CABLING 2ND LVL 43-46/E-J	-42
C1B644010	BLOCKWORK TO 2ND LVL WALLS GRID 35-43/E-J	-42
C1B645010	BLOCKWORK TO 2ND LVL WALLS GRID 43-46/E-J	-42
C1B544210	E-M 1ST FIX CONDUIT/CABLING 2ND LVL 35-43/E-J	-42
C1B545310	E-M 1ST FIX DUCT/PIPEWORK 2ND LVL 43-46/E-J	-42
C1B644210	PLASTER WALLS/CEILINGS 2ND LVL GRID 35-43/E-J	-42
C1B645210	PLASTER WALLS/CEILINGS 2ND LVL GRID 43-46/E-J	-42
C11400018	MANUFACTURE & DELIVER 1st SHIPMENT TO SITE	-81
C1B740030	TERRAZZO FLOORING TO 2ND LVL	-42
C1B450040	FIX CURTAIN WALL GRADE-3RD LVL GRID 25-46/RA	-75
C1B450090	COMPLETE CURTAIN WALL GRID 25-46/RA	-75
C1B740050	CEILING FINISHES TO 2ND LVL	-42
C1B740090	FINAL DECORATION TO 2ND LVL	-42
C1A900000	COMPLETE EAST TERMINAL & HANDOVER	-42
C1B940095	PUNCHLIST/CLEAN/FURNITURE INSTALLATION 2ND LVL	-42

Figure 6.2 Case study – driving critical path (April 2007).

In this case, the presence of bona-fide pacing was established from contemporaneous evidence (and eventually accepted by the tribunal). The late completion of the Runway Extension was deemed irrelevant because it was an elective, or voluntary, form of re-sequencing. In any event, it was found that the Runway Extension did not contribute to any delay to completion and was not on the critical path at any time.

6.2.5 Terminal Building – are delays to the Terminal Building relevant?

Are delays to the Terminal Building relevant, when the ultimate task completed was the Control Tower? The float deterioration chart indicated that there were concurrent competing paths along the Control Tower and Terminal Building, and that neither of these was delayed voluntarily through pacing or otherwise by any contractor risk events. To determine whether each delay event was truly on the as-built critical path from time to time, the tribunal appointed expert carried out a 'float map' exercise to determine the location of the critical path from time to time, and to determine whose delays were driving that critical path, based on the best available evidence. The method used is a form of 'Float Mapping', which is described below.

6.3 Float mapping – approach and methodology

The approach to float mapping can also be described as a form of window analysis:

> 'Window analysis is especially helpful when a critical path programme which was updated on a regular basis was employed on the project. To delay project completion, the critical activities of the project must have been delayed. The window analysis only analyses critical activities occurring during specific periods of time on a project. The periods analysed are the same periods of time as those when the project was updated. For instance, if the project was updated monthly then the window analysis would be monthly.'[2]

This reference was relied on by the tribunal expert to support his 'argument(s)' that the monthly windows analysis was an appropriate breakdown to use for this project. When determining whether the Control Tower or Terminal Building delays should be considered in a critical path analysis the critical status of the events along the longest path to the completion in each programme update needed to be discretely quantified. The activities in the schedule which had the least amount of total float, which were also on the longest path of activities

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[2] Kris R. Nielsen and Patricia D. Galloway (1984) 'Proof Development for Construction Litigation'. *American Journal of Trial Advocacy* 7, 433.

in the schedule, were deemed to be critical to the completion of the project. The least amount of float can be zero, or any other figure, depending on whether the programme was projecting an early (positive float) or delayed (negative float) completion. These activities comprised what is known as the critical path. During the life of a project the critical path can, and usually does, shift from one area of the project to another, as it was argued by the claimant's expert in this case study. When analysing project programmes for use in a delay claim, it is vital to know which activities were critical on a contemporaneous basis. This is commonly referred to as one form of an 'as-built critical path'. Taking definitions from the SCL Protocol:

> '. . . critical path – The sequence of activities through a project network from start to finish, the sum of whose durations determines the overall project duration.[3] There may be more than one critical path depending on workflow logic . . .'
>
> '. . . critical path analysis (CPA) and critical path method (CPM) – The critical path analysis or method is the process of deducing the critical activities in a programme by tracing the logical sequence of tasks that directly affect the date of project completion . . .'

When describing the process of identifying the as-built critical path, the AACEI RP-FSA states that:

> The as-built critical path cannot be directly computed using CPM logic since networked computations that generate float values can be generated only to the future (right) of the data date. Because of this technical reason, the critical set of as-built activities is often called the controlling activities as opposed to critical activities. Even in a modeled collapsible as-built (3.8) float is not a relevant indicator of criticality because the late dates are not used in modeling the as-built schedule.
>
> The closest the analyst can come to a direct computational determination is to cumulatively collect from successive schedule updates the activities that reside on the critical path between the data date and the data date of the subsequent update. The same technique can be used to determine the as built near-critical activities. If the updates are available, the following is the recommended protocol.
>
> a. Use all the critical and near-critical activities in the baseline schedule. If modifications were made to the baseline for analysis purposes use both sets of critical activities, before and after the modification.
>
> b. For each schedule update, use the critical and near-critical chains of activities starting immediately to the right of the data date.
>
> c. Also use the predecessor activities to the left of the data date that precede the chains found in (b) above.
>
> d. Use the longest path and near-longest path criteria in addition to the lowest float path criterion in identifying the activities.

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[3] Project Management: Vocabulary, BS 6079-2:2000 Part 2, 2.41.

e. If weather or other calendar factors are at issue, also use a baseline recalculated with an alternate calendar reflecting actual weather or other factors to gather critical and near-critical activities.'

As confirmed in the SCL Protocol, it is a process of deduction, not necessarily calculation. This approach is consistent with the 'float mapping' approach used in this case study. Float mapping, put simply, is the process of extracting the float values for each activity from each of the contemporaneous CPM programme updates, then grouping and filtering those activities that were driving the longest path, which also had the least amount of float, to determine the as-built critical path.

6.3.1 Extracting float values

The first step in this exercise was to extract the raw data for the float values for all activities in every schedule update. This can be done manually, from hard copy programmes, or through the exchange of programming data from most available planning software into a database or spreadsheet package. Spreadsheets were used for this case study due to the number of CPM activities in each programme and small number of programme updates. This allows for the sorting, grouping and filtering of activities when identifying and demonstrating the as-built critical path. During this step, all activity data should be extracted for ease of reference, including durations, constraints, start and finish dates and other relevant progress or activity data that can be readily extracted and stored. Activity data for all activities in the programme should be extracted at this stage to ensure there is no bias away from, or towards, any potentially critical areas.

6.3.2 Creating a float map

The second step in this exercise is to construct a table listing all activities in every CPM programme, along with their respective float values from month to month, and identify which activities are potentially critical (i.e. largest negative float). This can be performed directly from step one. However, it is more likely that this will require careful data management, to ensure all float values are aligned with the correct activity.

This initial table will usually be very large and somewhat cumbersome due to the sheer quantity of data on large projects. Table 6.5 is an extract of some of the activities from the raw-data float map for this case study. Where there is an asterisk in a cell to the right of a float value, this signifies that the activity has been completed. Where there is a minus sign in a cell to the left of a float value it signifies that an activity did not exist until a later schedule. The activity ID and titles are listed, along with their respective float values for each update period in the project. This project was updated monthly.

Table 6.5 Raw data for the float map.

		2006			2007							
	Title	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Act	**CPM Programme File Name**	**1006**	**1106**	**1206**	**0107**	**0207**	**0307**	**0407**	**0507**	**0607**	**0707**	**0807**
C11400017	Submit & obtain approval 1st shop drawings	17	2	–64	–65	–73	–74	–	–	–	–	–
C11400018	Manufacture & deliver 1st shipment to site	17	2	–64	–65	–73	–74	–81	–81	–86	–50	–49
C1B544210	E-M 1st fix conduit/cabling 2nd lvl 35-43/E-J	–8	–18	–40	–33	37	23	–42	–40	–46	–38	–
C1B730090	Final decoration to 1st lvl	–27	–23	–40	–33	–14	–62	–57	–56	–70	–74	–85
C1B733056	Lath & plaster ceiling 1st lvl grid 35-46/J-RA	*	*	*	*	*	–37	–43	–35	–48	–55	–105
C1C320200	Duct bank/cabling to temp control rm in w jetty	*	*	*	*	*	*	*	*	*	*	–71
C1C3A0210	Construct 2 lifts columns 4th-5th lvl cont tower	0	–7	–11	–16	–33	–85	–	–	–	–	–
C1C4F0045	Fix curtain wall to control tower vcr lvl	*	*	*	*	*	–31	–31	–31	–47	–49	–63
C1C560010	E-M 1st fix services installation to control	10	3	–1	–6	–19	–27	–23	–30	–54	–51	–71
C1C660020	Plaster control tower walls internally	6	–1	–5	–10	–27	–26	–22	–14	–25	–45	–69
C1C860010	1st fix installation/cabling for tower equipment	10	3	–1	–6	–19	–27	–23	–30	–54	–51	–71
C1C860050	Install/test & commission tower equipment	0	–7	–11	–16	–27	–31	–31	–31	–59	–61	–71
C1C900099	New control tower operational	0	–7	–11	–16	–27	–31	–31	–31	–59	–61	–71
C1C900100	Decommission existing control tower by others	*	*	*	*	*	*	*	*	*	*	–71

Float values can be manipulated by a planner in many ways and should therefore never be used as the sole indicator of determining the location of the driving path or the as-built critical path. For example, float values are affected by constraints imposed on activities in the programme, differences in calendar assignments between activities and the use of optional constraints, such as zero total float constraints. Altering network calculation options by using 'progress over-ride' instead of 'retained logic' will also affect the amount of float, and the longest path to completion from time to time. Another issue is that sometimes the activities with the least float are not even scheduled to occur for many more months, and therefore are not driving the contemporaneous critical path. The programmer/analyst carrying out a float mapping exercise should be aware of any factors which may have created 'false float' in the programmes being relied upon, and correct these, where possible (e.g. by deleting zero float constraints or using retained logic instead of progress over-ride settings). Alternatively, the analyst could elect to rely on another form of analysis if the problem is systematic and uncorrectable without altering the structure and fabric of the programme (e.g. over-reliance on constraints in lieu of proper logical relationships).

6.3.3 Identify driving activities

The third step in the process is to highlight all of the activities meeting the following two factors that determine the 'driving' activities within each of the programmes:

- The activity must be on the 'longest path' to completion.
- The activity must be ongoing or scheduled to begin within the update period.

It is important to note that the longest path often changes throughout the project and for this reason it is analysed on a month by month or update by update basis. While it is possible that the critical path shifts daily, in this case study no daily-update regime was employed. When accurate progress data is available, and the size and nature of the dispute warrants the precision, it is possible to prepare daily progress programmes which can identify how the critical path shifted on a daily basis. However, these programmes can only be developed forensically, and when it is only contemporaneous monthly updates that are available, these usually suffice for narrowing the activities down to those which are relevant to critical and concurrent delays.

The resulting and final float map should highlight only activities that are on the longest path during a particular update, and are scheduled to start during that update. Those activities deemed to be 'driving' are those that are in progress, and thus driving the current critical total float. In April 2007, for example, the driving critical path has a float value of minus 42 days to completion as seen in Figure 6.2.

