Developing a Comprehensive Construction Delay Analysis Technique

By

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ABSTRACT

The need to minimise potential disputes regarding construction project delays has resulted in the use of numerous delay analysis techniques to apportion parties' responsibilities concerning the time and cost overruns. While existing techniques have long been relied upon to address delay claims; none is capable of thoroughly and satisfactorily addressing matters of contention to help bring about the amicable settlement of claims and, hence, to minimise the chances of claims degenerating into expensive disputes. This study critically aims to develop a robust and comprehensive technique for helping to resolve to delay claims more equitable without creating difficulties or conflicts amongst contracting parties.

The first part of this research presents a comprehensive review of the rationale underpinning construction delay claims, which include: recognising the construction delay claims; analysing the types of schedule impacts; classifying the effects of the schedule impacts. It also includes the discussions of current delay analysis processes in use, current delays analysis issues and current delays analysis techniques. The discussions include the limitations and capabilities of delay analysis techniques for tackling all the delay analysis issues in delay claims. The second part of the research discusses research methodologies for adopting a qualitative method in this study. It includes a survey that conducted to investigate the shortages in the current practice in the construction delay claims analysis and how best can overcome these shortages. The results obtained are used as an underpinning for a new framework that can assist practitioners of the delay claims analysis in the construction industry. The third part of this research proposes a new delay analysis method. It will help determine the extent to which various techniques can deal robustly with problematic delay claim analysis issues.

In sum, this research will offer a much clearer picture of the real gaps that exist in delay analysis which resulted in the need for a new and improved technique, such as that developed and proposed in this research, to solve all of the underlying issues. The research also draws some recommendations for future research in this area.

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DEDICATION

to those who inspire me…

The memory of my father and my sister (May Allah be merciful upon them) …

My Beloved mother…

My brothers and sister…

My wife and my brilliant kids

Saud

ACKNOWLEDGEMENT

The author at first would like to express his most profound appreciation and gratitude to Dr Nhuh Braimah for his encouragement, support, and patience in dealing with my frustrations throughout the course of this research. Also, special appreciation is extended for the generous co-operation and contribution of those researchers and practitioners who participated in this study.

I feel a deep sense of appreciation and gratitude for my mother, who formed part of my vision and taught me good things that matter in life. Her unfailing love and support have always been my strength. Her patience and sacrifice will remain my inspiration throughout my life. I am also very much grateful to all my family members for their constant inspiration and encouragement.

DECLARATION

I, Saud Alshammari, hereby declare that this thesis is entirely based on my own research. I hereby declare too that this thesis has not been and will not be submitted in whole or in part for any other qualification.

ABBREVIATIONS

DATs	Delay Analysis Techniques
DAIs	Delay Analysis Issues
EC Delay	Excusable Compensable Delay
NE Delay	Non- Excusable Delay
EN Delay	Excusable Non-compensable Delay
CO	Change Order
FMD	Force Majeure Delay
PFMD	Preventable Force Majeure Delay
UFMD	Unavoidable Force Majeure Delay
TFs	Total Floats
CDs	Concurrent Delays
CEs	Concurrent Effects
PDs	Pacing Delays
EoT	Extension of Time
LoP	Loss of Productivity
ES	Early Start
EF	Early Finish
PCD	Project Completion Date
TPDs	Total Project Delays
D	Duration
A@P.L	Acceleration at Project level
A@A.L	Acceleration at Activity level
ID	Impacted Day
OA	Owner Acceleration
CA	Contractor Acceleration
SA	Schedule Acceleration
SCL	Society of Construction Law
AACE	American Association of Cost Engineering

CHAPTER ONE: INTRODUCTION

1.1 Introduction

This chapter introduces the topic of the PhD research. It provides a background to the research, highlights the problems and explains the significance of the subject. The aim and objective are outlined and along with the questions that the research intends to answer. This chapter also describes the research design and presents the structure of the thesis.

1.2 Background to the Research

Construction delay claims have become an integral part of the construction industry and a significant source of conflict and dispute in construction projects (Walsh and Zehner, 2019; Yates and Epstein, 2006). A delay claim on a construction project may occur when the project time has been extended or when work has not been achieved as planned due to circumstances that were not expected when the parties entered into the construction contract. The claim theory is straightforward in construction delays; however, the claim analysis is quite complex (Jagannathan and Delhi, 2019; Barakat et al., 2018; Matt, 2010).

When dealing with a delay claim, determining its causes and allocating responsibility is the first step toward determining entitlement for any losses and damages. If a project's work is not completed on time or involves delays, the owner will lose profits or benefits, thereby quickly increasing financing costs. Similarly, a contractor will expend significant amounts in the form of lost opportunities and extended performance costs (Iyer and Manan Bindal, 2019; Assaf and Al-Hejji, 2006). Thus, in order to minimize the cost to and effort required of both the claimant and the defendant, a claim must be presented in a detailed and professional manner and include the basis, the scientific considerations, and relevant pieces of evidence

(Abdel-Khalek et al., 2019; Bramble and Callahan, 2010; Yates and Epstein, 2006; Matt, 2010).

Therefore, the objective of delay claim analysis is "to calculate the project delay and work backwards to identify how much of its attributable to the contracting parties; so that time and (or) cost compensation can be determined and decided" (Braimah, 2013). Currently, more than nineteen techniques have introduced for analysing delay claims (Magdy et al., 2019; Yang and Kao, 2009). These techniques suffer from several weaknesses and shortcomings that lead to inconsistent results in delay claims.

1.3 Problem Statement and Definition

The task of quantifying and justifying the effects of each schedule-impacting event for the purpose of proving the causation and quantum is well-recognised as complicated work (Kamandang and Casita, 2018; Strogatz at al., 1997). This issue is due in part to the nature of schedule-impacting events. Not only do these events occur due to a variety of causes (Kumaraswamy, 1997; Hanna and Heale, 1994; Borcherding, 1978), they also have different effects and implications resulting in complex ramifications and creating considerable difficulty to practitioners in the claims resolution. Thus, delay claims can be stressful, time-consuming, complicated and expensive (Yang and Teng, 2017; Assaf and Al-Hejji, 2006).

The challenging nature of resolving delay claims has resulted, in part, in numerous initiatives from practitioners and researchers over the years to improve delay claim settlements and reduce the high number of disputes (Jagannathan and Delhi, 2019; Burr, 2016). These initiatives include the needs for improvement, which can reduce the impact of Delay Analysis

Issues (DAIs) and increase the efficiency of Delay Analysis Techniques (DATs) in order to facilitate better accuracy in delay analysis results (AACEI, 2011).

However, there are several issues that are yet to be considered in the delay analysis process (Keane and Caletka, 2015; Burr, 2016; Yang at al., 2014). This research is based on the premise that one of the significant sources of difficulty in delay claims resolution is the use of improper methods for analysis (Al-Gahtani, 2006), and that such difficulty can only be reduced or eliminated by the development of an appropriate method that can overcome the current DAIs (Guida and Sacco, 2019; Braimah, 2013).

1.4 Aim and Objectives

As a result of the difficulties and ambiguities surrounding the quantification of responsibility for project delays and the apportionment of the responsibility borne by each party, there is a real need to establish a reliable method for analysing delay claims. Analysis methods can be used after the completion of the project and during the litigation to assess the claims after the damage has occurred. Additionally, they can be used during the schedule impact and before the project completion to verify the responsibility of any damage and avoid the chance of dispute between the contracting parties. Therefore, this research aims to propose a framework and develop a technique for analysing construction delay claims. In pursuit of this aim, the research objectives include the following:

- Investigate in detail the current practice of delay and disruption analysis in construction claims. This includes the evaluation of the theoretical concepts and legal principles in construction delay claims, the issue of delay analysis, and the current delay analysis techniques used for analysing construction delay claims. This objective is achieved through a comprehensive literature review in construction delay claims analysis.

- Explore the best practice of delay and disruption analysis in construction claims. This includes the analysis of court cases in delay and disruption claims and an evaluation of the expert views on the best practice for a reliable analysis of construction delay claims. This objective is avhived through documentary analysis of the court cases in delay and disruption claims and a questionnaire of experts and practitioners in delay and disruption claims analysis.
- Propose a framework and a technique for analysing the construction delay claims. The proposed framework and technique is mainly constructed and developed based on the best practice.
- Validate the proposed framework and technique in term of applicability, effectiveness, reliability and accuracy through a process of evaluation by researchers and practitioners.

1.5 Research Questions

To sufficiently address the identified aim and objectives, the study would need to answer the following questions:

- What is the current practice of delay and disruption claims analysis?
- What are the limitations in the current practice, and what is the best practice to overcome the limitations?

- How can appropriately resolve the responsibility of the schedule impacts in construction delay claims analysis, with little or no chance of dispute ensuing? Also, what is the specific characteristics and sound method for fairly analysing the schedule impacts and determining the responsibility between the contracting parties in construction delay claims?

1.6 Research Methodology

The issues to be dealt with in the research are very complex, comprising the theoretical concepts and legal principles on analysing the schedule impacts of the construction claims and quantifying the responsibility of the contracting parties for the cost and time overruns. The primary challenge in this research is to consider and explicitly state the overall design of the study, which has used different techniques and methods in different stages, as shown in Figure 1-1. To sufficiently carry out the identified objectives of the research, the research methodology involved significant steps as follows:

STEP 1: Review all publications regarding construction delay claims (**1-A**), delay analysis issues (**1-B**), and delay analysis techniques (**1-C**). These publications range from books, journal papers, conference papers, dissertations, and online documents for knowing all the related topics of analysing the construction schedule impacts.

STEP 2: Determine, through STEP 1, the research problem(**2-D**), the research objectives and questions (**2-E**), as well as the research philosophy and methodology (**2-F**) for investigating the current practice and exploring the best practice of analysing the construction delay claims.

STEP 3: Conduct qualitative analysis research by using two methods; First, investigate the documents and the court cases for the issues of contention encountered in the construction delay claims (**3-G**); Second, a questionnaire survey with the experts of the forensic schedule delay analysis (**3-H**). These two methods have been adopted in this research to determine, among others, the limitations in the existing delay analysis techniques, the actual issues confronting their proper use in resolving delay claims, and how these limitations can be mitigated.

STEP 4: Analyse the data that collected from step 3 to determine any shortages in current delay processes and how best they can be deal with for obtaining better results (**4-I**).

STEP 5: Propose a comprehensive framework for developing a reliable technique that can analyse the schedule impacts with considering most of DAIs (**5-J**).

STEP 6: Develop a sophisticated technique for analysing the construction projects delay and responsibility for delay damages (**6-K**). The technique procedures will be demonstrated by using a hypothetical case study. This technique will also be compared with the current techniques in resolving the delay claims, which will help to minimise the concern of practitioners in the construction industry at large.

STEP 7: Assess the reliability and the accuracy for the developed technique for its use in the construction delay claims analysis by following the international's recommended practice protocol for Forensic Schedule Analysis by American Association of Cost Engineering (AACE). Also, validate the developed method by soliciting the views of experts in this field with regard, among other things, to the appropriateness and relevance of the technique to the industry.