Although the majority of the activities on the driving critical path in April 2007 have a total float value of –42, there are three activities (C11400018, C1B450040, and C1B450090) with greater negative float values. Rudimentary analysis indicates that these are being constrained with a ‘finish no later than’ (FNLT) constraint, as illustrated by the intermediate milestone activity C1B450090, ‘complete curtain wall grid 25–46/RA’. When anomalous float paths exist, these need to be evaluated, explained, and in many cases dismissed for consideration of critical delays.

The driving activities in the above ‘driving path’ are those which satisfy our two tests set out above. The most critical path is –42 (after the FNLT constraint is dismissed). The activities which are either ongoing or scheduled to commence in the next 30 days are:

- **C1B545210 :** E-M 1st fix conduit/cabling 2nd level 43–46/E-J
- **C1B644010 :** Blockwork to 2nd level walls grid 35–43/E-J
- **C1B645010 :** Blockwork to 2nd level walls grid 43–46/E-J
- **C1B544210 :** E-M 1st fix conduit/cabling 2nd level 35–43/E-J
- **C1B545310 :** E-M 1st fix duct/pipework 2nd level 43–46/E-J
- **C1B644210 :** Plaster walls/ceilings 2nd level grid 35–43/E-J

These activities have been highlighted in black in Figure 6.3, under the column for April 2007 (CPM Programme File Name ‘0407’) where the driving critical path is indicated as –42 days.

Tasks with greater negative float were discounted because they failed to meet the criteria set. Either they were not on the driving path, or were not scheduled to commence in the next 30 day window. The process was repeated for all available programmes until the driving activities in each programme were identified. Now that all driving activities are identified, expert judgement and experience are required to link the driving activities, thus deducing an ‘as-built critical path’ (or paths) from commencement to completion.

6.3.4 As-built critical path

The activities highlighted in black in Figure 6.3 meet both criteria: ongoing or scheduled to start within one month and on the longest path of the project during the update in which they are highlighted. When only hard copies of programmes are available, the first criteria can be determined, but the longest path to completion may not be apparent, and determining which tasks are ‘driving’ will require an objective assessment, based on interpretation of any reported float values and the analyst’s experience.

Where it is apparent that the driving activities in subsequent months are unrelated, it may be necessary to identify two parallel critical paths. When this occurs, all driving activities must be grouped and sorted so that the need for a parallel critical path can be evaluated. In this case study the tribunal expert

Act	Title	2006			2007											08
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
	CPM Programme File Name	1006	1106	1206	0107	0207	0307	0407	0507	0607	0707	0807	0907	1007	1107	1207	0108
	Maximum Delay (Total Float)	-28	-23	-64	-65	-73	-85	-81	-81	-86	-74	-105	-95	-145	-167	-121	-123
C11400017	Submit & obtain approval 1st shop drawings	17	2	-64	-65	-73	-74	-	-	-	-	-	-	-	-	-	-
C11400018	Manufacture & deliver 1st shipment to site	17	2	-64	-65	-73	-74	-81	-81	-86	-50	-49	-75	-	-	-	-
C1B115030	Protection works to ex fuel line grid 42-46/A-B	-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B115040	Protection works to ex fuel line grid 35-42/A	-15	-23	-60	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215310	Construct strip found grid 42-46/A	-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215450	Construct 1st lift columns grid 35-41/A	-15	-23	-60	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215570	Construct 1st lift wall grid 41-43/A-B	-15	-6	-42	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215610	Backfill/blind lwr lvl slab grid 43-46/A-E	-27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B216060	Install services below grade slab grid 43-46/E-J	-28															
C1B328220	Construct grnd beams grade lvl grid 35-43/A-D	-15	-23	-60	-53	-	-	-	-	-	-	-		-	-	-	-
C1B328230	Construct columns grade 1st lvl grid 37-43/-D,E	5	-23	-60	-53	-	-	-	-	-	-	-	-	-	-	-	-
C1B534210	E-M 1st fix conduit/cabling 1st lvl 35-43/E-J	-27	-21	-32	-36	-49	-57	-57	-50	-70	-	-	-	-	-	-	-
C1B534310	E-M 1st fix duct/pipework 1st lvl 35-43/E-J	-14	-21	-32	-36	-49	-50	-51	-50	-70	-	-	-	-	-	-	-
C1B544210	E-M 1st fix conduit/cabling 2nd lvl 35-43/E-J	-8	-18	-40	-33	37	23	-42	-40	-46	-38	-	-	-	-	-	-
C1B544310	E-M 1st fix duct/pipework 2nd lvl 35-43/E-J	-8	-18	-34	-27	45	23	-40	-43	-52	-42	-16	-	-	-	-	-
C1B545210	E-M 1st fix conduit/cabling 2nd lvl 43-46/E-J	24	24	28	13	4	-2	-42	-47	-67	-	-	-	-	-	-	-
C1B545310	E-M 1st fix duct/pipework 2nd lvl 43-46/E-J	8	9	3	-13	-1	-17	-42	-41	-61	-	-	-	-	-	-	-
C1B634210	Plaster walls/ceilings 1st lvl grid 35-43/E-J	-27	-21	-32	-33	-14	-57	-57	-56	-70	-	-	-	-	-	-	-
C1B644010	Blockwork to 2nd lvl walls grid 35-43/E-J	-8	-18	-40	-33	37	23	-42	-41	-	-	-	-	-	-	-	-
C1B644210	Plaster walls/ceilings 2nd lvl grid 35-43/E-J	-8	-18	-40	-33	-14	-42	-42	-42	-	-	-	-	-	-	-	-
C1B645010	Blockwork to 2nd lvl walls grid 43-46/E-J	24	24	28	13	-1	-17	-42	-41	-61	-	-	-	-	-	-	-
C1B710090	Final decoration to lower lvl grids 35-46/A-J	-28	-9	-15	8	-8	-24	-24	-4	-22	-31	-81	-81	-90	-106	-121	-
C1B715059	Fix acoustic ceiling lwr lvl	*	*	*	*	*	*	*	*	*	*	*	-81	-74	-97	-121	-
C1B729010	Reinstatement & Marking E Terminal Apron Area															-97	-121
C1B730090	Final decoration to 1st lvl	-27	-23	-40	-33	-14	-62	-57	-56	-70	-74	-85	-90	-90	-108	-120	-
C1B731040	Terrazzo floor tiling 1st lvl grid 25-35/J-RA														-108		
C1B733056	Lath & plaster ceiling 1st lvl grid 35-46/J-RA	*	*	*	*	*	-37	-43	-35	-48	-55	-105	710	-69	-108	-	-
C1C320200	Duct bank/cabling to temp control rm in w jetty	*	*	*	*	*	*	*	*	*	*	-71	-73	-73	-144	-118	-123
C1C3A0210	Construct 2 lifts columns 4th-5th lvl cont tower	0	-7	-11	-16	-33	-85	-	-	-	-	-	-	-	-	-	-
C1C4F0045	Fix curtain wall to control tower vcr lvl	*	*	*	*	*	-31	-31	-31	-47	-49	-63	-74	-145	-167	-	-
C1C560010	E-M 1st fix services installation to control	10	3	-1	-6	-19	-27	-23	-30	-54	-51	-71	-95	-144	-167	-120	-
C1C660020	Plaster control tower walls internally	6	-1	-5	-10	-27	-26	-22	-14	-25	-45	-69	-71	-134	-167	-	-
C1C860010	1st fix installation/cabling for tower equipment	10	3	-1	-6	-19	-27	-23	-30	-54	-51	-71	-95	-144	-167	-	-
C1C860050	Install/test & commission tower equipment	0	-7	-11	-16	-27	-31	-31	-31	-59	-61	-71	-81	-145	-167	-118	-109
C1C900099	New control tower operational	0	-7	-11	-16	-27	-31	-31	-31	-59	-61	-71	-81	-103	-119	-118	-123
C1C900100	Decommission existing conrol tower by others	*	*	*	*	*	*	*	*	*	*	-71	-81	-103	-119	-118	-123

Figure 6.3 Driving activities.

determined that the Control Tower and Terminal Building were competing for dominance, as indicated in the float deterioration analysis provided in Figure 6.1. To identify the activities which were driving these competing, concurrent driving paths, the activities were coded and grouped according to their location (Figure 6.4).

It is obvious that when the critical path shifts from the Terminal Building to the Control Tower in January 2007, the Terminal Building is still in delay, and is deemed to be a 'near critical' path if January 2007 and February 2007 were analysed in isolation of the balance of the programme updates. Near critical paths have the potential to become critical, and delays which force near critical paths to overtake as the most critical path, are also relevant. For this reason, an understanding of concurrent effect is important: this was discussed in Chapter 5. In our example (Figure 6.4), the Terminal Building was 'near critical' in January and February 2007, but overtook as critical in March 2007.

Before evaluating the excusable delay events against the driving paths identified above there was one final step in the process of deducing the as-built critical path from our float data. Near critical paths were identified by linking the successors and predecessors of driving critical activities in the months in which either path (Terminal Building or Control Tower) were near critical. To illustrate this point more clearly, these months are indicated in 'grey' in Figure 6.5.

The resulting network illustrates our as-built critical paths, along two parallel areas of the project, the Terminal Building (Concurrent Critical Path 1) and the Control Tower (Concurrent Critical Path 2). This is a contemporaneous critical path because it shows the critical path was primarily located in the Terminal Building to the last activity completed, even though the Control Tower was on what many would deem the 'dominant' critical path. It might be said that only delays to the areas which were driving the contemporaneous as-built critical path are relevant, as they represent the 'dominant delay' at the time.

The chart in Figure 6.6 provides a summary of the calculated completion date projected each month using the delays experienced at both the Control Tower, and the Terminal Building.

It is likely that delays along both paths are relevant. The contract completion date was 1 August 2007. The Terminal Building was completed on 12 December 2007 (133 days late) and the Control Tower was completed on 15 January 2008 (167 days late). Applying a simple 'but for' query yields the most basic common sense test to determine if the delays to the Terminal Building are relevant. '*But for' delays to the Control Tower, when would the project have completed?* The answer is that it would be no earlier than 12 December 2007, when the Terminal Building was complete.