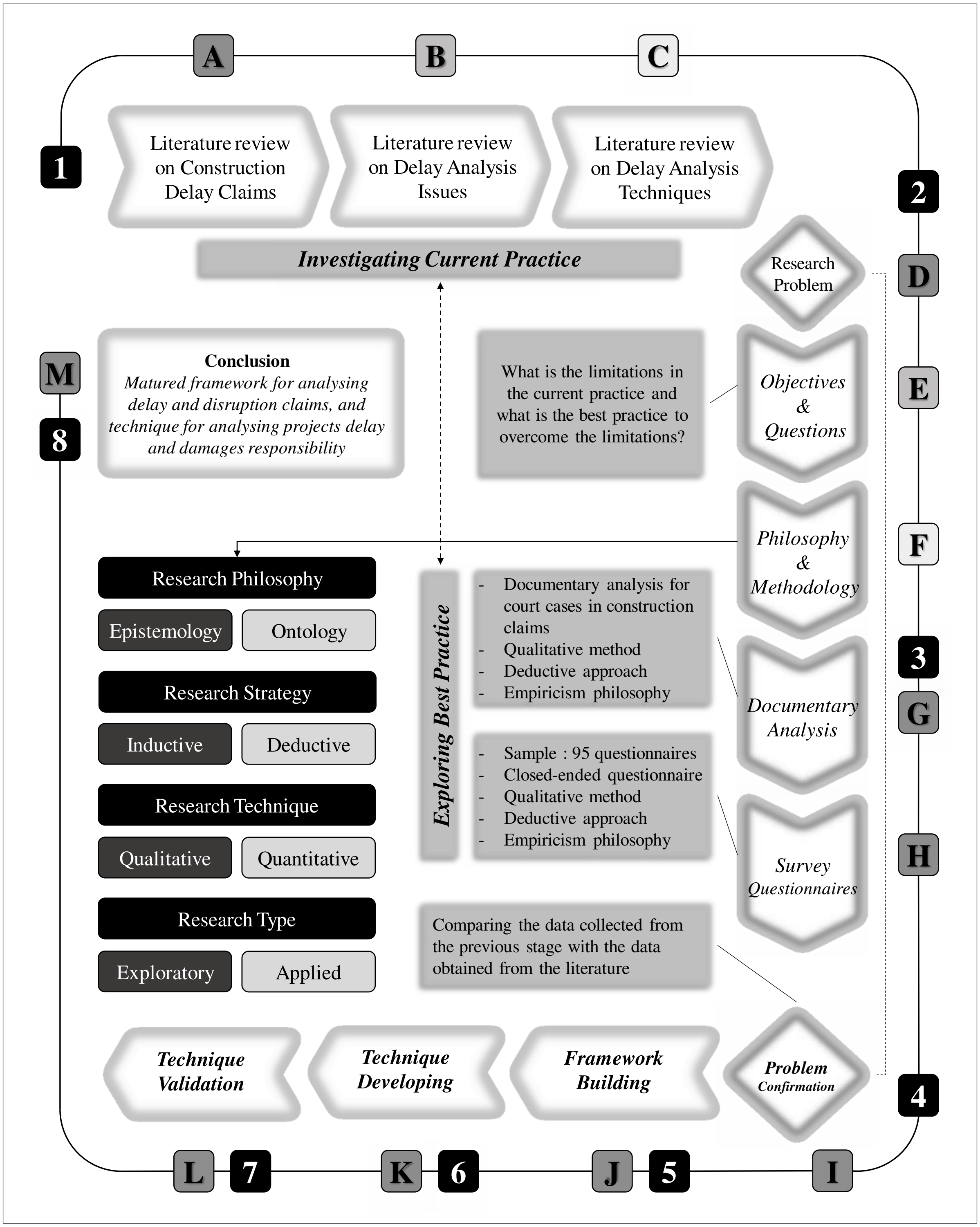


Figure 1-1: The overall research design and scenario

1.7 Research Contribution to Knowledge and Industry

Recently, delay and disruption in construction projects claims are one of the most challenging and controversial disputes to settle. Despite developing many Delay Analysis Techniques (DATs) and identifying many Delay Analysis Issues (DAIs), difficulties in the fair and equitable resolution of the delay claim still persist. In attempting to resolve the issues of delay claims analysis, this research investigated the current practices and methodologies and associated problems. The outcomes of the research offer many potential benefits to practitioners and researchers, which can assist claim parties to resolve such claims with less difficulty and equitably addresses these claims with little or no chance of dispute ensuing. A summary of the significant research achievements and contributions to knowledge arising from this research are as follows:

1. A review of the existing DATs methodologies in use as reported in the literature. It provides up-to-date information on this subject matter, which would be very useful to researchers and practitioners investigating in this area.
2. The current status of delay and disruption claims has been established based on the adopted research methods. Areas addressed by the research methods included the factors and issues influencing the delay claims analysis, the limitations and shortcomings of the current delay claims analysis, and the determination of the best approach for analysing the construction delay claims. The findings of this investigation can be used against the claiming parties to enhance the chances of a speedy and amicable settlement. Such improvement will particularly benefit practitioners in this field to understand the construction claims matters that can be promoted.

3. An innovative technique for analysing the construction project delays has been developed. The developed technique is intended to serve as a tool for claims analysts, schedulers, judges, jury members, lawyers, triers-of-fact, contractors, and owners. It is believed that the developed technique has been presented within a standard framework and rigorously defined covers all possibilities for the construction delay claims.

1.8 Structure of the Thesis

The thesis comprises seven areas, which are represented in ten chapters. A brief introduction to each chapter is given in this section to outline the logical progression of the thesis.

Chapter 1 introduces the topic and provides a brief overview of the thesis, including a background to the research, problem statement and definition, aims and objectives, research questioners, research methodology, and research design and scenario.

Chapter 2, 3, and 4 forms the literature review. Chapter 2 provides an in-depth review of the literature on construction delay claims. It summarises the types of schedule impact as well as the issues related to the project time and cost. Chapter 3 focused on the issues of delay analysis. Chapter 4 intends to review the existing delay analysis techniques as well as their shortcomings in producing reliable results of delay claims.

Chapter 5 outlines the method adopted in this research and explains the rationale of this method. The chapter presents the stages of data collection and explains the method of collecting and analysing those data.

Chapter 6 presents and discusses the findings of data collocation and analysis. This chapter also includes a comprehensive survey with practitioners to determine, among others, the real needs of available delay analysis techniques, the actual issues confronting their proper use in resolving delay claims, the extent of the issues in practice and how best they can be mitigated.

Chapter 7 and 8 constructs and explains the framework and the method based on the results obtained from the findings in chapter 6. Chapter 7 illustrates the process with the aid of flowcharts to ensure a better appreciation of what the use of the framework entails. This framework and method are a contribution to the profession based on the results from chapter 2, 3, 4 and 6. Chapter 8 includes a case-study employed to demonstrate the application of the procedures for the proposed technique. This chapter ends with a comparison between the existing DATs and the developed method based on the analysis results.

Chapter 9 presents and discusses the validations and limitations for the proposed technique which derived from a survey that conducted for this purpose.

Chapter 10 summarises the results and significant findings of the research. It highlights the contribution to knowledge and suggests particular areas for future research. Also, this chapter will show the reader that the thesis satisfies its objectives.

CHAPTER TWO: DELAY AND DISRUPTION IN CONSTRUCTION PROJECTS

2.1 Introduction

This chapter reviews the challenges present in various aspects of disputes in construction delay claims that arise from impacts to the construction schedule. It provides critical analysis for the most relevant literature on construction delay claims in general and the impact of scheduling issues in particular. Additionally, it includes a review of existing practices for analysing the effects and responsibilities as well as the liability for cost and time overrun issues. This chapter begins by investigating the most common types of schedule impacts. This is followed by a review on evaluating the effects resulting from a schedule impact along with the existing practices for assessing these effects. Therefore, this chapter presents detailed knowledge drawn from the literature pertaining to the analysis of this phenomenon in construction delay claims.

2.2 Construction Delay Claims

In most construction project contracts, there is a specified date by which the project's works described in the agreement must be completed. However, it is typical for construction projects not to be completed by the original contract time due to different events impacting the schedule, such as progress delays, change order and disruption. If a project did not complete on time, an owner would lose benefits or profits, and the financing costs could add up quickly. Similarly, a contractor would expend significant amounts in missed opportunities and extending performance costs (Perera, 2016; Assaf and Al-Hejji, 2006).

Also, delay claims due to the schedule impacts are the most common and costly issue encountered in construction projects (Zhao and Dungan, 2018; Alkass et al., 1996). In the construction delay claims, project schedules typically involve two periods of a project duration time, named as shown in Figure 2-1: the original contract period and the delayed period. Due to the variance between As-planned schedule and As-built schedule, many projects end up in arbitration and litigation (Kamandang and Casita, 2018; Yates, 2006). Many events can impact the project schedule in construction projects. For example, disruption is an impact that alters the performance or work sequence expected at the contractual time, which can affect the project cost and (or) time. Also, suspension and termination, which are a directive stoppage of the project works, have financial impacts on the projects (Bramble et al., 1990; Wickwire et al., 2003). However, the most popular events of schedule impacts that considered by the existing delay analysis processes and may influence the analysis results are: delays, acceleration, change orders, and disruption (Magdy et al., 2019; Al-Gahtani, 2006). Therefore, the following section will focus on the events of the schedule impacts due to their effects in producing a successful result in construction delay claims.

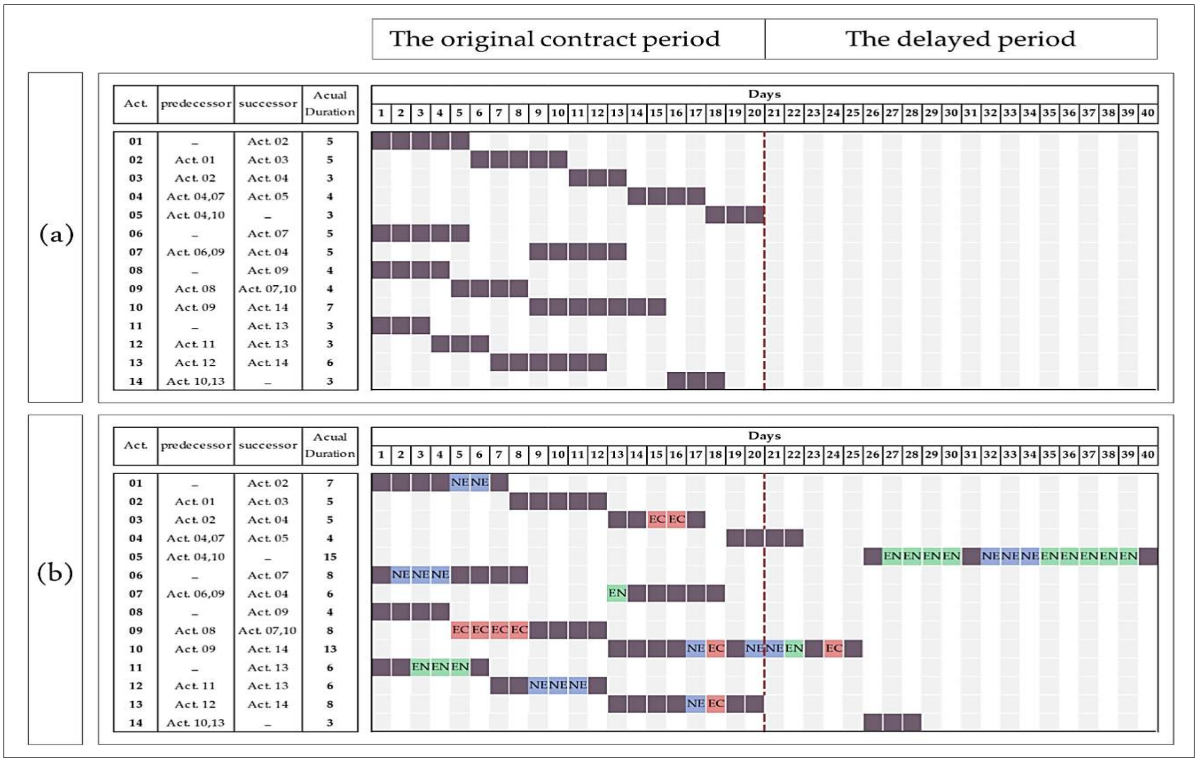


Figure 2-1: Two periods in the construction projects; the original contract period and the delayed period; for (a) As-planned schedule; (b) As-built schedule

2.3 Types of Schedule Impacts

Delays, accelerations, change orders, and disruptions are the events that have potential impacts on the schedule entirely or partially (Arcuri and Hildreth, 2007). This section discusses the types of schedule impacts and their responsibility among the contracting parties.

2.3.1 Delays

In construction claims, the term "delay" can be used to indicate two different meanings in the legal context of construction law (Zarei et al., 2018; Bramble and Callahan, 2010). Delay can be used to mean the period that increased in the overall project time for performance or any given activity. It can also be used to the event that affects the performance of a particular activity, with or without affecting the project completion date. In general, delay in construction projects can be considered as a time lag in completion of activities from its specified time as per contract directly affecting construction cost. Management and performance problems, inclement weather, lack of resources are examples of delays that may increase the time required to perform the project's works and may also increase the costs of the contracting parties involved (Bramble et al., 1990; Bramble and Callahan, 2010).

In construction projects, classifying the delay events is essential to determine its responsibility among the contract parties, so that the potential losses or damages due to the events can be assigned to the responsible party. In construction projects, there are generally three types of delays (Kog, 2019; Zack, 2000; Arditi and Robinson, 1995; Ibbs, 1984; Arditi et al., 1985). The types of delay events that have been recognised in the literature, as shown in Table 2-1, will be discussed as follow:

Table 2-1: Responsibility for Project Delay.

Delay Responsibility			**Delay Analysis**
Contractor	**Owner**	**Third Parties**	
NE			Liquidated Damages
	EC		Compensable Damages
		EN	Time Extension

(1) Non-Excusable Delays: Non-Excusable (NE) delays are the delay events that are attributed to the contractor's action or fault. In this case of delay, the contractor is not entitled to a time extension or a damages recovery and would also be responsible for any damages that the owner may incur. Examples include failure to coordinate the work, a lack of equipment on the site, low productivity, removal of defective work, subcontractors' actions, and a failure to evaluate the site (Arditi and Robinson, 1995).

(2) Excusable Compensable Delays: Excusable Compensable (EC) delays are delays that are caused by, are within the control of or are due to the negligence of the owner, who is contractually responsible. These are the delays that typically entitle the contractor to both a time extension and delay damages. Examples include a failure to grant site access, rough drawings and specifications, and the late arrival of owner-furnished material (Zack, 2000).