Delays to both the Terminal Building and Control Tower were therefore isolated, and analysed along each respective driving as-built critical path. This method of analysis has many strengths:

Act	Title	2006			2007												08
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
	CPM Programme File Name	1006	1106	1206	0107	0207	0307	0407	0507	0607	0707	0807	0907	1007	1107	1207	0108
	Critical Path Delay	**-28**	**-23**	**-60**	**-65**	**-73**	**-85**	**-42**	**-50**	**-70**	**-74**	**-85**	**-95**	**-145**	**-167**	**-121**	**-123**
	Maximum Delay (Total Float)	-28	-23	-64	-65	-73	-85	-81	-81	-86	-74	-105	-95	-145	-167	-121	-123
Concurrent Critical Path 1 - Terminal Building																	
C1B115030	Protection works to ex fuel line grid 42-46/A-B	-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215310	Construct strip found grid 42-46/A	-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215570	Construct 1st lift wall grid 41-43/A-B	-15	-6	-42	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215610	Backfill/blind lwr lvl slab grid 43-46/A-E	-27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B216060	Install services below grade slab grid 43-46/E-J	-28															
C1B115040	Protection works to ex fuel line grid 35-42/A	-15	-23	-60	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215450	Construct 1st lift columns grid 35-41/A	-15	-23	-60	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B328220	Construct grnd beams grade lvl grid 35-43/A-D	-15	-23	-60	-53	-	-	-	-	-	-	-		-	-	-	-
C1B328230	Construct columns grade 1st lvl grid 37-43/-D,E	5	-23	-60	-53	-	-	-	-	-	-	-	-	-	-	-	-
C1C3A0210	Construct 2 lifts columns 4th-5th lvl cont tower	0	-7	-11	-16	-33	-85	-	-	-	-	-	-	-	-	-	-
C1B544210	E-M 1st fix conduit/cabling 2nd lvl 35-43/E-J	-8	-18	-40	-33	37	23	-42	-40	-46	-38	-	-	-	-	-	-
C1B545210	E-M 1st fix conduit/cabling 2nd lvl 43-46/E-J	24	24	28	13	4	-2	-42	-47	-67	-	-	-	-	-	-	-
C1B545310	E-M 1st fix duct/pipework 2nd lvl 43-46/E-J	8	9	3	-13	-1	-17	-42	-41	-61	-	-	-	-	-	-	-
C1B644010	Blockwork to 2nd lvl walls grid 35-43/E-J	-8	-18	-40	-33	37	23	-42	-41	-	-	-	-	-	-	-	-
C1B645010	Blockwork to 2nd lvl walls grid 43-46/E-J	24	24	28	13	-1	-17	-42	-41	-61	-	-	-	-	-	-	-
C1B644210	Plaster walls/ceilings 2nd lvl grid 35-43/E-J	-8	-18	-40	-33	-14	-42	-42	-42	-	-	-	-	-	-	-	-
C1B544310	E-M 1st fix duct/pipework 2nd lvl 35-43/E-J	-8	-18	-34	-27	45	23	-40	-43	-52	-42	-16	-	-	-	-	-
C1B534210	E-M 1st fix conduit/cabling 1st lvl 35-43/E-J	-27	-21	-32	-36	-49	-57	-57	-50	-70	-	-	-	-	-	-	-
C1B534310	E-M 1st fix duct/pipework 1st lvl 35-43/E-J	-14	-21	-32	-36	-49	-50	-51	-50	-70	-	-	-	-	-	-	-
C1B634210	Plaster walls/ceilings 1st lvl grid 35-43/E-J	-27	-21	-32	-33	-14	-57	-57	-56	-70	-	-	-	-	-	-	-
C1B730090	Final decoration to 1st lvl	-27	-23	-40	-33	-14	-62	-57	-56	-70	-74	-85	-90	-90	-108	-120	-
C1B731040	Terrazzo floor tiling 1st lvl grid 25-35/J-RA														-108		
C1B733056	Lath & plaster ceiling 1st lvl grid 35-46/J-RA	*	*	*	*	*	-37	-43	-35	-48	-55	-105	710	-69	-108	-	-
C1B710090	Final decoration to lower lvl grids 35-46/A-J	-28	-9	-15	8	-8	-24	-24	-4	-22	-31	-81	-81	-90	-106	-121	-
C1B715059	Fix acoustic ceiling lwr lvl	*	*	*	*	*	*	*	*	*	*	*	-81	-74	-97	-121	-
Concurrent Critical Path 2 - Control Tower																	
C11400017	Submit & obtain approval 1st shop drawings	17	2	-64	-65	-73	-74	-	-	-	-	-	-	-	-	-	-
C11400018	Manufacture & deliver 1st shipment to site	17	2	-64	-65	-73	-74	-81	-81	-86	-50	-49	-75	-	-	-	-
C1C4F0045	Fix curtain wall to control tower vcr lvl	*	*	*	*	*	-31	-31	-31	-47	-49	-63	-74	-145	-167	-	-
C1C560010	E-M 1st fix services installation to control	10	3	-1	-6	-19	-27	-23	-30	-54	-51	-71	-95	-144	-167	-120	-
C1C660020	Plaster control tower walls internally	6	-1	-5	-10	-27	-26	-22	-14	-25	-45	-69	-71	-134	-167	-	-
C1C860010	1st fix installation/cabling for tower equipment	10	3	-1	-6	-19	-27	-23	-30	-54	-51	-71	-95	-144	-167	-	-
C1C860050	Install/test & commission tower equipment	0	-7	-11	-16	-27	-31	-31	-31	-59	-61	-71	-81	-145	-167	-118	-109
C1C320200	Duct bank/cabling to temp control rm in w jetty	*	*	*	*	*	*	*	*	*	*	-71	-73	-73	-144	-118	-123
C1C900099	New control tower operational	0	-7	-11	-16	-27	-31	-31	-31	-59	-61	-71	-81	-103	-119	-118	-123
C1B729010	Reinstatement & Marking E Terminal Apron Area															-97	-121
C1C900100	Decommission existing conrol tower by others	*	*	*	*	*	*	*	*	*	*	-71	-81	-103	-119	-118	-123

Figure 6.4 Case study – concurrent driving critical paths.

Act	Title	2006			2007												08
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
	CPM Programme File Name	1006	1106	1206	0107	0207	0307	0407	0507	0607	0707	0807	0907	1007	1107	1207	0108
	Maximum Delay (Total Float)	-28	-23	-64	-65	-73	-85	-81	-81	-86	-74	-105	-95	-145	-167	-121	-123
Concurrent Critical Path 1 - Terminal Building																	
C1B115030	Protection works to ex fuel line grid 42-46/A-B	**-15**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215310	Construct strip found grid 42-46/A	**-13**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215570	Construct 1st lift wall grid 41-43/A-B	**-15**	**-6**	**-42**	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215610	Backfill/blind lwr lvl slab grid 43-46/A-E	**-27**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B216060	Install services below grade slab grid 43-46/E-J	**-28**															
C1B115040	Protection works to ex fuel line grid 35-42/A	**-15**	**-23**	**-60**	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215450	Construct 1st lift columns grid 35-41/A	**-15**	**-23**	**-60**	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B328220	Construct grnd beams grade lvl grid 35-43/A-D	**-15**	**-23**	**-60**	**-53**	-	-	-	-	-	-	-		-	-	-	-
C1B328230	Construct columns grade 1st lvl grid 37-43/-D,E	**5**	**-23**	**-60**	**-53**	-	-	-	-	-	-	-	-	-	-	-	-
C1C3A0210	Construct 2 lifts columns 4th-5th lvl cont tower	**0**	**-7**	**-11**	**-16**	**-33**	**-85**	-	-	-	-	-	-	-	-	-	-
C1B544210	E-M 1st fix conduit/cabling 2nd lvl 35-43/E-J	**-8**	**-18**	**-40**	**-33**	**37**	**23**	**-42**	**-40**	**-46**	**-38**	-	-	-	-	-	-
C1B545210	E-M 1st fix conduit/cabling 2nd lvl 43-46/E-J	**24**	**24**	**28**	**13**	**4**	**-2**	**-42**	**-47**	**-67**	-	-	-	-	-	-	-
C1B545310	E-M 1st fix duct/pipework 2nd lvl 43-46/E-J	**8**	**9**	**3**	**-13**	**-1**	**-17**	**-42**	**-41**	**-61**	-	-	-	-	-	-	-
C1B644010	Blockwork to 2nd lvl walls grid 35-43/E-J	**-8**	**-18**	**-40**	**-33**	**37**	**23**	**-42**	**-41**	-	-	-	-	-	-	-	-
C1B645010	Blockwork to 2nd lvl walls grid 43-46/E-J	**24**	**24**	**28**	**13**	**-1**	**-17**	**-42**	**-41**	**-61**	-	-	-	-	-	-	-
C1B644210	Plaster walls/ceilings 2nd lvl grid 35-43/E-J	**-8**	**-18**	**-40**	**-33**	**-14**	**-42**	**-42**	**-42**	-	-	-	-	-	-	-	-
C1B544310	E-M 1st fix duct/pipework 2nd lvl 35-43/E-J	**-8**	**-18**	**-34**	**-27**	**45**	**23**	**-40**	**-43**	**-52**	**-42**	**-16**	-	-	-	-	-
C1B534210	E-M 1st fix conduit/cabling 1st lvl 35-43/E-J	**-27**	**-21**	**-32**	**-36**	**-49**	**-57**	**-57**	**-50**	**-70**	-	-	-	-	-	-	-
C1B534310	E-M 1st fix duct/pipework 1st lvl 35-43/E-J	**-14**	**-21**	**-32**	**-36**	**-49**	**-50**	**-51**	**-50**	**-70**	-	-	-	-	-	-	-
C1B634210	Plaster walls/ceilings 1st lvl grid 35-43/E-J	**-27**	**-21**	**-32**	**-33**	**-14**	**-57**	**-57**	**-56**	**-70**	-	-	-	-	-	-	-
C1B730090	Final decoration to 1st lvl	**-27**	**-23**	**-40**	**-33**	**-14**	**-62**	**-57**	**-56**	**-70**	**-74**	**-85**	**-90**	**-90**	**-108**	**-120**	-
C1B731040	Terrazzo floor tiling 1st lvl grid 25-35/J-RA														**-108**		
C1B733056	Lath & plaster ceiling 1st lvl grid 35-46/J-RA	*	*	*	*	*	**-37**	**-43**	**-35**	**-48**	**-55**	**-105**	**710**	**-69**	**-108**	-	-
C1B710090	Final decoration to lower lvl grids 35-46/A-J	**-28**	**-9**	**-15**	**8**	**-8**	**-24**	**-24**	**-4**	**-22**	**-31**	**-81**	**-81**	**-90**	**-106**	**-121**	-
C1B715059	Fix acoustic ceiling lwr lvl	*	*	*	*	*	*	*	*	*	*	*	**-81**	**-74**	**-97**	**-121**	-
Concurrent Critical Path 2 - Control Tower																	
C11400017	Submit & obtain approval 1st shop drawings	**17**	**2**	**-64**	**-65**	**-73**	**-74**	-	-	-	-	-	-	-	-	-	-
C11400018	Manufacture & deliver 1st shipment to site	**17**	**2**	**-64**	**-65**	**-73**	**-74**	**-81**	**-81**	**-86**	**-50**	**-49**	**-75**	-	-	-	-
C1C4F0045	Fix curtain wall to control tower vcr lvl	*	*	*	*	*	**-31**	**-31**	**-31**	**-47**	**-49**	**-63**	**-74**	**-145**	**-167**	-	-
C1C560010	E-M 1st fix services installation to control	**10**	**3**	**-1**	**-6**	**-19**	**-27**	**-23**	**-30**	**-54**	**-51**	**-71**	**-95**	**-144**	**-167**	**-120**	-
C1C660020	Plaster control tower walls internally	**6**	**-1**	**-5**	**-10**	**-27**	**-26**	**-22**	**-14**	**-25**	**-45**	**-69**	**-71**	**-134**	**-167**	-	-
C1C860010	1st fix installation/cabling for tower equipment	**10**	**3**	**-1**	**-6**	**-19**	**-27**	**-23**	**-30**	**-54**	**-51**	**-71**	**-95**	**-144**	**-167**	-	-
C1C860050	Install/test & commission tower equipment	**0**	**-7**	**-11**	**-16**	**-27**	**-31**	**-31**	**-31**	**-59**	**-61**	**-71**	**-81**	**-145**	**-167**	**-118**	**-109**
C1C320200	Duct bank/cabling to temp control rm in w jetty	*	*	*	*	*	*	*	*	*	*	**-71**	**-73**	**-73**	**-144**	**-118**	**-123**
C1C900099	New control tower operational	**0**	**-7**	**-11**	**-16**	**-27**	**-31**	**-31**	**-31**	**-59**	**-61**	**-71**	**-81**	**-103**	**-119**	**-118**	**-123**
C1B729010	Reinstatement & Marking E Terminal Apron Area															**-97**	**-121**
C1C900100	Decommission existing conrol tower by others	*	*	*	*	*	*	*	*	*	*	**-71**	**-81**	**-103**	**-119**	**-118**	**-123**

Figure 6.5 Illustration of critical paths.