(3) Excusable Non-Compensable Delays: Excusable Non-compensable (EN) delays are delays that have not resulted from the fault of the owner or the contractor. They include the delay events that allow the contractor to a time extension for the whole delay period, but it is not allowed damages for delay-related costs. Therefore, the owner would be required to extend the project for the same period of the delay, without any right to late completion damages. Examples include "Acts of God," unusually severe weather, and unforeseen labour/material shortages (Arditi et al., 1985).

2.3.2 Accelerations

Project acceleration that is required to overcome delay is one of the most common causes of schedule impacts in construction projects. It means shortening the original duration of project activities or the project schedule (Harjanto, 2019). Thomas (2000) described acceleration as having more work to perform in the same period or having a shorter period to perform the same amount of work. When the delay events occurred, some of the project activities may be delayed and the other activities may be accelerated (Wickwire et al., 1991). Thus, the complexity of managing the construction project would be increased with accelerating the delayed project, while the owner and the contractor do not fully know the delay responsibilities (Al-Gahtani, 2006).

Levin (1998) defines three types of acceleration that should not affect the project completion date unless agreed upon between the contract parties, which are:

(1) Voluntary acceleration or Contractor Acceleration (CA), which occurs when the contractor makes an individual effort to accelerate the work;

(2) Directed acceleration or Owner Acceleration (OA), which occurs when the owner orders the project contractor to accelerate the work; and

(3) Constructive acceleration or Schedule Acceleration (SA), which occurs when the contractor accelerates to finish the work according to the planned schedule due to excusable delays have occurred but without a granted of the time extension.

2.3.3 Change Orders

Another primary type of a potential impact to the project schedule involves change or variation order. Change or variation order on construction projects is the formal document that is used to modify the scope of works from the agreed contractual agreement (Shrestha et al., 2019). Due to the matter of practical reality and various factors, a construction project may include deviation from the original scope by addition, substitution or omission some of the works. During the delay claims analysis, the change order, as well as the responsibility for any effect on the project cost and time incurred due to this change order, is the owner responsibility. Thus, the effect of the change order and the responsibility for any effect due to the change order should not be neglected in the delay claims analysis (Al-Gahtani, 2006).

As the project schedule could be impacted by delay and acceleration that belong to the responsibility of different contracting parties, the schedule also could be impacted by change order or variation order due to different responsibilities. The causes of variations and change orders can be grouped based on the responsibility of the contracting parties into three types (Shrestha and Fathi, 2019; Keane et al., 2010; Ibbs et al., 2001; Fisk, 1997), which are:

(1) Directed Changes or Owner-Related Variations, which the owner has directed the contractor to make specific changes to the works required by the contract and specifications;

(2) Constructive Changes or Contractor-Related Variations, which the request come from the contractor to change for responding to alterations in design or project scope; and

(3) Cardinal Changes or Neither Party-Related Variations, which is a change (either directed or constructive) that is clearly beyond the overall of the contract scope such as a change in economic conditions, unforeseen problems or different site conditions.

2.3.4 Disruptions

Disruption can be defined as any change or modification to the method of performance or planned work sequence that can arise from a variety of causes, resulting in increasing the performance difficulty and the performance cost (D'Onofrio, 2018; Cushman and Carpenter, 1990). Thus, any changes on the as-planned schedule may cause disruption, even if the original scope of the work has not been modified (Lee, 2016).

In construction claims, the disruptions can be caused by any event of the schedule impacts such as delay, acceleration, or change order. In determining any potential damages due to the disruption, the effect of disruption on the schedule should be measured first. After that, the cost of the damages could be quantified to the responsible party who has caused such disruption - whether the owner, the contractor or a source out of their control (Arcuri and Hildreth, 2007).

In this regard, when a disruption arises due to any change in schedule, the work performance may be interrupted as well, thereby preventing or hindering the workflow of the project partially or entirely. Additionally, such interruptions may cause a cumulative impact, which is referred to as the ripple effect of changes, causing an overall effect on productivity (Jones, 2001; Lee, 2016). For measuring and quantifying the cumulative damages caused by disruptions, there are many methods such as earned value analysis, measured mile, earned value management, and lost productivity analysis among others (Schwartzkopf, 1995; Chou el at., 2010; Siu and Lu, 2011; Wauters and Vanhoucke, 2015; Lee, 2016). To gain a deeper insight into how work interruptions tend to impact work performance, the following section reviews the effects of schedule impacts and any potential damages that might ensue as a result.

2.4 The Effects of the Schedule Impacts

Each construction project starts with a plan to complete the agreed work. Once the project commences, the schedule updates and revisions create new schedules. Eventually, the final schedule is the final record for the project that has all the effects, final documentation of actual starts and finishes of activities, delays, change orders, accelerations, and other factors that affected the project such as disruptions, which is the schedule of "as-built" (AACEI, 2011). Therefore, the difference between as-planned schedule and as-built schedule can be used as evidence to measure the effects and determine the responsibilities for the schedule impacts, which need an adequate analysis and require a comprehensive understanding of the process for the legal delay claims (Fawzy et al., 2018; Bramble and Callahan, 2010).

The determination for the responsibility of the schedule impacts - whether caused by the owner, contractor, or another source out of their control- is the first process for evaluating the effects, which can be compensable to the innocent party suffering damages (Bramble and

Callahan, 2010). Al-Saggaf (1998) describes a formal schedule analysis procedure for the schedule impacts by the following five steps: (1) data gathering; (2) data analysis; (3) identification of the cause; (4) classification of the type of delay; and (5) assigning responsibility. The purpose is "to calculate the project delay and work backwards to try to identify and recognise how much of it is attributable to each party (owner, contractor, or neither) so that time and (or) cost compensation can be determined and decided" (Kamandang and Casita, 2018; Zarei et al., 2018; Braimah, 2013).

When the impact occurs on the schedule, the project time and (or) cost will be impacted, resulting in different losses to each party such as the loss from using the project for the owner and the cost of extending the project performance for the contractor. Therefore, time and cost are the possible effects for the project when the schedule of the project get affected (Lari et al., 2019; Bramble and Callahan, 2010; Keane et al., 2010; Larsen et al., 2015). Therefore, the rest of this section will discuss the DAIs and their impact types in the schedule according to their related influences on the project time or the project cost.

2.4.1 Time-Related Issues

The analysis for time-related issues is one of the essential parts of dispute resolution, even though the outcome of a claim may be dependent on a multitude of factors. The analysis establishes the arguments in the entitlement of claims, and the result of the analysis plays a critical part in computing the responsibility for damages. Therefore, identifying the schedule impacts and allocating responsibility for the schedule impacts is more often argumentative because it involves one party's gain and the other party's loss (Jagannathan and Delhi, 2019; Fawzy et al, 2018; Duah and Syal, 2017; Arditi and Pattanakitchamroon, 2008).

There are many ways in which the construction project schedule can be impacted. For example, an event of delay may be the result of direct action or failure to act, such as a delay due to lack of resource. In this case, the contractor is responsible for this delay caused by the lack of resources. However, the resource could be impacted due to owner-caused delay. In this case, the direct action (owner-caused delay) have contributed in impacting the project schedule and caused another delay indirectly (delay that due to resource overloading), which this delay that happened indirectly would be an owner responsibility (Nguyen and Ibbs, 2006).

Some experts in delay claims have emphasised that "a delay that would have been prevented by the due care of one party would be compensable damage to the innocent party suffering cost damages as the result of the delay impact" (Bramble and Callahan, 2010, pp. 1-10–1-12). Therefore, if a delay solely resulted from one of the contracting parties, the opportunity of any delay damage would be recovered by the other party. Therefore, the events of the schedule impact can have two different effects at the same time. For instance, a delay can have a direct effect on activity by stopping and delaying the execution work. In the meantime, this delay can also lead to secondary consequence (or indirect effect) on the execution of other works in a different timeframe for the same activity or another activity (SCL, 2002, p. 44).

For example, when the work for any activity is unable to be carried out due to an owner delay, the first effect would be a loss of time due to the owner delay. In the meantime, the effect of the owner delay extends into impacting the resource allocation for another activity. Thus, the delay caused by resource overloading become the indirect effect of the owner delay. In this case, the project time will be affected twice. The first effect is the loss of time due to the owner delay. The second effect is the loss of time due to resource overloading as the indirect effect of the owner delay. Disruption or loss of productivity and extending the original contract period into a period of force majeure are other examples of the secondary consequences or indirect effects of any event that impacts the schedule in a way that may cause a delay in a different timeframe for an activity or overall project duration (SCL, 2002; Nguyen and Ibbs, 2006; Bramble and Callahan, 2010; Nelson, 2011; Braimah, 2013; Alshammari et al., 2017; Zhao and Dungan, 2018).

The context of delays significantly affects the delay responsibility. Contractors are prone to view most delays as the responsibility of the owner while owners frequently attempt to tag delays as contractor caused (Zack, 2001; Nguyen and Ibbs, 2006). The following are the most relevant issues to the responsibility for delay time in the claims.

2.4.1.1 Resource Allocation

The types of schedule impacts detailed above are directly attributable to different parties on the project, along with any significant impact (Ottesen and Martin, 2019; Arcuri and Hildreth, 2007). Once the event of delay, acceleration or change order occurs on the schedule, the baseline schedule for the project resource allocation may be impacted and therefore will not be suitable for the following work in the schedule. This issue has been widely discussed in the literature (See, e.g. SCL, 2002; Peters, 2007; Kuhn, 2007; Kastor and Sirakoulis, 2009).

Ibbs and Nguyen (2007) discussed the analysis of delay responsibility under the effect of resource allocation, along with a case study. Figure 2-2 illustrates the as-planned, as-built, and collapsed as-built schedules for the case study. The contractor will only be able to allocate two backhoes on this site. Numbers denoted in each activity bar indicate the number of backhoes needed for that activity. During the project performance, there are two 2-week delays by the owner (EC delays) and the contractor (NE delays) on two activities, namely "excavation trench 1 in 4th and 5th week" and "excavation trench 2 in 2nd and 3rd weeks," respectively as shown in the as-built schedule.

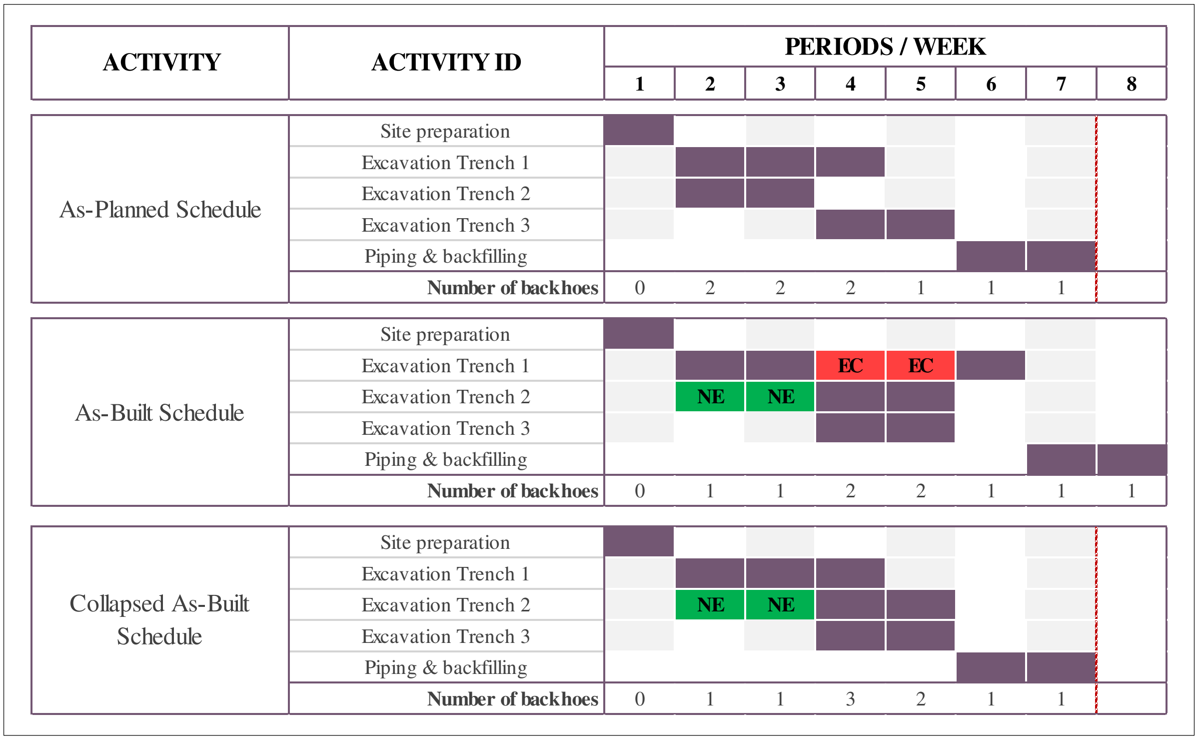


Figure 2-2: Schedules of motivating example for the resource allocation, (adapted from Ibbs and Nguyen, 2007)

This case study is showing that resource allocation is an essential fact in delay claims, which need to be considered during the responsibility analysis. It indicates that with or without EC delay in 4th and 5th week, the contractor cannot perform due to the overloaded of backhoes. At the fourth week, the work would have required three backhoes for simultaneously performing the three excavation activities. The owner must be responsible for 4th and 5th week if the effect of resource allocation is not taken into consideration in this circumstance. However, by considering the resource allocation, the contractor also cannot perform in this week and the week after due to the lack of resource. In this case, Excavation Trench 1 has been delayed by concurrent delays: one caused by direct action from the owner; and the other caused by indirect action from the contractor due to unavailability of the resource. Also, Excavation

Trench 2 will have the same case of Excavation Trench 1, which will be concurrent delays for the same reason.

In contrast, if the 2nd and the 3rd week have delayed due to the owner-caused delay, the contractor also cannot perform due to unavailability of the resource. In this case, the delay responsibility is entirely different for the 4th and 5th week. Owner-caused delays in 2nd and 3rd week have consequential impacted on Excavation Trench 1, for which the contractor cannot perform due to the unavailability of the resource. Therefore, the owner-caused delays are directly impacting the Excavation Trench 2 and indirectly have impacted Excavation Trench 1. In this case, the contractor should not be responsible for 4th and 5th week (for example: due to the lack of resource), which should be considered during the analysis of delay responsibility.

This case demonstrates that resource-related issues such as constraints, availability, or broader term resource allocation can cause further delays (or delays that happened indirectly) to the project. The case study confirmed that the delay events directly impacted the schedule and caused an indirect impact on the schedule by impacting the resource levelling. Therefore, resource allocation practice may substantially affect the credibility of schedule analysis and should not be neglected (Hegazy, 1999; Kim and de la Garza, 2005).

Some of the schedule impacts may result in unrealistic resource allocation in the following work, which turns to delay the project schedule. Therefore, resource over-allocation should be considered in the schedule analysis in order to arrive at an accurate analysis for the delay responsibility. Al-Gahtani (2006) indicated that resource levelling typically requires float utilization to achieve optimal resource usage and such utilisation could lead to increased risks in terms of cost and time. Also, Braimah (2013) pointed to the importance of resource allocation during the delay claims analysis, which ignoring such issue will yield inaccurate and untrustworthy results. Ibbs and Nguyen (2007) also proved that the results of a schedule analysis are affected by a failure to analyse resource allocation sufficiently.

2.4.1.2 Loss of Productivity

One essential delay cause is a loss of productivity that is usually experienced by a contractor while accomplishing the project works less than the planned rate of production. Two different causes of productivity loss are hard to be distinguished. First is the loss of productivity due to impacting the project schedule by delays or change orders. Second is the loss of productivity due to the poor performance for the project implementation. In this case, the analysis of delay responsibility with consideration of the issue of lost productivity plays a crucial role in solving a delay claim based on the time-related effect (Zhao and Dungan, 2018; Lee at al., 2005).

Delay, acceleration, change order or disruption are common causes of lost productivity. During the identification of the cause for a delay with the schedule, the lost productivity may be found to be the sole reason for that delay, resulting from a previous cause. Therefore, a contractor should prove that he did not cause the delay due to lost productivity and whether it extended the project completion or not (Ryu et al., 2003).

Lee and Diekmann (2011) discussed a method for delay analysis that considers the production rate. In this method, the authors have attempted to justify the need for nonlinear production rates as part of the delay analysis methodology. For analysing the situations of additional schedule impacts caused by lost productivity, Ibbs et al. (2007) also discussed the methods for estimating lost productivity, as shown in Figure 2-3. Therefore, the methods for quantifying lost productivity can be classified into three major groups: cost-based methods including the jury verdict, total cost, and modified total cost methods; industry-based methods including general studies and specific studies methods; and project practice-based methods including comparison studies, sampling methods, earned value analyses, measured mile analyses, baseline productivity analyses, and system dynamics modelling.

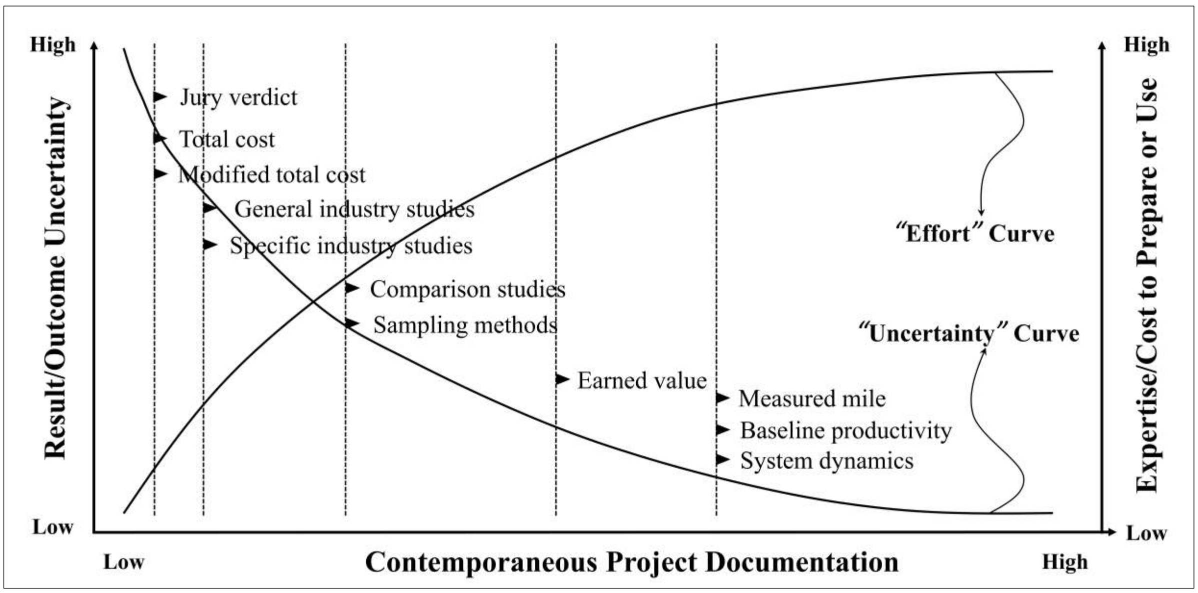


Figure 2-3: The methods for quantifying losses and damages resulting from disruption (adopted from Ibbs et al., 2007)

It is noteworthy that the disruption is always caused by a direct impact on the project schedule (Lee et al., 2005). For example, change order or delay event that occurs on the schedule as a direct impact may cause the disruption or loss of productivity. Therefore, loss of productivity may significantly affect the delay responsibility and should not be neglected.

2.4.1.3 Force Majeure

Force majeure is typically recognised as an excusable risk. It is a delay risk that only entitles contractors for time extensions, where neither parties are entitled to a compensation of any additional cost to recover delay damages. Although practitioners share a general concept that a delay due to force majeure is often classified as an Excusable Non-compensation (EN) delay (Kululanga et al., 2001), this contradicts many claims that have concluded in favour of grant compensations for force majeure delays (Ridder and Weller, 2014; Loulakis and McLaughlin, 2010; Wright, 2006; Bruner, 2000; Rauh, 1996; Polkinghorne and Rosenberg, 2014). The contradiction arises due to the fact that the determination of delay responsibility and the recovery of delay damages will depend on the facts surrounding the claim, precise measurements for determining the real delay cause, and proper analyses for allocating its responsibility (Barakat et al., 2018; Yates and Epstein, 2006).

Alshammeri et al. (2017) discussed the responsibility for force majeure delays before and after the original contractor period, as shown in Figure 2-4. Based on analysing some court cases relating to force majeure claims (DTC's claim, 2012; Charles's claim, 1991), the study concluded that the force majeure delays that occur after the original contractor period are Preventable Force Majeure Delay (PFMD). The result indicates that the responsibility of force majeure delay before the original contract period is an unavoidable delay, which entitles contractors only to time extensions. In contrast, the force majeure after the original contract period is the responsibility for each event that extends the project performance into this delay. Therefore, PFMD concept indicated that the events of the schedule impact might push the project performance into a period of force majeure and substantially affect its responsibility, which should not be neglected during the analysis of delay responsibility (Alshammeri et al., 2017).

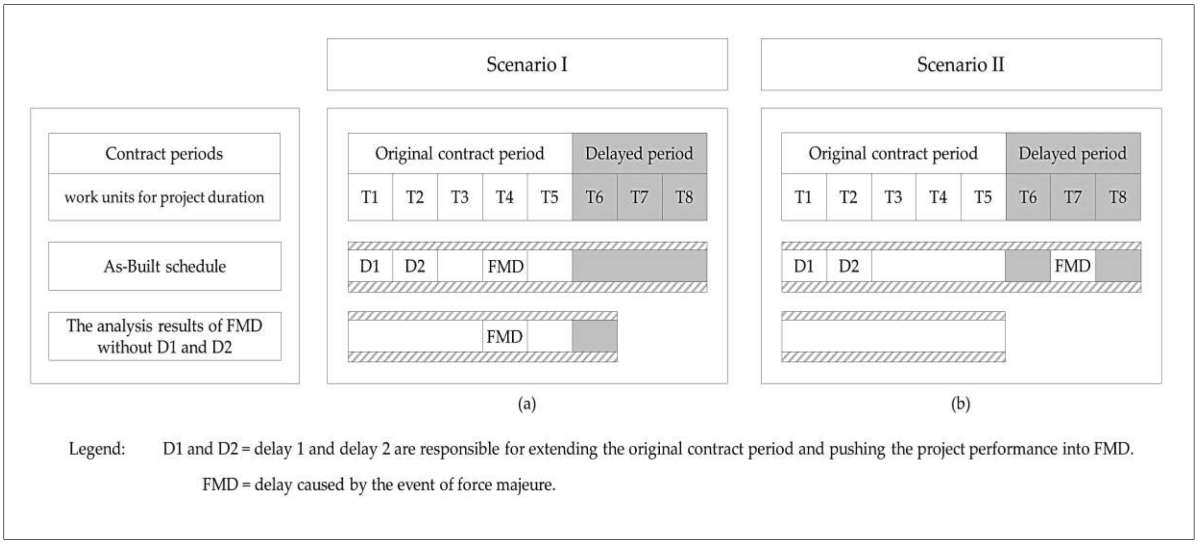


Figure 2-4: The two timings for the occurrence of force majeure delay during the contractual periods

2.4.2 Cost-Related Issues

As mentioned earlier, project time could be affected twice directly and indirectly from the same event causing the schedule impact. In this case, there will be potential losses or damages due to the impacted time. For example, when a contractor experienced a delay event, there are two possible scenarios for incurring an additional cost: (1) increasing the resources to overcome the impacted time; (2) extending the project performance to overcome the delayed period due to the delay. In both scenarios, there will be significant delay damages to be supported by one or more of the contracting parties, which is the most significant area for the construction disputes to recover the losses incurred as a result of delay (Strogatz at al., 1997; Bramble and Callahan, 2010; Shrestha and Zeleke, 2018; Shrestha and Fathi, 2019).