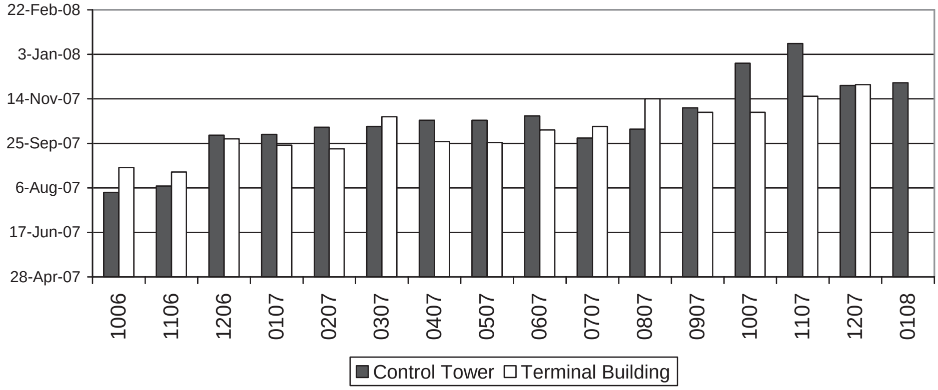


Figure 6.6 Calculated completion dates.

- it relies on readily available contemporaneous progress programmes;
- it recognises the dynamic nature of the critical path;
- it recognises changes in logic, activity durations and contractor's intentions;
- it allows identification of multiple critical paths;
- it is intuitive and easy to understand;
- conclusions are readily supported by contractor prepared as-built records;
- it can identify both loss and gains achieved between progress updates;
- it can demonstrate the actual impact of known delay events;
- it does not require any impacting, or collapsing, of the CPM programme, and is therefore not theoretical by nature;
- it can identify the concurrent effect of delays in the update period in which work was actually carried out; and
- it can identify critical delay in the update period in which work was actually carried out, and the period in which the costs were actually being incurred.

Taking the events agreed to as 'employer risk events' by the parties, we can now determine which were truly on the critical path, which contributed to critical delay, and which were simply concurrent events. Table 6.6 identifies the float loss, or gain, in each window, along with the employer risk events (A through M), which were aligned with the windows in which they occurred.

Each of the employer risk events can be allocated to either the Terminal Building, or the Control Tower. The duration of each was set out in Figure 6.4. The duration of each event can now be set against the amount of float lost in each respective window, to determine whether the employer risk events affected the critical path, and how much delay actually resulted when the impact of each employer risk event was being experienced. The following chart illustrates how these delays can simply be mapped against the as-built critical path, according to the activity each affected. This is illustrated in Figure 6.7.

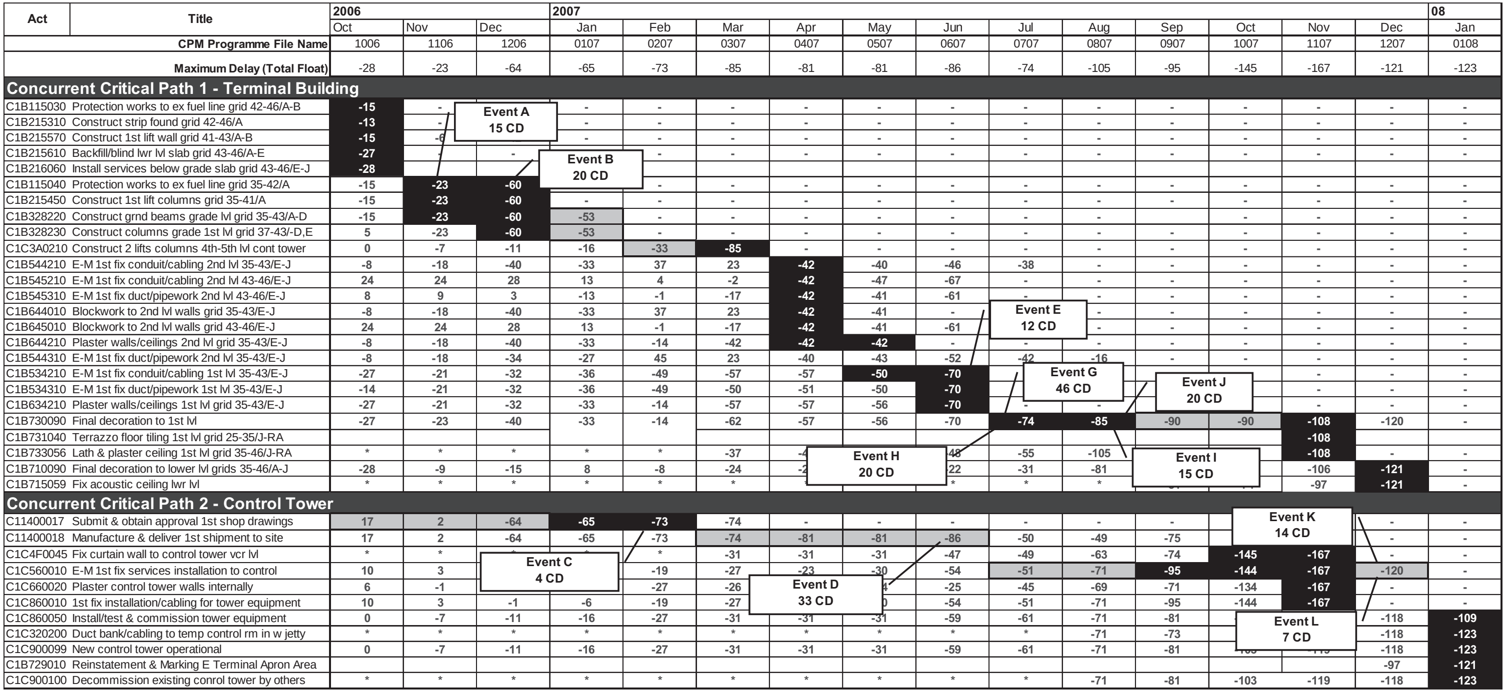
Table 6.6 Employer risk event table.

Programme File Name	Data Date	Projected Completion Date	Total Float	Float Loss/Gain in Window	Delays Pleaded in Window
1006	1-Oct-06	29-Aug-07	–28		
1106	1-Nov-06	24-Aug-07	–23	–5	
1206	1-Dec-06	30-Sep-07	–60	37	A
0107	1-Jan-07	5-Oct-07	–65	5	B
0207	1-Feb-07	13-Oct-07	–73	8	
0307	1-Mar-07	25-Oct-07	–85	12	
0407	1-Apr-07	12-Sep-07	–42	–43	C
0507	1-May-07	20-Sep-07	–50	8	
0607	1-Jun-07	10-Oct-07	–70	20	
0707	1-Jul-07	14-Oct-07	–74	4	D, E
0807	1-Aug-07	25-Oct-07	–85	11	F, G, H
0907	1-Sep-07	4-Nov-07	–95	10	I, J
1007	1-Oct-07	24-Dec-07	–145	50	
1107	1-Nov-07	15-Jan-08	–167	22	
1207	1-Dec-07	30-Nov-07	–121	–46	
0108	1-Jan-08	2-Dec-07	–123	2	K, L
As-Built	15-Jan-08	15-Jan-08	–167	44	M

The amount of delay attributable to an event can in some cases exceed the amount of delay actually measured by float loss in each period. This is due to the fact that progressed programmes contain sequencing, duration and logic alterations from month to month. Additionally, the impact of some employer risk events is measured over the course of more than one 30 day window.

By linking the events identified to the actual delay experienced, as measured by the float deterioration from month to month, the tribunal expert was able to summarise the results and compare the discrete as-built critical path delays to the results pleaded in the time impact analysis conclusions. The employer risk events which were deemed to be relevant could then be reviewed for concurrency and dominance with other delays, in windows in which more than one employer risk event was experienced. The duration of the employer risk events are tabulated below, along with the Critical Path (CP 1 or CP 2) which they potentially affected.

Where there were two delays in the same window, the larger of the two was considered relevant for calculating the contractor's entitlement in each window. In August 2007 there were two delay events that impacted on CP 1, the Terminal Building. Both of these events are excusable. Had one event been excusable, and the other non-excusable, arguments regarding concurrent delay would have been relevant. In our case study, the delay of 20 days was carried forward to the entitlement assessment, as it was determined to be the 'Maximum Delay Calculated in TIA', as summarised at the bottom of the table in Figure 6.8.



Act	Title	2006			2007												08
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
	CPM Programme File Name	1006	1106	1206	0107	0207	0307	0407	0507	0607	0707	0807	0907	1007	1107	1207	0108
	Maximum Delay (Total Float)	-28	-23	-64	-65	-73	-85	-81	-81	-86	-74	-105	-95	-145	-167	-121	-123
Concurrent Critical Path 1 - Terminal Building																	
C1B115030	Protection works to ex fuel line grid 42-46/A-B	-15	-		-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215310	Construct strip found grid 42-46/A	-13	-		-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215570	Construct 1st lift wall grid 41-43/A-B	-15			-	-	-	-	-	-	-	-	-	-	-	-	-
C1B215610	Backfill/blind lwr lvl slab grid 43-46/A-E	-27	-	-		-	-	-	-	-	-	-	-	-	-	-	-
C1B216060	Install services below grade slab grid 43-46/E-J	-28															
C1B115040	Protection works to ex fuel line grid 35-42/A	-15	-23	-60		-	-	-	-	-	-	-	-	-	-	-	-
C1B215450	Construct 1st lift columns grid 35-41/A	-15	-23	-60	-	-	-	-	-	-	-	-	-	-	-	-	-
C1B328220	Construct grnd beams grade lvl grid 35-43/A-D	-15	-23	-60	-53	-	-	-	-	-	-	-	-	-	-	-	-
C1B328230	Construct columns grade 1st lvl grid 37-43/-D,E	5	-23	-60	-53	-	-	-	-	-	-	-	-	-	-	-	-
C1C3A0210	Construct 2 lifts columns 4th-5th lvl cont tower	0	-7	-11	-16	-33	-85	-	-	-	-	-	-	-	-	-	-
C1B544210	E-M 1st fix conduit/cabling 2nd lvl 35-43/E-J	-8	-18	-40	-33	37	23	-42	-40	-46	-38	-	-	-	-	-	-
C1B545210	E-M 1st fix conduit/cabling 2nd lvl 43-46/E-J	24	24	28	13	4	-2	-42	-47	-67	-	-	-	-	-	-	-
C1B545310	E-M 1st fix duct/pipework 2nd lvl 43-46/E-J	8	9	3	-13	-1	-17	-42	-41	-61	-	-	-	-	-	-	-
C1B644010	Blockwork to 2nd lvl walls grid 35-43/E-J	-8	-18	-40	-33	37	23	-42	-41	-		-	-	-	-	-	-
C1B645010	Blockwork to 2nd lvl walls grid 43-46/E-J	24	24	28	13	-1	-17	-42	-41	-61		-	-	-	-	-	-
C1B644210	Plaster walls/ceilings 2nd lvl grid 35-43/E-J	-8	-18	-40	-33	-14	-42	-42	-42	-	-	-	-	-	-	-	-
C1B544310	E-M 1st fix duct/pipework 2nd lvl 35-43/E-J	-8	-18	-34	-27	45	23	-40	-43	-52	-42	-16	-	-	-	-	-
C1B534210	E-M 1st fix conduit/cabling 1st lvl 35-43/E-J	-27	-21	-32	-36	-49	-57	-57	-50	-70					-	-	-
C1B534310	E-M 1st fix duct/pipework 1st lvl 35-43/E-J	-14	-21	-32	-36	-49	-50	-51	-50	-70					-	-	-
C1B634210	Plaster walls/ceilings 1st lvl grid 35-43/E-J	-27	-21	-32	-33	-14	-57	-57	-56	-70	-	-			-	-	-
C1B730090	Final decoration to 1st lvl	-27	-23	-40	-33	-14	-62	-57	-56	-70	-74	-85	-90	-90	-108	-120	-
C1B731040	Terrazzo floor tiling 1st lvl grid 25-35/J-RA														-108		
C1B733056	Lath & plaster ceiling 1st lvl grid 35-46/J-RA	*	*	*	*	*	-37			-48	-55	-105			-108	-	-
C1B710090	Final decoration to lower lvl grids 35-46/A-J	-28	-9	-15	8	-8	-24				-31	-81			-106	-121	-
C1B715059	Fix acoustic ceiling lwr lvl	*	*	*	*	*	*			*	*	*			-97	-121	-
Concurrent Critical Path 2 - Control Tower																	
C11400017	Submit & obtain approval 1st shop drawings	17	2	-64	-65	-73	-74	-	-	-	-	-	-			-	-
C11400018	Manufacture & deliver 1st shipment to site	17	2	-64	-65	-73	-74	-81	-81	-86	-50	-49	-75			-	-
C1C4F0045	Fix curtain wall to control tower vcr lvl	*	*			*	-31	-31	-31	-47	-49	-63	-74	-145	-167	-	-
C1C560010	E-M 1st fix services installation to control	10	3			-19	-27	-23	-30	-54	-51	-71	-95	-144	-167	-120	-
C1C660020	Plaster control tower walls internally	6	-1			-27	-26			-25	-45	-69	-71	-134	-167	-	-
C1C860010	1st fix installation/cabling for tower equipment	10	3	-1	-6	-19	-27			-54	-51	-71	-95	-144	-167	-	-
C1C860050	Install/test & commission tower equipment	0	-7	-11	-16	-27	-31	-31	-31	-59	-61	-71	-81			-118	-109
C1C320200	Duct bank/cabling to temp control rm in w jetty	*	*	*	*	*	*	*	*	*	*	-71	-73			-118	-123
C1C900099	New control tower operational	0	-7	-11	-16	-27	-31	-31	-31	-59	-61	-71	-81			-118	-123
C1B729010	Reinstatement & Marking E Terminal Apron Area															-97	-121
C1C900100	Decommission existing conrol tower by others	*	*	*	*	*	*	*	*	*	*	-71	-81	-103	-119	-118	-123