With more detailed for the potential losses or damages that may occur due to the events of the schedule impacts, Figure 2-5 that adopted from Ibbs and Nguyen (2007) shows two scenarios of how the cost of potential damages could happen on the project. There is a delay event happened in occurs on day 2 on excavation Trench 2. Due to this delay, the schedule has also impacted on day 3 due to the resource conflict or loss of productivity. In this situation, Ibbs and Nguyen (2007) stated that there are two possible scenarios to overcome the issue on day 3, which is the result of the delay on day 2, as follow:

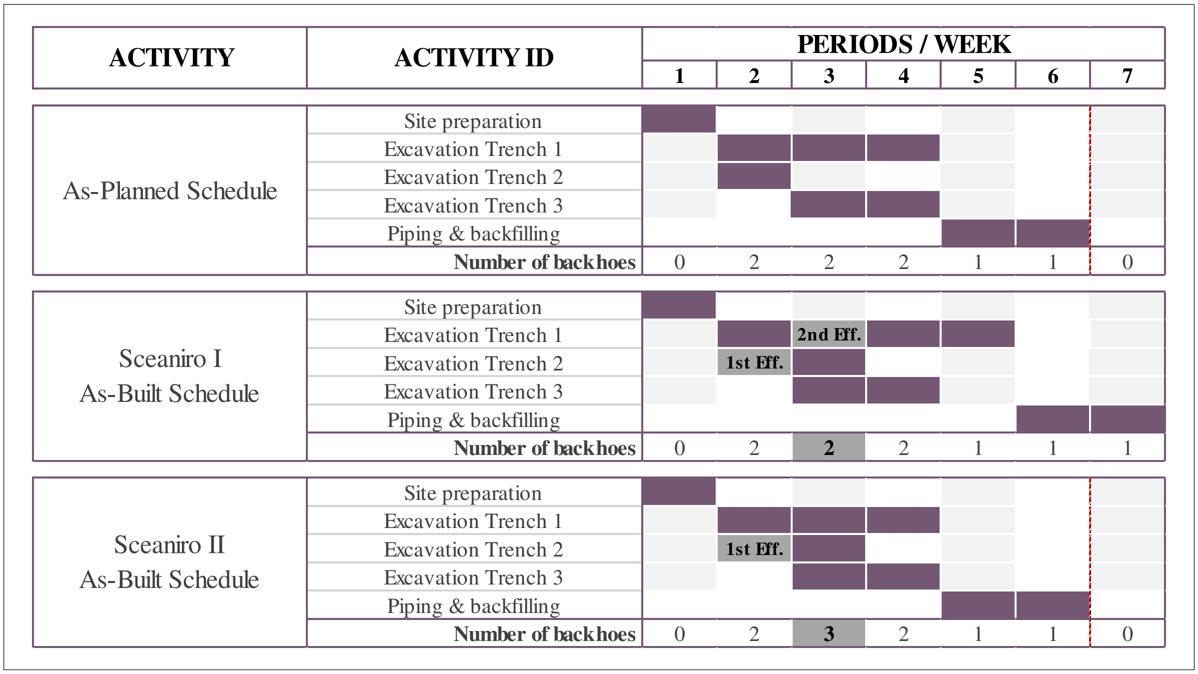


Figure 2-5: Schedules of motivating example, (adapted from Ibbs and Nguyen, 2007)

A scenario I: The delay event on day 2 extends excavation Trench 2 up to day 3 as the first effect of the delay. In Day 3, the contractor cannot perform excavation Trench 3 due to the resource conflict. The impact on day 3 is the result of the same event, which becomes the 2nd effect that extended excavation Trench 3 up to day 5 and the overall project up to day 7. In this case. There are three possible damages cost or losses, as follow:

1. The potential losses and damages for the result of extending excavation Trench 2 up to the 3rd day.

2. The potential losses and damages for the result of extending excavation Trench 1 up to the 5th day.

3. The potential losses and damages for the result of extending the overall project duration from day 6 up to the 7th day.

A Scenario II: The delay event on day 2 extends excavation Trench 2 up to day 3 as the first effect of the delay. However, the contractor performed in Day 3 for excavation Trench 3 by increasing the resource (t the contractor rented one more backhoe on day 3 to overcome this issue). Due to the delay impact on day 2, the contractor experienced an additional cost for increasing the resource to meet the completion date (day 6). In this case. There are two possible damages cost or losses, which are different and not the same, as follow:

1. The potential losses or damages as the result of extending excavation Trench 3 up to the 3rd day.
2. The potential losses and damages due to the increase of the resource on day 3.

All these potential losses and damages explained in the scenario I and II are not similar. In the scenario I, all these potential losses and damages are related to the loss of time, which have been presented in lawsuits of the construction delays. In scenario II, the potential losses or damages due to increasing the resource in Day 3 is related to the loss of time; while the potential losses or damages due to increasing the resource in Day 3 is a direct loss of money. In legal and judicial claims of construction that underpinned by the legal judgements, forensic schedule analyses must be used to prove the loss of time and therefore demonstrate any related losses due to that. Thus, the nature of such losses and damages should be incorporated in the methods of delay analysis for proving the responsibility of any direct damage or indirect losses

(Darbyshire, 1982; Unruh and Worden, 1993; SCL, 2002; Harris and Ainsworth, 2003; Ibbs and Nguyen, 2008; Bramble and Callahan, 2010). Therefore, the following section will demonstrate the types of potential damages that can be recovered by applying the delay analysis processes in the construction projects.

2.4.2.1 Damages Recoverable

Damage costs are classified in the literature at different levels within different categories, such as owner damages and losses, contractor damages and losses, direct-damages cost, indirect-damages cost, time-related damages, and cost-related damages among others. Each type of delay damages that can be recoverable involves different types of proof. Therefore, the claimant should develop and present evidence to show that the claimed delays are reasonably attributable to the responding party (Strogatz at al., 1997; Holland and Jr, 1999; Carter and Gorman, 2000; Harris and Ainsworth, 2003; Shrestha and Zeleke, 2018; Parikh et al., 2019).

Strogatz at al., (1997) described various types of delay damages that can be claimed for both the owner and contractor. In this study, the delay damages have been divided into two types of costs: owner delay damages and contractor delay damages. A liquidated damages clause governs owner's entitlement in the construction contract. However, the owner must be prepared to prove the actual damages incurred as a result of the delay in case of the absence of such a provision. While the quantity and nature of damages sought by project owners differ from owner to owner due to the type of business, the damages sought by contractors are generally similar, regardless of the specific type of project being built or the nature of the work being performed by the contractor.

Carter and Gorman (2000) divided the delay damages costs into two types of damages: direct damages and indirect damages. Those damages that arise from a breach of contract ordinarily and naturally are considered direct damages, such as lost rental value for the owner and lost profit for the contractor. This type of damages is related to different losses during the delay period and may be recoverable by the innocent party. The consequential or indirect damages generally do not flow naturally from the delay, they are considered to be losses at a different level that are not directly related to the project; such as profits, income, financing, business, reputation, and others. The ability to recover those damages may depend on several factors.

Harris and Ainsworth (2003) analysed the cost system in construction projects to identify the potential damages in the construction delay claims. The cost elements in this analysis are divided into two levels: time-related costs and activity-related costs. These types of damages can be discussed as follows: (1) due to extending the overall project time, the project will incur damages that are related to increasing the project time would be increased, such as the overhead cost and supervision; and (2) due to impacting the project progress, the project will also incur damages that are related to changing the work productivity and sequence, such as the damages of direct cost for increasing the project progress.

Holland and Jr (1999) defined four types of delay damages, which are: direct costs, indirect costs, job overhead, and general overhead. The definitions emphasised that terms of those types of damages vary in the meaning from firm to firm in construction. For example, Ahuja and Campbell (1988) take the approach for dividing construction costs into the direct cost and indirect cost. The direct costs include labour, materials, production equipment, and supplies that must be incorporated into a distinct feature of the completed work. In contrast, the indirect costs include other items that are not made a part of the completed work, such as contractors' overheads, profit, contingencies, escalation, and interest during the construction period.

Other examples include Coombs and Palmer (1989), who takes the approach of dividing construction costs into a direct cost and an indirect cost. Direct costs include any cost that can be explicitly identified with a construction project and unit of production within a construction project. However, indirect costs include any cost that can be identified with a construction project but not a specific unit of production. Also, Pratt (1995) takes another approach for dividing construction costs into (1) direct costs include material, labour, and production equipment; and (2) general expenses include indirect costs that are necessary for the facilitation of the construction project.

From the above review, it can be concluded that the construction damages cost can be incurred at three different levels for the owner or the contractor, which are as follow:

1. Damages costs at the businesses level: it includes those costs that cannot be identified readily with a specific project. For owner and contractor, general business expenses that are incurred by the home office in supporting on-going projects cannot be tied directly to a given project. At this level, the delay analysis cannot be applied and used to verify the damages costs or any additional expenses and allocate them to one of the on-going projects (Neil, 1981). As a result of delaying the project, the owner or contractor may be able to recover their consequential damages to various types of business (Strogatz at al., 1997).

2. Damages costs at the project level: it includes the costs that will be affected due to extending the project duration. At this level, the cost of the damages that are directly related to the project duration can be claimed, which should be considered during the delay analysis process to verify the responsibility among the parties for impacting the project

duration. When the overall project duration is affected, the impacted duration needs to be analysed for quantifying the cost of the damages at this level. Although the quantum of damages differs from owner to contractor during the project extension time (Strogatz at al., 1997), determining the responsibility of the total project extension time among the parties will determine the compensation cost of damages for each party (Braimah, 2013). For example, the owner damages costs at this level due to the project extension time include extended supervision, additional engineering charges, site administration, travel, site security, temporary telephone, field office supplies, bond and insurance expenses, lost profits and rents, which will not be affected unless the overall project duration is affected.

3. Damages costs at the activity level: it includes the costs that will be affected due to extending the project's activity duration. Delay, acceleration, change orders and disruption can affect the activity cost, which is not necessary to impact the overall project duration. For example, the additional cost due to extending the time for specific equipment at a specific activity may occur on the non-critical path (Harris and Ainsworth, 2003). Another example is that pushing the execution for activity on the non-critical path may incur an additional cost that are related to the time finish of the activity, without affecting the activity duration and the overall project duration. In this case, the process of the delay analysis should be able to consider the cost of the damages at the activity level for more accurate results.

2.4.2.2 Analysing the Damages Responsibility

Although assessment of any claim for delay damages usually depends on the terms of the contract, the system of the civil and conventional law has established distinct methodologies to redress the resulting injury from the failure of any party to meet the contractual commitment. For example, the claim document must explain the legal basis for entitlement, whether that is under the contract or at law (SCL, 2002). In the principles of the legal construction system, it is clear that costs resulting from the schedule impacts for which a party is entitled to compensation may be claimed (Bramble and Callahan, 2010). Therefore, claims analysts, lawyers, and other construction professionals should be able to assess the effects on the project and quantify any damages or losses.

Most claims for delay are dealt with retrospectively, and the claimant is usually forced to rely on the project records to attempt to establish a causal relation for the identified losses, which is all too often inadequate for sufficiently evidencing a delay claim (Nelson, 2011). Therefore, construction delay claims have been the object of vast and considerable efforts aimed at enhancing the documentation of the causal events and entitlement issues, along with efforts to quantify the damage caused by schedule impacts and the resultant asserted cost damages. In practice, the analyses and quantification of damages are usually considered well after the scheduling and responsibility for the schedule impacts analyses have begun. The documentation obtained through the scheduling and responsibility analysis efforts will provide the vital evidence pertaining to the events of the schedule impacts for the damages incurred (Harris and Ainsworth, 2003; Alena et al., 2015; Yang and Teng, 2017; Lari et al., 2019).

Carter and Gorman (2000) described the processes to prove damages that lie with the party making a claim. The claimant must determine the claim type, whether it is a delay claim, disruption claim, acceleration claim, or scope claim. In each claim, the claimant should specify the damages type, whether direct damage or indirect damage. Additionally, the claimant needs to accurately identify the cause and establish the entitlement to a claim. The described processes for proving any delay damages can be summarised as follows:

1. The initial step to prove the entitlement is to identify the impact on the schedule and determine why the impact occurred. This step assigns the impact responsibility to an appropriate party. The impact on the schedule is determined on case-by-case basis for each impact on the schedule that occurred. Once the impacts on the schedule have been quantified, each impact should be analysed to ascertain whether it should affect the excusability or compensability of any other impacts. This stage of the analysis relies heavily on the project record. Therefore, comprehensive documentation dramatically increases the reliability of the entitlement analysis.

2. Once the schedule impacts have been allocated to the responsible party, analysing the liability for any losses or damages can be conducted. Two critical elements are necessary to prove the recoverable damages: (1) whether the impact is excusable, and if so (2) whether the damages arising from that impact are compensable. Although the common law provides general rules regarding excusability and compensability in determining the recoverable damages, it has been noted that a delay that would ordinarily be non-compensable may be transformed into a compensable delay (Alshammari et al., 2017). Therefore, the determination of responsibility for schedule impacts (in this stage) will depend on the facts surrounding the claim, precise measurements for determining the real delay cause, and proper analyses for allocating its responsibility (Khandel and Soliman, 2019; Yates and Epstein, 2006).

3. Once the impact on the schedule has been identified, and its liability has been established and classified, the schedule can be analysed to determine the responsibility for any losses

or damages to the contracting parties. In this stage, the claimant should attempt to prove that the damages that have incurred is the result of impacting the schedule by another party (Strogatz at al., 1997). There are many existing Delay Analysis Techniques (DATs) which can be used to prove the responsibility for the delay damages. However, each of these DATs, which will be discussed in chapter 3, produce different results for the damages responsibility when applied to the same set of claim data (Braimah, 2013). These differences can be attributed to their differential capability to consider the DAIs.

4. The standard practice for capturing claimable damages is to segregate the costs that are a direct result of impacting the project schedule (Harris and Ainsworth, 2003). However, the quantification of damages is complex and challenging because of the different attributes of the contracting parties. When events occur that impact the project schedule, the project cost will be impacted and result in different losses for each party, such as the value of the project for the owner or the cost to the contractor of extending the project performance. Thus, the damages and losses sustained by project owners will be different from those sustained by project contractors. Furthermore, the damages and losses will differ between projects (Strogatz at al., 1997). Therefore, the method of analysis should possess the capability of capturing claimable damages for any case of schedule impact.

2.5 The Current Practice of Delay Claims Analysis

From the above review of the related literature, the direct schedule impacts include direct delays and direct disruption, which could cause a loss of time. Furthermore, these impacts may lead indirectly to further delays or/and disruptions to the schedule, which may additional delays or/and disruptions as the result of resource conflict, loss of productivity, or PFMD

(Bramble et al., 1990; Trauner, 1990; Wickwire et al., 2003; Assaf and Al-Hejji, 2006; Matt, 2010; Alshammari et al., 2017; Zhao and Dungan, 2018).

The responsibility analysis for any direct or indirect loss of time that happened on the schedule should be considered at a stage prior to the liability analysis for any potential losses or damages due to the loss of time. For example, the responsibility for the damages cannot be carefully measured if the responsibility for the loss of time due to resource conflict has not been allocated accurately, as discussed in section 2.4.1.1 (Ibbs and Nguyen, 2007). Thus, the excusability and compensability for any loss of time and therefore the responsibility for potential damages cannot be determined prior to allocating the responsibility for any loss of time on the schedule (Bramble and Callahan, 2010). Thus, the analysis at this stage (stage1) includes the determination of responsibility for any direct or indirect cause of time lost, which includes the responsibility analysis for the loss of time due to resource conflict, loss of productivity, and PFMD.

Because the processes for determining the responsibility for any loss of time differ from those that determine the responsibility for any losses or damages due to the loss of time, a large amount of information is required for the analysis. This fact will depend on the facts surrounding the claim, precise measurements for identifying the real delay cause, and proper analyses for allocating its responsibility (Yates and Epstein, 2006). For example, if the owner causes a delay to activity and another delay occurs after the delay caused by the owner, the responsibility analysis for the second delay should be conducted to assess the cause of the second delay and assign its responsibility and determine whether it has occurred as a consequence of the first delay or due to another cause. Thus, it is required to obtain a resource-loading schedule, data for productivity before and after the impact, documentation for granting an extension of time, and many other data (Ibbs and Nguyen, 2007; Braimah, 2013; Yang et al., 2014; Lee, 2016; Alshammari et al., 2017; Ottesen and Martin, 2019).

The process that is undertaken following the resolution of responsibility for any loss of time that occurred on the schedule requires a different approach. Determining the responsibility for all potential losses and damages that the contracting parties may claim due to the project delays is the objective of DAT (Braimah, 2013). At this stage (stage 2), the requirements would be entirely different from the prior stage (stage 1). While the prior stage of the analysis requires a diverse application of data and methods, this stage of the responsibility analysis for damages can be conducted based entirely on the responsibility for the schedule delays or losses as determined using the project schedules (Alkass et al., 1996; Al-Gahtani, 2006).

A review of the existing literature shows the potential for tracking the responsibility based on any losses or damages (see, e.g. Mohan and Al-Gahtani, 2006). For example, claiming damages due to schedule impacts would involve three steps. First, proving the entitlement by specifying the event on the schedule, identifying its effect, and determining its responsibility (Cushman et al., 2001); this process should be determined at stage1. Second, demonstrating and proving a causal link between schedule cause and effect or the relationship between the damage and schedule impact (Finke, 1997); this is the objective of the analysis at stage2. Third, computing the cost damages, which are subject to several criteria regarding the burden of proof from the innocent parties. Therefore, once the responsibility of all schedule impacts (delays, accelerations, change orders and disruptions) have been attributed to the responsible party in the analysis of stage1, the effects can be analysed in the analysis of satge2. However, the analysis in stage 2 could be affected by the DAIs, such as concurrent delays. Thus, ignoring

DAIs during the delay analysis process would also affect the ability of DATs to produce an accurate result in the delay claims analysis.

2.6 Summary

This chapter has discussed construction delay claims and the current practice of delay claims analysis. It began by discussing the types of schedule impacts and their effects. The effects of schedule impacts were also discussed based on the issues of time and cost that the project may incur.

This chapter also reviews the current practice for analysing schedule impacts in terms of any loss of time due to direct responsibility and indirect responsibility. This includes direct delays, direct disruptions, change orders and accelerations, which may lead to another loss of time due to the resource conflict, loss of productivity, and PFMD. Thus, the analysis of the liability for any losses or damages is based on the responsibility for any loss of time caused by the schedule impacts. However, the analysis of the responsibility for any losses or damages is subjected to many DAIs. The DAIs can be used to evaluate the DATs for producing an accurate result during the analysis process. Thus, chapter 4 aims to evaluate the existing DATs based on the current practice of delay claims analysis, as discussed in section 2.5, as well as the DAIs, which will be discussed widely in chapter 3.

CHAPTER THREE: DELAY ANALYSIS ISSUES

3.1 Introduction

This chapter reviews the Delay Analysis Issues (DAIs) that have a significant effect on calculating the responsibility during construction delay claims analysis and therefore determining the responsibility for any potential losses or damages to the contracting parties. These issues include individual delay and acceleration events, concurrent delays, concurrent effects, pacing delay, total float consumption and ownership, the issue of delay damages and recoverable day, and the issue of cost damages for the delay and acceleration. This review focuses on the discussion of DAIs and their definitions, their occurrence situation on the schedule and their effects on analysing the schedule impacts. Including the DAIs during the delay analysis process is an indicator of the capability of a method/technique in analysing the delay claims and producing valid results. Further, ignoring one or more of the DAIs may affect the results for the schedule delay analysis, therefore affecting the responsibility for the damages.

3.2 Issues of Delay Analysis

There have been continuous improvements focused on addressing critical issues relating to delay claims analysis. In various contributions aimed at enhancing smooth delay claims settlement and reducing the high level of disputes, many issues relating to the delay analysis have been presented, which include the following: concurrent delays (Arditi and Robinson, 1995), pacing delays (Zack, 2000), accounting for migration of the critical path (Kartam, 1999), dealing with the effects of acceleration (Arditi and Patel, 1989), float ownership (Al-Gahtani and Mohan, 2007), productivity losses (Zhao and Dungan, 2018; Lee et al., 2005), resource allocations (Ottesen and Martin, 2019; Ibbs and Nguyen, 2007) and many other relevant issues that have also been reported by different authors in the literature (Braimah, 2013; Al-Gahtani, 2006).

Each of the following issues will be discussed based on their the criticality of their occurrence on the schedule, their impacts on the project completion date or the total floats and their effects for any potential damages/losses and benefits/savings due to their impact. This critical analysis will help to highlight the DAIs that have any effect on determining the responsibility of any damage at the project-level and the activity-level, as discussed in Chapter 2.

3.2.1. The Issues of Individual Delay

The individual delay event; including change order and disruption, is the underlying issue for analysing the project delays, which have been discussed in many kinds of literature (see for example Shi et al., 2001). As discussed in chapter 2, when a delay event (include change order and disruption) occurs on the project schedule, the responsibility of this event should be defined first based on the time-related effect. After that, the analysis process should determine any effect for its occurrence to analyse the cost related effect (Bramble and Callahan, 2010).

Figure 3-1 shows an example of the two possible scenarios of individual delay events on the project schedule. Scenario A demonstrates the impact of delay event when it has occurred on the critical path (day 5). Because the delay in this scenario has occurred on the critical path, the delay has extended the project completion date and increased the Total Float (TF) on the non-critical path(s). Scenario B demonstrates the impact of a delay event that occurred on the non-critical path (day 5). Because the delay in this scenario has occurred on the non-critical path, the delay has decreased the TF on the non-critical path(s). Therefore, the two possible effects of any individual delay event on the schedule. The analysis of the two scenarios are summarised in Table 3-1, which will be discussed as follow:

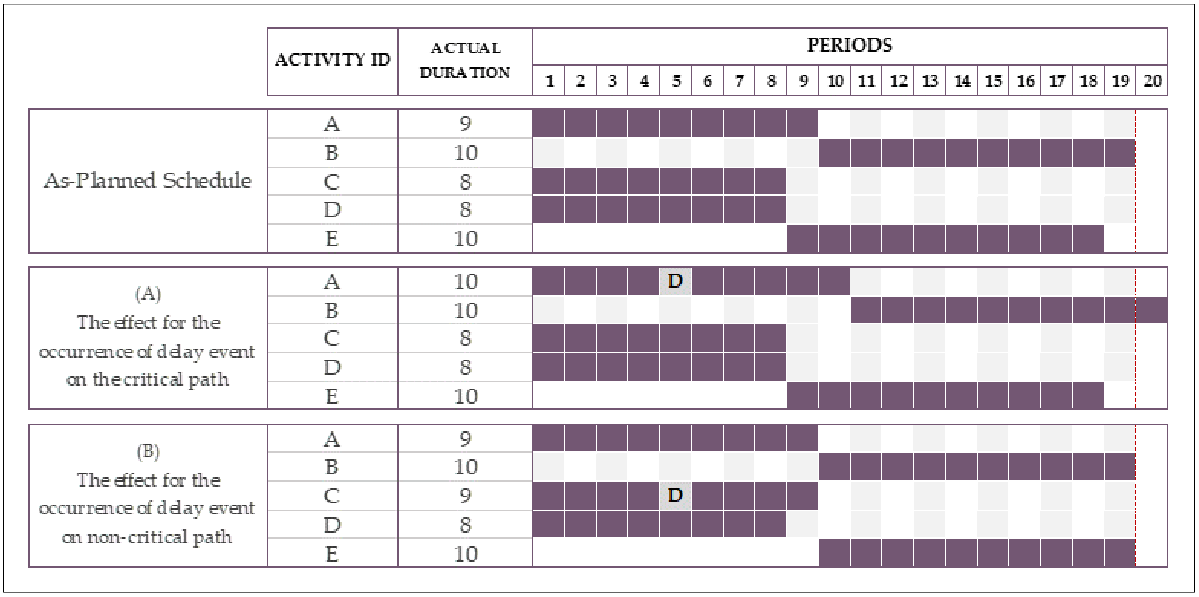


Figure 3-1: The possible two effects of individual delay events on the schedule

Table 3-1: The possible effects of individual delay event on the project schedule

Scenario	The Impacted Path	The Effect On	
		Project Completion Date	Project Total Float
A	Critical	Delayed	Increased
B	Non-critical	-	Decreased

In Scenario (A), the delay that occurred on day 5 has extended the project completion date. This delay event also increased the total float on the non-critical path on day 20. In this scenario, the analysis process should have the capability to calculate the impact on the overall project duration and determine the responsible party (Alkass et al., 1996). Also, the increased on the float generated by this delay in Day 20 should not be neglected during the analysis if the other party has consumed it (Al-Gahtani, 2006), and without a new commitment to the new completion date or granted an Extension of Time (EoT) up to day 20 (SCL, 2002).

In contrast, scenario (B) shows the delay that occurred on day 5 has occurred on the non-critical path (C-E) and consumed one day of the total float. This delay event has not extended the project completion date, while the total float on day 19 on the same path have consumed. In this scenario, the analysis process should have the capability to calculate the impact on the total float and determine the responsible party (Shrestha and Fathi, 2019; Al-Gahtani, 2006).

In these scenarios, the analysis process should determine the effects of the individual delay event on delaying the project completion date and (or) changing the amount of the total floats. It means that the analysis process should have the capability to: (1) calculate any extension on the project completion date and determine the responsibility for this extension; and (2) compute any increase or decrease in the total float. The result of the analysis would determine: (a) which of the contracting party is responsible for delaying the project completion date, and who has the right to own any increased in the total float; and (b) which of the contracting party is responsible for consuming the project float (Al-Gahtani and Mohan, 2007; Bramble and Callahan, 2010).

The two possible effects of scenario (A) and (B) would lead to identifying any potential losses or damages that may happen due to loss of time by this delay event (Cushman and Carpenter, 1990). As shown in Table 3-2, the potential losses or damages may happen at two different levels. In scenario A, the possible damages and losses would happen at both project-level and activity-level. The potential damages at the project level would be due to extending the project completion date from day 19 up to day 20. However, the potential at the activity-level, the effects would be due to extending the Duration (D) of activity A and pushing the Early Start (ES) of activity B. For scenario B, the potential damages and losses would happen at the activity-level only. Extending the Duration (D) of activity C and pushing the Early Start (ES) of activity E are the possible and potential damages or losses. Therefore, the delay analysis process should have the capability to consider the responsibility, among the contracting parties, for any potential losses or damages on the schedule due to the delay event at the project-level and the activity-level (Strogatz et al., 1997).