Figure 6.7 Delays mapped against the as-built critical path.

Event Rev	**Description**		**2006**			**2007**												**08**
		CP	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
A	Additional services below slab	1		**15**														
B	Additional protection works to underground utilities	1			**20**													
C	Shop Drawing approval	2						**4**										
D	Revised columns to Control Tower	2									**33**							
E	Revised blockwork to Terminal Building	1									**12**							
F	Revised Curtain Walling to Term Building	n/a										10						
G	M&E revisions - 1st Fix 2nd Level Term Bldg	1										**46**						
H	M&E revisions - 1st Fix 1st Level Term Bldg	1										**20**						
I	M&E revisions - 1st Fix Grnd Level Term Bldg	1											**15**					
J	Terrazzo floor changes - Term Bldg	1											**20**					
K	Revised curtain walling to Control Tower	2															**14**	
L	Accoustic celing revision - Control Tower	2															**7**	
M	Revised retail layout - Term Bldg	n/a																24
	Maximum Delay Calculated in TIA	**152**	**0**	**15**	**20**	**0**	**0**	**4**	**0**	**0**	**33**	**46**	**20**	**0**	**0**	**0**	**14**	**24**
	Terminal Building Critical Delays	113		15	20						12	46	20					
	Control Tower Critical Delays	51						4			33						14	

Figure 6.8 Concurrent critical path employer risk event table.

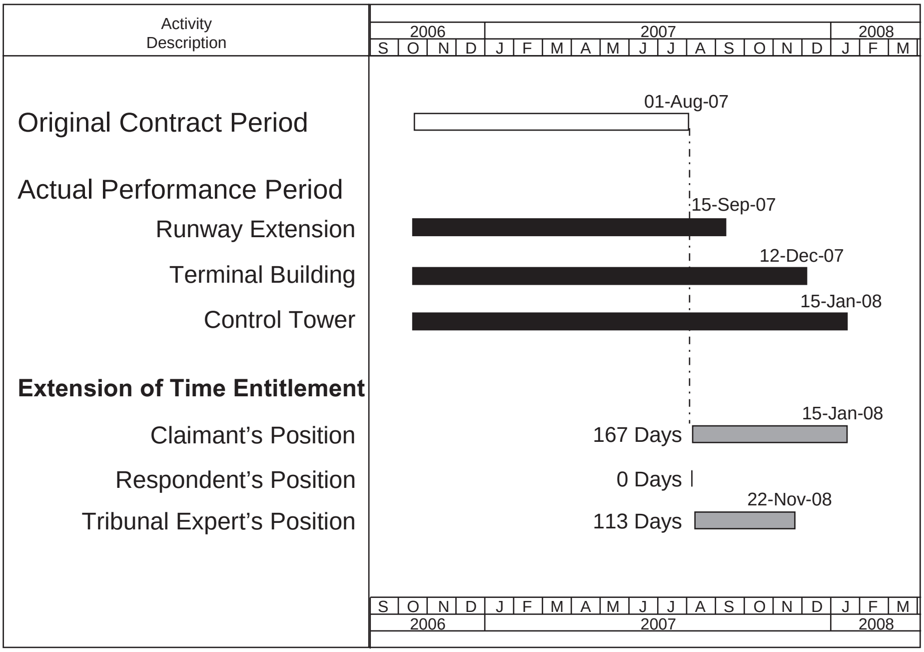


Figure 6.9 Tribunal expert analysis result.

The tribunal expert concluded that the contractor was entitled to either 113 days of excusable, compensable delay due to delays experienced along the Terminal Building Critical Path or, alternatively, 51 days of excusable, compensable delay along the Control Tower Critical Path (see Figure 6.9).

By keeping the impact of unrelated events separate, and quantifying their impact along discrete parallel critical paths, it was possible to arrive at an assessment that was both fair and reasonable which was also based solely on contemporaneous evidence and analyses relied on by the party appointed experts. This contemporaneous update windows analysis provided the arbitration tribunal with the key needed to link liability and causation and was relied upon in their award.

Ultimately, the tribunal relied on the as-built critical path when determining the final EOT award of 100 calendar days. While there were reductions to the amount of time awarded for certain events due to the underlying facts and available evidence, the tribunal expert's approach was citied as being helpful because it was '*based on, and in accordance with the facts of the case, and helpful in understanding the timeline of events, with a contemporaneous perspective*'.

6.4 Demonstrating acceleration

In the same case, there was both a claim for acceleration, and an allegation that the claimant failed to act on instructions to accelerate the work. The float maps were based on the contemporaneous programmes, which were themselves argued by the JV to have been accelerated from February 2007 onwards, with acceleration through additional resources and re-sequencing implemented each month. To assist in quantifying how much, if any, acceleration was actually achieved, the expert simply analysed the actual progress achieved in each window, against each activity (actual start, actual finish, % complete, etc.) and updated the non-accelerated logic in the January 2007 programme. This was the programme in place and being used to manage the works before attempting acceleration.

This technique is actually straight forward to carry out, owing to the functionality of most of today's high-end CPA network analysis software which allows for the transfer of progress data to and from various assigned 'target' and 'baseline' files. However, the process requires much skill and care, and the conclusions must be checked and confirmed manually. The results can be thrown off if any new activities were created in either the accelerated or unaltered logic programmes. For instance, if an activity was added as a new activity in the February 2007 programme update, it would not have existed in the January programme, and would therefore skew the resulting projected completion date. By importing progress into the January 2007 programme, and recalculating a projected completion date for each month in which the JV argued it had implemented acceleration, the amount of delay that would have been projected, absent of any attempted acceleration, is apparent.

The resulting completion date calculated from the progressed programmes with the original logic, as compared to the accelerated programmes with the same logic, is illustrated in Figure 6.10.

This analysis determined that the JV had achieved acceleration in eight consecutive months, (February 2007 through September 2007). The projected completion date from the programmes used by the JV contemporaneously (incorporating acceleration measures) is shown in solid black. The projected completion date which would have been calculated without the

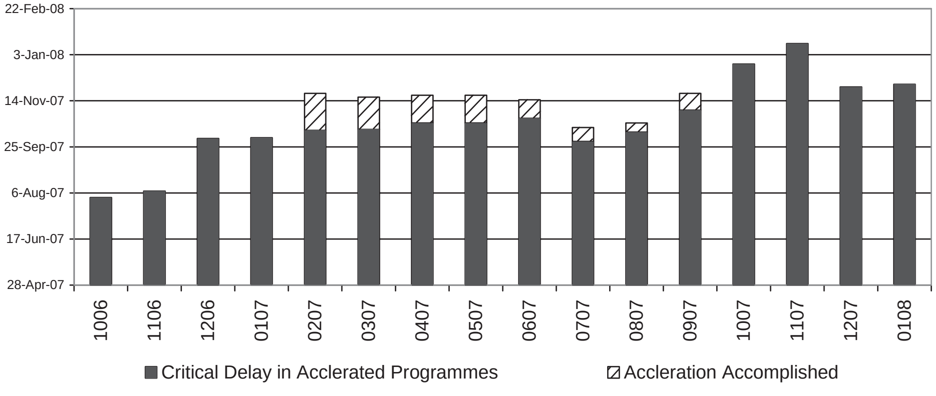


Figure 6.10 Calculated completion dates.

Activity	Predecessor	Rel	Lag	Description of Out of Sequence Progress
C1B357077	C1B357067	FS	0	started before its predecessor finished.
C1B451020	C1B403140	FS	12	started before its predecessor's lag would allow.
C1B512210	C1B516210	FF	0	started too early to allow it to finish on or after its predecessor's finish.
C1B513210	C1B516210	FF	0	started too early to allow it to finish on or after its predecessor's finish.
C1B513211	C1B516210	FF	0	started too early to allow it to finish on or after its predecessor's finish.
C1B516210	C1B516310	FF	0	started too early to allow it to finish on or after its predecessor's finish.
C1B536210	C1B636010	FF	12	started too early to allow it to finish after the expiration of its predecessor's lag.
C1B536310	C1B636010	FF	12	started too early to allow it to finish after the expiration of its predecessor's lag.
C1B544210	C1B644010	FF	6	started too early to allow it to finish after the expiration of its predecessor's lag.
C1B544310	C1B644010	FF	10	started too early to allow it to finish after the expiration of its predecessor's lag.

Figure 6.11 Progress reports output.

attempted acceleration is demonstrated by the hatched area in Figure 6.10, as demonstrated by the JV contemporaneous programmes. The amount of achieved acceleration is equal to the difference between the programmes with unaltered logic and accelerated programmes when the same amount of progress is inserted into both programmes.