Table 3-2: The potential losses and damages of an individual delay event

Scenario	**At the project level**	**At the activity level**	
		ES	**Duration**
A	1 day	1 day related to the Act. B	1 day related to the Act. A
B	0	1 day related to the Act. E	1 day related to the Act. C

3.2.2. The Issues of Individual Acceleration

The issue of individual acceleration event on impacting the project schedule is one of the delays analyses issues (Harjanto, 2019; Al-Gahtani, 2006). Figure 3-2 shows an example of the two possible scenarios of individual acceleration events on the project schedule. Scenario (A) demonstrates the impact of acceleration event when it has occurred on the critical path (day 6). Because the acceleration in this scenario has occurred on the critical path, the acceleration has reduced the duration of the project completion date and decreased the total float on the non-critical path(s). Scenario (B) demonstrates the impact of the acceleration event that occurred on the non-critical path (day 14). Because the acceleration in this scenario has occurred on the non-critical path, the acceleration has increased the total float on the non-critical path(s). Therefore, the two possible effects of any individual acceleration event on the schedule. The analysis of the two scenarios are summarised in Table 3-3, which will be discussed as follow:

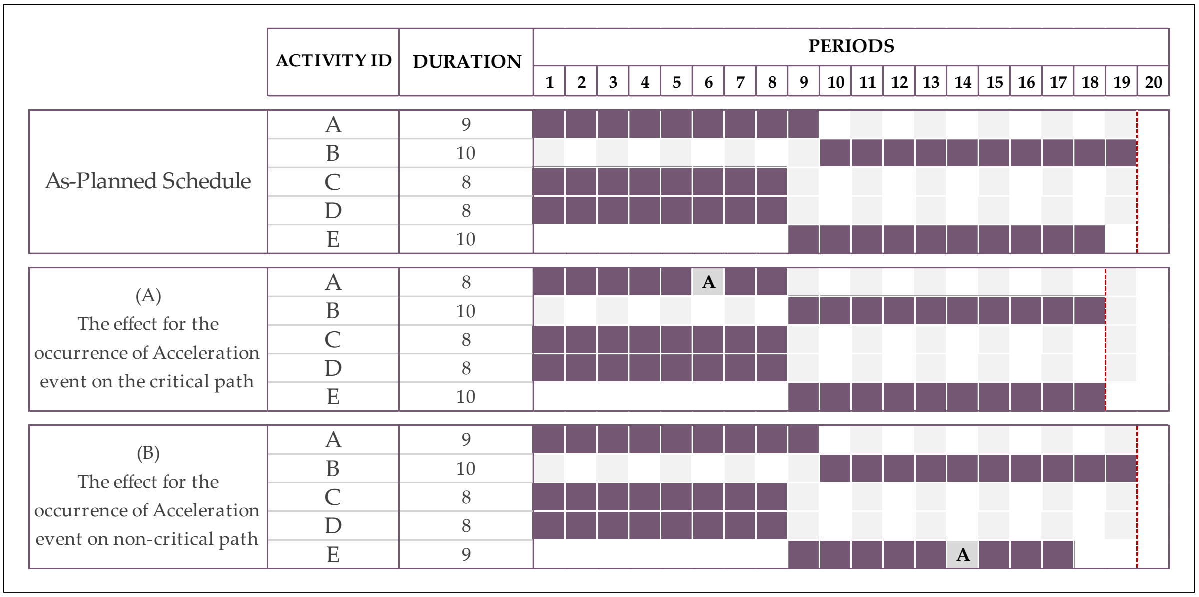


Figure 3-2: The possible two effects of individual acceleration events on the schedule

Table 3-3: The possible effects of individual acceleration event on the project schedule

Scenario	The Impacted Path	The Effect On	
		Project Completion Date	Project Total Float
A	Critical	Accelerated	Decreased
B	Non-critical	-	Increased

In scenario (A), the acceleration event has occurred on the critical path (A-B), which have impacted the project completion date. In meanwhile, this event has changed the total float on the non-critical path(s) of the project. Due to this event, the non-critical paths (C-E) and (D-E) become critical paths, with zero total float. In scenario (B), the acceleration event has occurred on the non-critical path that contributed to increasing the floats of the impacted path(s). Therefore, the two possible impacts of individual acceleration event on the construction project schedule are, as shown in Table 3-3: (1) reducing the overall project completion date and reducing the float on the non-critical path(s) due to its occurrence on the critical path; or (2) increasing the float on the non-critical path(s) due to its occurrence on the project non-critical path.

These two possible impacts of scenario (A) and (B) would lead to identifying any potential benefits or savings in the total cost due to the acceleration event, as shown in Table 3-4, the potential benefits or savings may happen at two different levels. In scenario A, the potential benefits and savings happened at both project-level and activity-level. At the project-level, the potential benefits and savings would happen due to the reduction of the completion date from day 19 to day 18 and reducing the total project cost related to the total project completion date by one day. At the activity-level, the potential benefits and savings would happen due to accelerate the Duration (D) of activity A and reduced the related cost one day and accelerate the Early Start (ES) of activity B and reduced the related cost one day. For scenario B, the potential benefits and savings happened at only activity-level. Accelerating the Duration (D) of activity E reduces the related cost one day is the only potential benefits and savings due to this acceleration. Therefore, the delay analysis process should have the capability to consider the responsibility, among the contracting parties, for any potential benefits or savings on the project due to the acceleration event at the project-level and the activity-level. During the delay analysis process, defining the acceleration type, acceleration responsibility, and determining the effect are critical factors to achieve an accurate result of project delay analysis (Al-Gahtani, 2006).

Table 3-4: The potential benefits or savings of individual acceleration event

Scenario	**At the project level**	**At the activity level**	
		ES	**Duration**
A	(-1) day	(-1) Day related to the Act. B	(-1) Day related to the Act. A
B	0		(-1) Day related to the Act. E

3.2.3. The Issues of Concurrent Delays

The concurrent delay considers as one of the most significant issues in the delay claims analysis. Society of Construction Law (SCL), in the second edition of delay and disruption protocol (2017), defined the concurrent delay as that "two or more delay events that their occurrence at the same time, one is an owner delay, the other is a contractor delay, and the effects of which felt at the same time". Also, the protocol provides a guide for analysing the issue of concurrent delay, where each of the delays must happen at the same time frame and lead to delay the project completion date (SCL, 2017).

To analysis the responsibility in a situation of concurrent delays, there are two rules used in US courts: the "Easy-Rule" and the "Fair-Rule" (Kraiem and Diekmann, 1987). As shown in Table 3-5, in Easy-Rule, any concurrent delay that has two different responsible parties is the responsibility of neither party (EN delay). Under the Fair-Rule, the responsibility for a concurrent delay belongs to neither party for any delay happened concurrently with EN. However, for the concurrent delay between EC and NE under the Fair-Rule, apportioned between both parties to the contract, while in the Easy-Rule it is not.

Table 3-5: Analysing the responsibility of concurrent delay

Concurrent Delay		**Delay Analysis**	
Delay 1	**Delay 2**	**Easy-Rule**	**Fair-Rule**
EC	EN	EN	EN
NE	EN	EN	EN
EC	NE	EN	½ EC + ½ NE

There is only one possible impact for the concurrent delay on the schedule. Concurrent delays must occur on the project critical paths and extended the project completion date (AACEI, 2011). As shown in Figure 3-3, EC delay (on day 14) and NE delay (on day 14) have contributed in extending the overall project duration one day (from day 19 up to day 20). In the meanwhile, these concurrent delays have also contributed to increasing the total floats on non-critical paths of the project (one day of float on day 20 for the paths D-J and E-J).

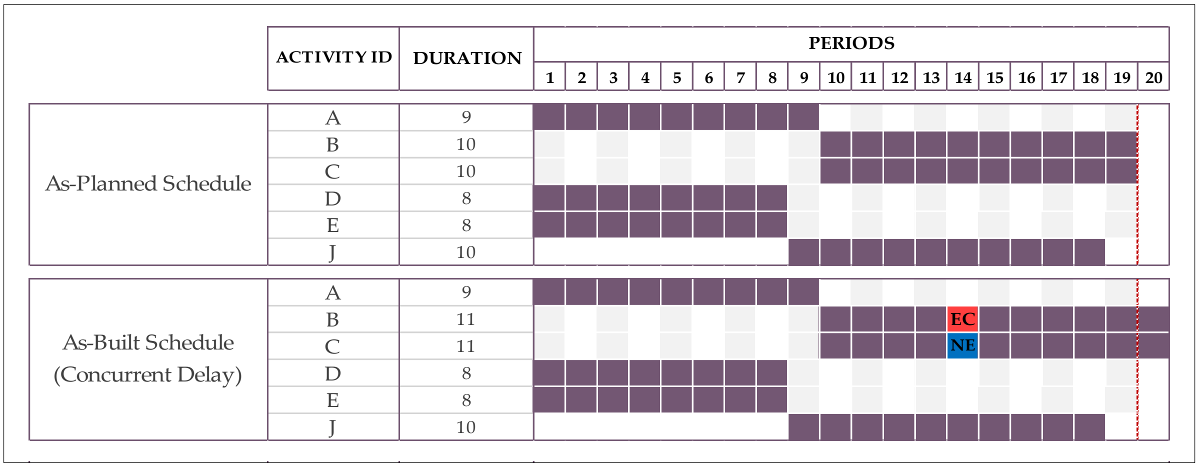


Figure 3-3: The possible effect of concurrent delays on the schedule

In the delay claims process, there are three significant difficulties for analysing concurrent delays (Arditi and Robinson, 1995). The first difficulty is that, if the events of the concurrent delay occur across two or more concurrent activities that have different start and finish dates, then the period of concurrency of the two or more delay events is difficult to define because only portions of these activities are concurrent. The second significant difficulty involves the formation of new critical paths due to consuming the total floats of non-critical activities. The third difficulty involves the issue of pacing delays (Al-Gahtani, 2006). However, the possible effects at the project-level and activity-level can be determined, as shown in Table 3-6.

Table 3-6: The possible effects of concurrent delays

Case Analysis	At the project level	At the activity level	
		ES	Duration
EC delay (day 14)	1 day	0	1 day related to the Act. B
NE delay (day 14)		0	1 day related to the Act. C

3.2.4. The Issues of Concurrent Effects

Concurrent effects are "the situation where two or more delay events arise at different times, but the effects felt at the same time" (SCL, 2017). The impact of the concurrent effects is similar to the impact of the concurrent delay in term of the occurrence timeframe for their effects and for impacting the project completion date. Table 3-7 shows the similarity and dissimilarity between concurrent delay and concurrent effects. While the situation of the concurrent delay requires that the events to occur at the same time and the effects of which are felt at the same time, the concurrent effect (include delay events and acceleration events) only require the effect to occur at the same time.

Table 3-7: The different between concurrent delays and concurrent effects.

The issue	**Conditions**	
	The occurrence time of the Events	**The occurrence time of the Effects**
Concurrent Delays	At the same time frame	At the same time frame
Concurrent Effects	At the different time frame	At the same time frame

To illustrate the similarities and differences between concurrent delays and concurrent effects and their effects, Figure 3-4 shows two situations for concurrent delays and concurrent effects that have occurred on the schedule. To analyse their impacts, AACEI (2011) have discussed the modelled methods for analysing the schedule impacts, which are Additive Modelling and Subtractive Modelling. In these modelled, the analyst inserts or extracts the schedule events representing delay into or from a Critical Path Method (CPM) network and compares the calculated results of the before and after states.

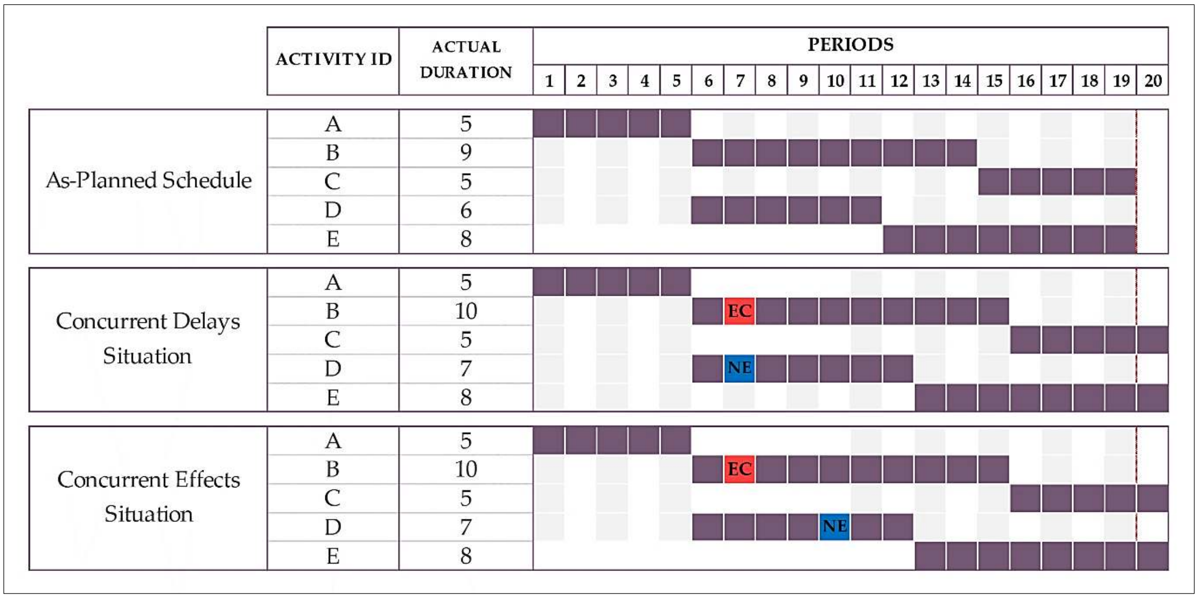


Figure 3-4: The impact of concurrent delays and concurrent effects on the schedule

In additive modelling method, the concurrent delays situation for both EC and NE on day 7 have contributed and led to delay the project completion date up to day 20. Also, in the subtractive modelling method, eliminating the impact of one impacted delay in the situation of the concurrent effects (EC on day 7 or NE on day 10) will not change the delay on the project completion date from day 20 to day 19. Therefore, the potential damages or losses for the concurrent delays and the concurrent effects at the project-level are similar by using additive and subtractive modelling of delay analysis (SCL, 2017; AACEI, 2011).