When the actual progress and sequence was compared with the planned sequence of works, it was apparent that the JV attempted acceleration by working out of sequence, advancing certain works in advance of their natural sequence as originally planned. This is demonstrated by 'out of sequence' progress reports, such as the one listed in Figure 6.11.

In addition to supporting cost data that indicated an increase in supervision, labour, plant and temporary work costs, this analysis indicated that the claimant was attempting to accelerate, by working out of sequence, increasing outputs, and reducing activity durations. While there are many forms of acceleration this analysis demonstrated that acceleration was in fact being attempted, and in some cases achieved. Due to the fact that the claimant was awarded less than a full extension of time, it was determined that the costs of acceleration were to be apportioned, in proportion with the claimant's and respondent's respective liabilities for time and prolongation costs, as determined from the as-built critical path analysis.

6.5 Presentation skills – demonstrative evidence

The presentation of delay claims is always challenging, for a number of reasons (many of which are true for any construction case). Delay claims often rely on specialist terminology and require the review and consideration of multiple documents including, e.g. contracts, job meeting minutes, specifications, drawings, shop drawings, change orders, notices and job correspondence. Such a plethora of documents can cause confusion if those that are to be relied upon are not presented succinctly and with clarity. Moreover, delay claims often require expert testimony to establish and/or pull together essential facts, and such testimony, even when technically competent, can be nearly incomprehensible if not carefully honed and presented. The use of demonstrative exhibits and graphics during all forms of dispute resolution is commonplace to overcome some of these obstacles.

It is well established that people are, largely, visual learners. They usually understand and retain information at a much higher rate when it is presented to them visually. A pure oral presentation of material would, to a large degree, be lost on an audience (including tribunals and courts). In support of this statement are studies in the US which have shown that jurors retain as little as 10% to 20% of the material presented to them orally.[4] It has also been found that jurors retain as much as 65% to 80%[5] of material presented to them visually or with visual supplements. The effect of using high-impact, demonstrative evidence assists greatly in the success of a case which includes complex technical issues. The focus of the demonstrative evidence in delay cases will often be in assisting the tribunal to develop an understanding of an overall project chronology in order to allow events being relied upon to be heard with respect to a universal project timeline. Timeline and chronology exhibits must be objective, factual and should not be prejudicial by underlining, highlighting or emphasising dates or events. It is necessary that the timeline be visually appealing, easy to follow, and big enough to include the entire period of time on one board or sheet. An expert must carefully plan the level of detail included in a timeline or chronology exhibit to ensure that it does not become cluttered with technical detail, jargon, text boxes, arrows, bars or dates. The expert should also make sure that these exhibits do not overuse colours, which could result in them becoming confusing, complex or unsightly in appearance.

Construction delay claims will also require the review and consideration of a significant number of project documents, including contract documents, specifications, tender information, compensation events, correspondence, e-mails, transmittals, drawings and relevant job meeting minutes. The most effective use of documents is to have a document or a page of a document 'blown up' into a much larger image, which is then pasted onto a foam board or displayed electronically to the fact finder so key elements can be identified which are relevant to the party's submissions. However, the overuse of this technique may result in the tribunal becoming bored or confused as to which documents were more relevant than others. It is possible to use a 'call-out box' on each document (an enlargement of certain text on the document) which is usually accentuated with highlighting or other graphics. Documents can be accentuated, while the 'timeline' described above should not be. This allows the tribunal to find important or relevant language quickly, while evidence is being presented during a hearing.

It is important to consider your audience. For example, how a particular adjudicator, arbitrator or judge might likely respond to the introduction of

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[4] John Selbak, 'The Prejudicial Effects of Computer-Generated Animation in the Courtroom', *Berkeley Technology Law Journal* 338, 352 (Fall 1994).

[5] Mary Quinn Cooper, 'Practitioner's Guide – The Use of Demonstrative Exhibits at Trial', *Tulsa Law Journal* 567, 568 (1999).

Figure 6.12 Power station project.

demonstrative evidence. There are different reasons to introduce or rely on demonstrative evidence. For example, on a nuclear power plant project one of the key elements of the case was to demonstrate the impact of installing large mechanical and electrical equipment in confined spaces at the same time as large scale civil engineering work was being carried out, the latter out of sequence (Figure 6.12).

At one point in the proceedings it was deemed that the arbitrator’s health would not allow him to be exposed to the low levels of radiation that were likely during a site tour of the operating plant. Therefore, a 3-D computer model of the facility was created, and that model projected through time, to demonstrate, side by side, the planned sequence and timing of the works as compared to the actual sequence and timing of the work (a ‘time-phased 3-D model’) (Figure 6.13).

While 4-D models are becoming more accessible, easier to prepare, and more common for both pre-planning and forensic analysis, other common forms of presenting demonstrative evidence include:

- charts and graphs (see Chapter 3, Section 3.4.4 for examples);
- CPM programmes and extracts;
- document blow-ups/call-outs;
- scale diagrams and models; and
- animations.

A computer animation is produced by linking a series of images, each of which is technically accurate, to show progress or events over time. Animations fall into two categories, demonstration and reconstruction.

Demonstration

This is usually designed to show how some physical principle or process works. A ‘demonstration’ animation could be produced to show an overview of a process plant, labelling all components or structures for identification.

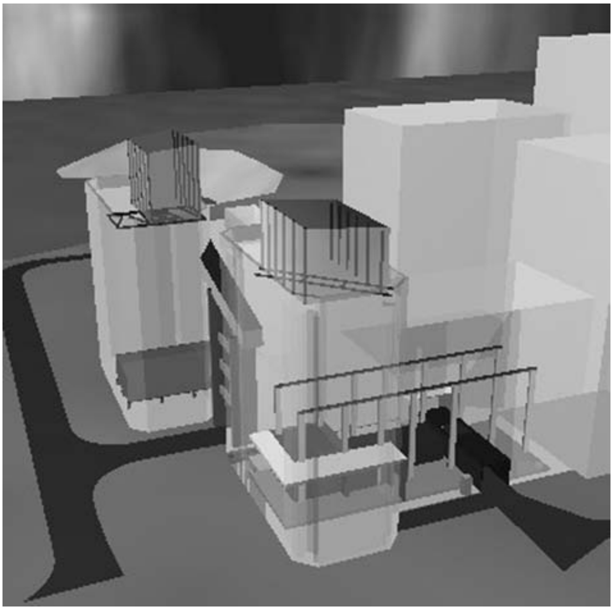

Figure 6.13 CAD model of the power station.

Next, the animation would zoom in on each piece of equipment, showing how it works by following the animated flow of the product through the entire process. Alternatively, the demonstration could illustrate how structural steel is fabricated, assembled or erected to explain a planned method that was intended. This type of animation does not show or indicate the party's position in the case. It is a tutorial aimed at educating the tribunal as to how a plant works, a process is carried out or how several components of a building relate to one another. This will assist them to later understand the opinion or evidence of an expert. For example, Figure 6.14 is an illustration that demonstrates why a gas main needed to be diverted when additional mini-bored piles were added to a facility.

The gas mains prior location and new location can be seen in relation to the existing foundations and proposed 're-designed bored-piles'. This image, and others like it, could save valuable time in a hearing.

Reconstruction

A reconstruction illustrates how events actually occurred sequentially, and is possibly the most complicated and controversial type of animation. While this type of evidence may simply represent, for example, an as-planned versus as-built sequence, they are usually relied upon to depict one expert's theory of what happened in a case. This type of animation could permit experts to give their theory of what happened, while a tribunal watched the story visually unfold in front of them.

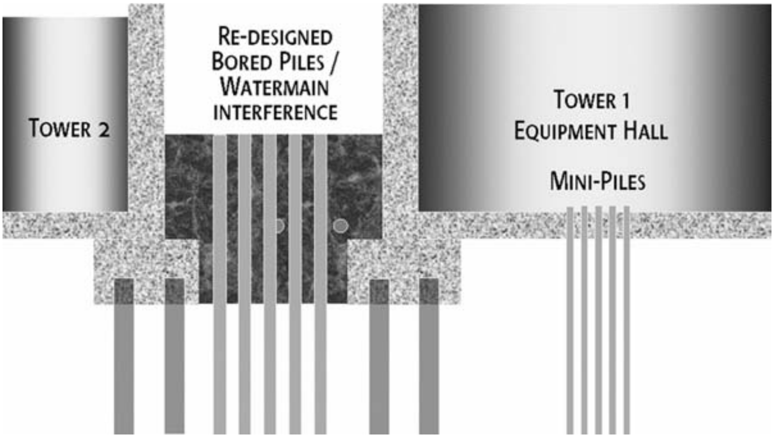

Figure 6.14 Illustration of relocated gas main.

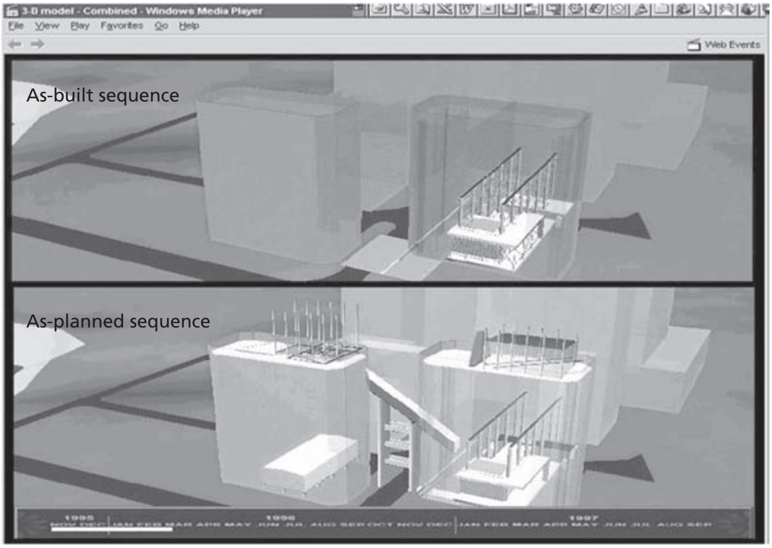

Figure 6.15 Animated model.

Again in the power project referred to previously, it was considered necessary to prepare a 4-D model (3-D time scaled animation) to demonstrate at various points in time how far in advance the civil engineering works should have been progressed in order to allow mechanical work to follow on.

Figure 6.15 indicates that a link bridge and control rooms in both 'halls' should have been available at this time (bottom image). The image on top indicates how late civil engineering works actually were at that stage in the project. The 3-D image, or 4-D model, must be consistent with the theme of the case being presented. However, it is important that the 'story' and illustrations do not stray from the available factual matrix. One should avoid adding elements to an illustration, based on assumptions, merely to complete the story-line which a judge, arbitrator or panel will be asked to draw a conclusion from. Demonstrations and illustrations should be factual, and should not skew or spin the available facts. There is a warning, however. Such demonstrations and illustrations are meant to be illustrative and helpful in understanding what actually happened, and can therefore often assist in explaining both sides of the story. They can sometimes be used just as effectively by the opposing side's experts.

In order to use a reconstructive animation in court, several pieces of information must be disclosed or exchanged with the legal representatives of the opposing party:

- identity of both the expert who created the animation and the expert who will testify as to the accuracy of the information depicted in the animation;
- identity of the hardware and software used to construct the animation;
- documents and other sources of data included in the animation; and
- computer data files that make up the completed animation.

Computer animations are time consuming to create, but also time consuming to rebuff. It should be noted that sufficient pre-trial disclosure is required for opposing counsel to have a fair chance to review the above-mentioned documentation and understand the basis of the animation.

Weather

A common feature of construction activity is delay caused by inclement weather. Demonstrating that weather was, or was not, 'exceptionally adverse' (or whatever test or threshold is set out in a particular form of contract) usually requires the presentation of complex data (e.g. wind, rain, temperature, humidity, or tidal flows). Presenting this data using simple charts, such as that provided in Figure 6.16, can assist in conveying which months or time periods exceeded the thresholds set, and thus support a claim for time extension entitlement.

6.5.1 Summary

The foundation for any demonstrative exhibit, computer animation or document call-out is specific to the exhibit. The foundation for a high impact 'demonstration' type animation must be supplied by the expert who can testify that

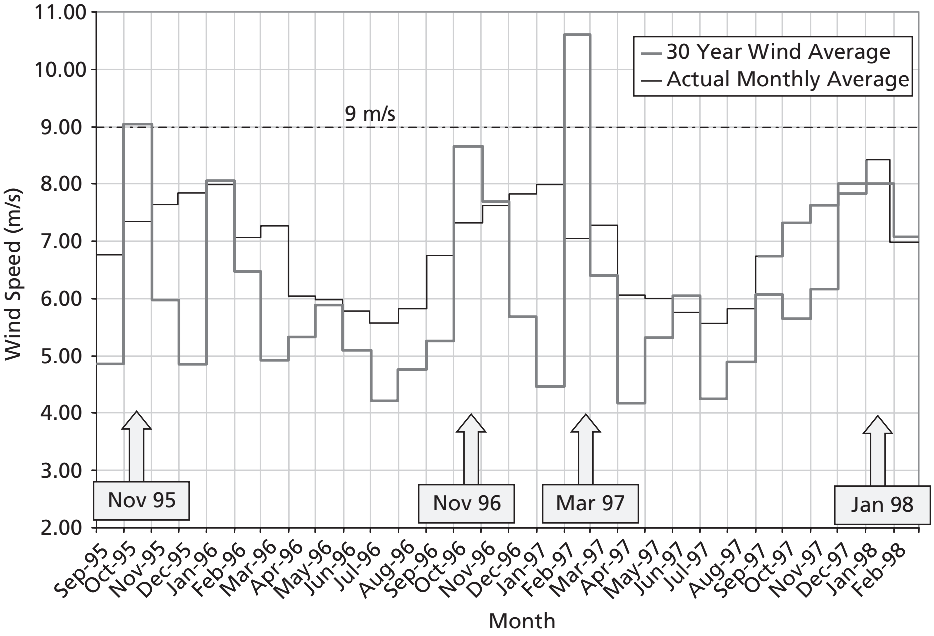

Figure 6.16 Weather depiction chart.

it is a fair and accurate representation of the operation, sequence, system, or relevant laws of physics at issue. An animation that is a ‘reconstruction’will need evidence from both the expert whose opinion is being animated and the producer of the animation to lay a proper foundation.

Whether a case would benefit from the use of 3-D/4-D modelling, animations, boards or charts, will depend on a number of factors and must also be considered in line with the size and nature of the case. Proportionality in terms of cost is a major factor which can also dictate the level of sophistication that may apply to any exhibit. A stepped approach could be applied depending on the stage in the claim cycle the case is at, e.g. early commercial negotiations, more formal adjudication or to support expert witness evidence in arbitration or court.

Appendix: Contractors Programme Submittals

Description

This section describes the requirements for the preparation, submittal, update and revision of the *Contractor's* Critical Path Method (CPM) Programme (in accordance with ECC 2nd Edn form).

Contractor's Work-plan

Within fourteen (14) calendar days after the *starting date* of the Contract, the *Contractor* will submit a Work-plan describing in detail the *Contractor's* approach and methods for undertaking work in accordance with the time constraints. This will consist of an interim CPM Programme with cost and man-hour loading to encompass the first one hundred and twenty (120) calendar days of work after the starting date.

Within thirty (30) calendar days, the *Contractor* will submit a complete cost loaded and man-hour loaded CPM Programme. This will include all milestone completion dates and all major critical paths and their respective activity constraints.

All programme submittals are subject to review and acceptance by the *Project Manager*. The *Project Manager* may withhold one quarter of the progress payments until the *Contractor* submits for acceptance a complete CPM Programme, in accordance with the requirements of Clause 31.2 of the conditions, to the *Project Manager*.

A progress review and update of the CPM Programme will be submitted with each monthly progress payment.

All CPM Programmes will be produced in the required software scheduling system.

Network reports shall include activity sorts by Work Breakdown Structure (WBS), Work Package, Cost Breakdown Structure (CBS) and critical path.

The designated standard for planning software shall be Primavera Project Planner or equal, subject to agreement with the *Project Manager*.

A three (3) week Look-Ahead Programme will be submitted and tabled at the weekly programming meeting. This submission shall include a two (2) week Look-Ahead Programme and reflect actual status of the work performed during the preceding week.

Preparation guidelines

The CPM Programme shall represent a practical plan to complete the work within the Contract time.

A programme showing the work completed in less than the Contract time may be found by the *Project Manager* to be impractical. A programme found to be unreasonable for the preceding reason or any other reason shall be revised by the *Contractor* and resubmitted.

A programme showing the work completed in less time than the Contract time, which is found to be practical by the *Project Manager*, shall be considered to have float. Float is the time between the scheduled completion of the work and the Contract completion date. Float is a resource available to both the *Project Manager* and the *Contractor*.

The *Contractor's* Programme shall take into account those weather conditions which are normally anticipated. Figures for rainfall, mists, wind speeds must be taken into account. The Contract time has been defined assuming these normal weather variances for the local area and will be based on at least a ten year average. The *Contractor* will provide copies of this data and the summation of the assumed number of adverse weather days per months to the *Project Manager* with the CPM programme.

No more than fifty percent (50%) of the activities shall be critical or near critical, subject to the *Project Manager's* approval. Near critical is defined as float in the range of one (1) to fourteen (14) days.

The CPM Programme shall clearly show the sequence and interdependence of submittals, material procurement and construction activities and shall specifically include:

1. The start and completion of all items of work, their major components and interim Contract completion dates, if any.
2. A programme of all submittals and material procurement activities, including:
   - Time for submittals, resubmittals and reviews.
   - Time for fabrication and delivery of manufactured products for the work.
   - The interdependence of procurement and construction activities.
3. Activities for maintaining Project Record Documents such as 'As-Built' drawings.

The CPM Programme shall:

- Be in sufficient detail to assure adequate planning and execution of the work. Activities should generally range in duration from one (1) to thirty (30) calendar days each.
- Be suitable, in the judgement of the *Project Manager*, to allow monitoring and evaluation of progress in their performance of the *work*.
- Be calendar time-scaled in the form of a precedence network (PDM).

The activities shall include:

- Description; what is to be accomplished and where.
- Responsibility code; identifies who performs the activity.

- The monetary value of each activity on the Programme for cash flow and payment purposes (cost loading), the total of activity costs shall equal the Contract amount and be in conformance with the activity schedule and current cost plan forecast.
- The number of man-hours that workers will be assigned to work on each activity.

The network shall:

- Show continuous flow from left to right.
- Identify days of work per week and shifts per working day.
- Include time for the *Project Manager* to review submittals or inspect the work.
- Identify the activities which constitute the controlling operations or critical path.

All programme submittals shall include one CD-Rom containing the programme, along with two (2) copies of the CPM reports and bar-charts. Costs for preparation of programme submittals will be borne by the *Contractor*. Submittal of the CPM Programme shall be understood to be the *Contractor's* representation that:

- The Programme meets the requirements of the Contract and that the work will be executed in the sequence indicated in the Programme.
- The *Contractor* has distributed the Progress Programme to Subcontractors for review and acceptance.

Review update and revisions

The *Project Manager* will review and return the *Contractor's* Programme with comments within the *period for reply*. After review by the *Project Manager*, the *Contractor* will accept, or promptly reject in writing, within the *period for reply* all comments to the Programme made by the *Project Manager*, and resubmit for final acceptance.

In conformance with a regular timetable of meetings, or as deemed necessary by the *Project Manager*, the *Contractor* will participate in a programme review with the *Project Manager*.

Any change in the work, planned restraints, logic, sequence or timing of work shall be submitted in a written revision to the impacted portion of the CPM Programme by the *Contractor* for the *Project Manager's* approval. Upon approval, the *Contractor* shall revise the computerised CPM accordingly.

Programming of approved changes is the responsibility of the *Contractor*. The *Contractor* shall revise the Programme to incorporate all activities involved in completing the changes in the work and submit it to the *Project Manager* for review and approval. The *Contractor* shall provide a separate fragnet for each change indicating the revised activity, whether the change is concurrent or sequential, the duration of the change and the restraints with his pricing of the change. Failure to request time and/or failure to provide the fragnet will result in the *Contractor* waiving his right for additional time.

If the *Project Manager* finds the *Contractor* is entitled to an extension of any completion date under the provisions of the Contract, the *Project Manager's* determination of the total number of days extension will be based on the current analysis of the programme and upon the date relevant to the extension.

The *Contractor* acknowledges and agrees that delays to non-critical activities will not be the basis for time extensions unless such delays cause those activities to become critical. Float is defined as the difference between the early and late start dates of an activity where the calculation of start dates is based on an unrestrained calculation of the predicted programme early completion date.

If the current CPM programme projects that estimated completion is thirty (30) calendar days or more behind the Completion Date, considering all time extensions, the *Contractor* shall submit a revised programme in accordance with the requirements of Clause 31.2 of the contract conditions prior to the subsequent *assessment date*. The *Project Manager* may withhold up to 25% of the Amount Due until a revised programme is submitted by the *Contractor* in accordance with the requirements of Clause 31.2 of this agreement.

Table of Cases

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Glossary

The nature of planning and programming, together with the practice of delay analysis, has thrown up a mini vocabulary of its own. The following is a brief listing and explanation of some of the more frequently used words or phrases.

Acceleration: The execution of a given scope of work in less time than anticipated or the carrying out of an increased scope of work within the originally anticipated duration.

Activity float (time risk allowance): Also known as time risk allowance, activity float is the amount of time included within an activity duration which is greater than the actual time needed to carry out that activity.

Activity-on-arrow (AOA) diagramming technique: A technique of illustrating a critical path network in which the arrows symbolise the activities. Also known as arrow diagramming method (ADM).

Activity-on-node (AON) diagramming technique: A technique of illustrating a critical path network in which the nodes symbolise the activities. Also known as a precedence diagramming method (PDM).

Actual cost of work performed (ACWP): Used in Earned Value Management systems, ACWP represents the cumulative actual cost of work performed on a project at any given point in time.

Additive modelling: Delay analysis techniques applied prospectively when the full extent of a delay is not yet known and delays to the completion must be projected. These rely on either the as-planned CPM logic, or the contemporaneous CPM logic in a recently updated, submitted and/or approved CPM programme. When using additive modelling techniques for delay analysis, the 'Cause' is known but the 'Effect' must be estimated, or projected. The time impact analysis and impacted as-planned methods are additive techniques.

As-built programme: A graphical or tabular record of the actual progress of a construction project, documenting, at a minimum, the start and end dates of every activity that actually took place. As-built programmes should also indicate periods of inactivity for each activity. As-built programmes vary in level of detail and content.

As-planned programme: Programme representing a contractor's intentions for carrying out the work prior to commencing any work represented on that programme. Also known as baseline programme.

Backward pass: In critical path method (CPM) programmes, it is the procedure whereby the latest event times (start or finish) for each activity in a network are determined.

Bar chart: A chart on which activities and their durations are represented by lines drawn to a common time scale; also known as Gantt chart.

Base programme: A programme representing a contractor's planned intentions, or actual performance, prior to measuring the impact of either an Employer Risk Event, or Contractor Risk Event. Delay analysis techniques which rely on single base programmes measure the impact of several events by reference to the same base. Delay analysis techniques which rely on multiple-base programmes measure the impact of events by reference to more than one base programme throughout the course of the project.

Branching logic: Used in probabilistic networking techniques, it is a form of conditional logic which indicates potential alternative logical relationships between two activities on a network.

Cascade diagram: A bar chart which illustrates the activities on a network sorted in ascending order by either start or finish event dates. Each subsequent activity on the cascade is usually dependent on a preceding activity in the same cascade.

Collapsed as-built: A method of delay analysis whereby the impact of either Employer Risk Events (ERE) and/or Contractor Risk Events (CRE) are 'subtracted' from an as-built programme to determine when the project would have been completed, 'but for' the events which are collapsed out of the network.

Compensable delay event: A delay event which is both excusable (excuses the party from damages) and which entitles the party to recovery of financial damages experienced as a direct consequence of that event.

Concurrency: The occurrence of two or more delay events at the same time, one an Employer Risk Event, the other a Contractor Risk Event. When the effects of both events have a direct impact on the completion date and are experienced at the same time, this is a 'concurrent delay.' When two 'concurrent delays' arise at different times, but the effects of those events are felt (in whole or in part) at the same time this is also known as 'concurrent effect'.

Constructive acceleration: Acceleration which is required when excusable delay events are experienced but no corresponding EOT is recognised by an employer, requiring a contractor to complete the works and any additional scope in the originally anticipated time for completion. Constructive acceleration can occur when an employer denies a valid EOT claim, or awards insufficient time for a valid EOT claim.

Contract completion date: The contractually specified date for completion.

Contractor risk event: An event which is at the Contractor's Risk under the contract. Caused by a Contractor Risk. When a delay results from a CRE, this is known as a Contractor Delay Event.

Cost performance index (CPI): A measure of relative financial performance of a project which is expressed as a percentage or ratio of actual cost experienced to the budget allowance for the same scope of work.

Cost variance: Any difference (positive or negative) between the actual expenditure against a project or element, and the planned/budgeted expenditure allowed for the same project or element.

Critical delay: A delay which has caused (or which can be shown to be likely to cause) a delay to either the contract completion date or the planned completion date.

Critical path: The sequence of activities through a critical path method (CPM) network from its start to its finish. In any given CPM network, there may be more than one critical path or parallel critical paths at any given time along the programme's time-line. Any delay to progress of an activity on a critical path will, without acceleration or re-sequencing, cause the overall project duration to be extended, and is by definition a 'critical delay'. The critical path changes from time to time, and whether a delay is a critical delay, depends on whether the activity in question was critical at the time the delay event occurred.

Critical path method (CPM)/network analysis: A method used for calculating a project's critical path, activity event times and float values.

Critical path analysis (CPA): A method of determining the critical path through a network. When networked programmes are not provided, it requires a process of deduction to determine the critical activities in a programme by tracing the logical sequence of tasks that directly affect the date of project completion. When fully networked programmes are utilised, the critical path is determined by way of CPM calculations (forward and backward pass) to determine early and late event times, and the total float available to each activity. It is a methodology or management technique that determines a project's critical path.

Culpable delay: A delay caused by an event which is the result of action or inaction by a contractor or otherwise at the contractor's risk under the contract.

Delay event: An event which results in delay to either a sequence of activities or to completion. Delay events are critical delays if they prolong the critical path to completion.

Dependency: Logical links between two immediately succeeding activities in a network to one another. Dependencies define the precedence in which the activities must be carried out. Also referred to as relationships, these can be defined as 'SS-Start to Start', 'SF-Start to Finish', 'FF-Finish to Finish', or the most common form, 'FS-Finish to Start'.

Deterministic network: Method of programming whereby each activity has a single fixed duration resulting in a programme and with an equally fixed duration (as opposed to probabilistic network which provides a range of possible activity durations and projected completion dates).

Disruption: An interruption to a sequence or flow of tasks which prevents them from achieving a planned rate of progress.

Duration: The amount of time required to perform a given activity in a network. In critical path method programming, the duration is used to determine the early and late event dates of a task by way of the 'forward' and 'backward' pass.

Early event dates: The earliest date, by which an activity can occur, determined by the forward pass. Early event dates include the Early Start Dates and Early Finish Dates.

Earned value management (EVM): A method of measuring the financial and time performance of an activity or project, requiring Actual and Budget Costs as well as a logically linked and updated CPM programme which is cost loaded with original budgets to determine both the Budgeted Cost of Work Scheduled (BCWS) and the Budgeted Cost of Work Performed (BCWP) from time to time. The BCWP is also known as the 'earned value' and assists in determining if a project is ahead, on, or behind plan, and over, under or on-budget.

Employer delay event (EDE): A delay resulting from an Employer Risk Event (ERE).

Employer risk event (ERE): An event which occurs and which is an obligation, liability or otherwise at the risk of the employer under the contract.

Excusable delay: An event which entitles a contractor to additional time, but not necessarily additional money under the contract.

Float: The amount of time available to an activity in addition to its planned duration. Total Float is the most common form of float referenced and frequently discussed in forensic delay analysis.

Free float: The amount of time which an activity can be delayed beyond its early event dates without causing delay to the early event dates of its successor activities.

Gantt chart: A time phased representation of tasks and their respective durations start and finish dates. Also known as a Bar chart – named after the originator, Henry Gantt.

Global claim: A claim which determines compensation for more than one Employer Risk Event but does not identify or demonstrate a discrete causal link between the loss claimed as a direct result of each discrete Employer Risk Event relied upon.

Impact: The measurable effect of either an ERE or a CRE on the date upon which an activity in a network is planned to be carried out. Impacts can be positive or negative and are usually measured by reference to a base programme which existed prior to the occurrence of the event.

Lag: The minimum necessary amount of time between the finish (or start) of one activity prior to the finish (or start) of a succeeding activity in a network. It may be a positive or negative number. Lag times are defined by reference to the type or relationship being utilised (SS, SF, FF or FS) and are defined from the perspective of a preceding activity's logic to one of its successor.

Late event dates: Latest date by which an activity must occur as determined by the 'backward pass'. Late event dates include Late Start and Late Finish dates.

Lead: *See 'Lag' above*. From the perspective of a successor activity, the 'lag' in a relationship to a preceding activity is referred to as the 'lead'.

Liquidated and ascertained damages (LADs); liquidated damages (LDs): A pre-agreed rate of damages to be paid to an employer for delays to completion experienced due to non-excusable delays. Usually expressed as a fixed rate, daily or weekly, but can vary according to a pre-agreed schedule of damages. LADs/LDs can apply to both sectional and final completion dates.

Method statement: A document describing a contractor's intentions for the means and methods to be employed when carrying out the works, setting out temporary works to be used, assumptions underlying the programme logic and driving resources upon which the task is dependent.

Milestone: An event date signifying the commencement, interface or completion of a significant task or contractually identified scope of work.

Mitigation: Reducing the severity or extent of delay or disruption anticipated due to an event, changed condition or factor, regardless of whether caused by an Employer or Contractor Risk Event.

Must start/must finish constraint: A type of constraint date imposed on an activity which requires it to be commenced or finished on a determined date. These constraints over-ride logic in the programme and interfere with natural float and event date calculations.

Negative float: A measure of how far behind programme a task or sequence of activities are from time to time. When float is negative, the 'earliest' it can start is later than the 'latest' date which it must start so as not to cause delay (*see total float*).

Non-compensable event: An event which does not provide relief to a contractor in the form of additional compensation for delay or disruption.

Non-excusable delay: An event which does not provide relief to a contractor in the form of additional time for completion or additional compensation for delay or disruption. Non-excusable events are those caused by contractor risk events.

PERT: Acronym for Project Evaluation and Review Technique. PERT is a probabilistic programming technique which is similar to critical path method analysis, but whereby the probability of completing the project by the contract completion date is determined and monitored by way of a quantified risk assessment based on optimistic, pessimistic and most likely activity durations for each task in the network.

Planned completion date: This is the date when a contractor plans to complete the works in accordance with the contract, as supported by a contractually compliant or accepted programme.

Practical completion: The date which is achieved when all required contractual obligations have been met, subject only to very minor items of work left incomplete (e.g. 'de minimus') or those included in the warranty. Substantial completion may or may not include commissioning, and should be defined in each particular contract. Substantial completion is usually the date when the obligation to insure and control a facility passes from a contractor to an employer and the date from which the defects liability period commences.

Precedence diagram: A critical path method network utilising the activity-on-node diagramming technique.

Probabilistic network: A critical path method network containing several alternative paths to completion depending on the frequency of the occurrence of one of three durations for each task (optimistic, pessimistic, or most likely) based on probabilities allocated to each task.

Programme: A network of activities required to complete a phase, project or group of projects indicating the sequence, timing and dependencies of each activity on the other activities in the network. Also known as the schedule.

Project control cycle: The process of communicating the plan, monitoring actual progress and measuring actual performance against the plan. The control cycle also involves the identification and implementation of corrective measures or modified plans, as necessary, to account for or react to changes or deviations from the plan.

Project management: The process of planning, monitoring and control of all aspects of a project and the effort of managing, communicating, directing and motivating the parties involved in the project to achieve the project objectives on time and to the specified cost, quality and performance requirements.

Prolongation: The time related costs that are experienced due to the extended duration of the works as a result of a delay or delay events.

Resource: An expendable commodity required for the completion of an activity, e.g. finance and labour.

Resource levelling: The process of amending activities' start and finish dates, within their available float, in an attempt to 'smooth' the resource usage on a given project. Resource levelling reduces the peaks and troughs in resource utilisation.

Schedule: *See programme.*

Schedule performance index: A measure of relative schedule performance of a project which is expressed as a percentage or ratio of budgeted cost (allowance) for work performed (BCWP) to the budgeted cost (allowance) for work scheduled (BCWS).

Slack: *See float.*

Stakeholder: A person, group, public or private body who have a vested interest in the success of an organisation, the outcome of a project or the effect that the project has on the environment in which it is being carried out.

Sub-network: A small group of activities, logically linked, used to illustrate a particular scope of work, added, revised or being considered for insertion into the programme (also referred to as Frag-net).

Subtractive modelling: Methods of delay analysis which are dependent on the removal (subtraction) of events from an as-built programme which reflects the actual sequences and durations in which the project was completed. Subtractive modelling techniques include the Collapsed As-Built method used for determining when a project would have been achieved 'but for' the event or sequence of events being analysed.

Total float: The amount of time available to an activity in addition to its planned duration. Total float is the most common form of float frequently referenced and discussed in forensic delay analysis. Total float is measured as the difference between an activity's early and late dates.

Updated programme: A version of the baseline programme which has been amended to reflect actual progress achieved from time to time, along with any revisions to planned durations and the sequence for completing the remaining scope of work. The final updated programme should depict an as-built programme. It is also referred to as a ‘progressed programme’.

Work breakdown structure (WBS): A hierarchical dictionary which defines every element of the complete project and cross refers these elements to their respective task (activity) and value (budget and actual). The hierarchy of the WBS is described as levels. These levels allow for the summary reporting of cost and programme status from time to time (*see earned value*).

Works: The scope of work required to be carried out as defined in the contract.

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