Figure 3-5 shows an example of two scenarios of the potential damages or losses due to the concurrent effects. In scenario (A), the delay that happened to the overall project duration (from day 19 up to day 20) could not be removed without removing both delays. In scenario (B), pushing the Early Finish (EF) of activity J (from day 18 up to day 19) and consuming the float (on day 19) have occurred due to both delays (NE delay on day 4 and EC delay on day

7). Table 3-8 shows the potential damages or losses at the project-level and the activity-level for both scenarios (A) and (B).

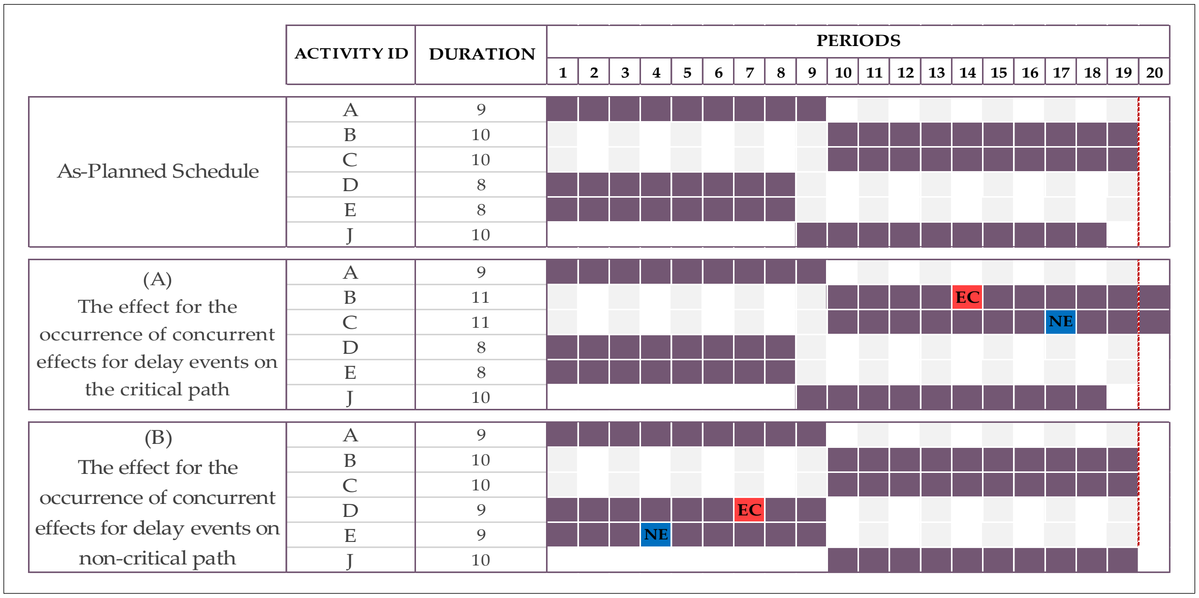


Figure 3-5: The possible two effects of concurrent effects for delay events on the schedule

Table 3-8: The possible damages and losses for concurrent effects due to delay events.

Case Analysis	**Delay Event**	**At the project level**	**At the activity level**	
			ES	**Duration**
A	EC (day 14)	1 day	0	1 day related to the Act. B
	NE (day 17)		0	1 day related to the Act. C
B	NE (day 4)	0	0.5 day related to the Act. J	1 day related to the Act. D
	EC (day 7)		0.5 day related to the Act. J	1 day related to the Act. E

Therefore, the issues of concurrent effects situations should not be ignored during the delay analysis, which differs from the case of pacing delay that will be discussed and covered in the following section (Section 3.3.5). In the case of concurrent effects, the Extension of Time (EoT) has not been granted due to the first delay, while the EoT has granted in pacing delay situation (Zack, 2000). Therefore, the second delay in the concurrent effect situation would remain responsible for any potential damages with the first delay. Also, the possible impacts of the concurrent effects may lead to another DAI, which is the issue of floats consumption (Al-Gahtani and Mohan, 2007). When the completion date extended by concurrent effects, the total float will increase on the non-critical path(s). Therefore, impacting the project completion date and the project total floats are two DAIs that should be considered during the analysis process before any damage's responsibility can be determined (Fawzy et al, 2018; Nguyen and Ibbs, 2008).

3.2.5. The Issues of Pacing Delay

A pacing delay can be defined as "the deceleration of the project work, by one of the project parties to the contract, due to a delay to the end date of the project caused by the other party, to maintain steady progress with the revised project schedule". For example, in the case of the owner caused a delay on the critical path, the contractor may decide to decelerate non-critical work activities in response to the owner delay. In this case, the contractor benefits from the pacing delay caused by the owner by claiming compensation for any damages in the project time, while also reducing costs by decompressing certain non-critical activities (Zack, 2000).

To understand the pacing delay issue, consider a situation, as shown in Figure 3-6, in which an owner causes a delay (EC delay on day 7) in the critical path and increases the floats of the non-critical path activities. Now, if the contractor consumes the increase of the float by decelerating the work of non-critical activities (NE delay on day 10), then the contractor can receive the benefit of consuming the increased float resulting from the owner's critical path delay. Also, since the owner is responsible for any damages resulting from delaying the critical path, only the owner has the right to consume this increased float (Al-Gahtani, 2006).

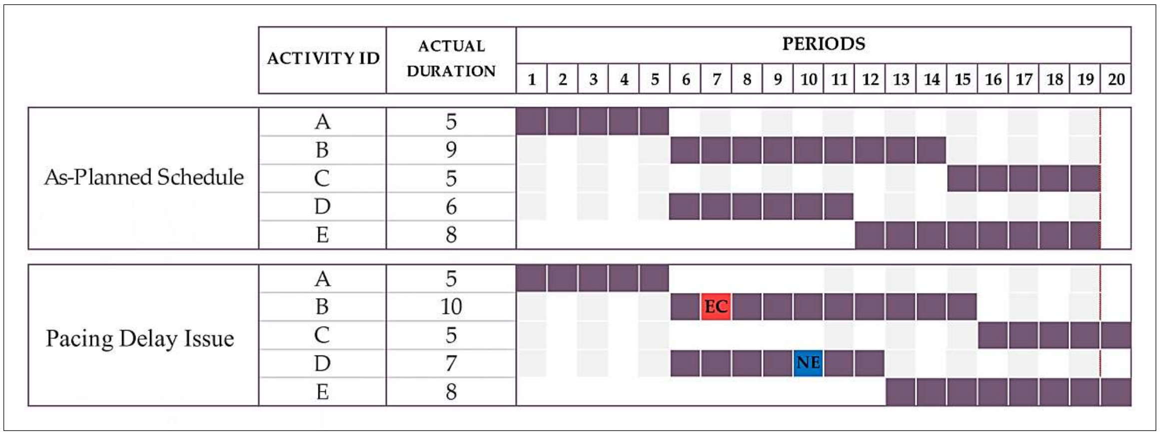


Figure 3-6: Pacing delay issue

The float on day 20 (that have consumed by the contractor delay on day 10) generated by the owner delay (due to EC delay on day 7). Al-Gahtani (2006) discussed this issue in the delay analysis process, which this issue has not yet resolved to the satisfaction of the contracting parties.

3.2.6. The Issues of Total Float Consumption and Ownership

In the Critical Path Method (CPM), Total Float (TF) or slack defined as "the total amount of time which allow activity for a delay without delaying the project completion date." It can be used as an indicator to know how many days left for an activity to be critical. The issue of float significantly affects the analysis of delay claims due to its potential of changing the successor non-critical activity into critical and vice versa. Also, the associated issues of changing the total float as a result of impacting the critical or non-critical path would affect the result of the analysis for delay responsibility. However, the float ownership is another vague issue in delay analysis, which can affect the project as to the result of float consumption by the contracting parties.

The following questions are the common issues related to the total floats and float ownerships during the analysis of schedule delay (Nguyen and Ibbs, 2008). Who owns the total floats in the initial As-Planned schedule? Who owns the increase in the amount of the total floats? Moreover, as a result of changing the initial total float, who has the right to get a credit or discredit for changing the total float? In this regard, floats ownership usually specified in the conditions of the contract. The construction project contracts typically state that float belongs to the owner, the contractor, the project, or on a “first-come-first-served" basis (Arditi and Pattanakitchamroon, 2006). If not, several concepts dealing with float ownership have been proposed and discussed in the literature (Ponce de Leon, 1986; Householder and Rutland, 1990; De La Garza et al., 1991; Pasiphol, 1994; Pasiphol and Popescu, 1994; Pasiphol and Popescu, 1995; SCL, 2002; Prateapusanond, 2003; Al-Gahtani, 2006). These concepts summarised as follow:

1. Project Concept (SCL, 2002). It is the concept of “First-come-first-served” and entitles both the owner and the contractor the right to consume the project floats (Arditi and Pattanakitchamroon, 2006). When a party-cased delay occurs first and uses up the total floats, the other party becomes responsible for causing any delay that extend the project completion date. The UK delay and Disruption protocol’s position on float ownership is that if the clause stating the entitlement of float is not specified in the contract, the float should belong to a project (SCL, 2002). Therefore, it is the most popular concept for the float ownership that introduced in the legal cases because its flexibility for both parties to use their right in consuming the project floats. However, it has several drawbacks. It does not consider the contract risk. For example, in a lump sum contract, the owner has the right to consume the project floats without the contractor’s ability to manage the contract

risk. Also, it lacks a precise method of distributing the project floats among the contracting parties to manage their risk, which may lead to unsound analysis for the project delay and create a dispute environment.

2. Owner Concept (Pasiphol, 1994; Prateapusanond, 2003). It entitles the owner to own the project total floats and disentitles the contractor to consume the project floats. The benefit of this concept is the ability to account the contractor delays and therefore resolving the pacing delay issue. However, this concept has several drawbacks. For example, in a lump sum contract, the contractor would accept the contract risk with a limitation imposed on the contract's right to manage it or use the resource levelling.
3. Contractor Concept (De La Garza et al., 1991). It entitles the contractor to own the project total floats and disentitles the owner to consume the project floats. The support of this concept is that the contractor has the right to manage the project work, the equipment, and the cash flow to achieve the project completion date on time and within the planned budget. Although this concept has a legal base, it still has some drawbacks. For example, in some contracts where the owner bears the contract risk, the concept does not allow the owner to utilise the floats. Besides, the contractor can consume the floats, which can lead to increase the project risk as well as the project cost, and the owner solely bears the risk.
4. Bar Concept (Ponce de Leon, 1986). It is a concept for accounting the responsibility of delay on the critical and non-critical paths. It considers the delay on the non-critical path as a critical delay. The purpose of this concept is to minimise the effect of consuming float with the delay analysis result. One of the weakness and drawbacks of this concept is the restriction of both parties from using the as-planned float and therefore prevents their right

in managing the project and (or) minimise the cost. Also, it is not considered the increased in the float as the critical paths delayed.

5. 50/50 pre-allocation concept (Prateapusanond, 2003). This concept starts by dividing the floats between the contracting parties and works in tracking the responsibility for consuming the amount of the float for each party. The concept has many drawbacks (Nguyen and Ibbs, 2008). For example, it allows only 50% for the float consumption for each party, which makes the use of this concept impossible or problematic.
6. Commodity concept (De La Garza et al., 1991). Many believe that the contractor owns the floats but must trade it on demand by the owner. Therefore, this concept gives the contractor a full contractor over the float, with the flexibility of the owner to buy any float from the contractor throughout a pre-agreement formula designed in the contract. One of the weakness and drawbacks of this concept is the fact that the owner in some contract carries the risk and have the right to own the float.
7. Contract risk concept (Householder and Rutland, 1990). It is a concept that allows the party who loses or gains as a result of the fluctuation in the project cost to use and own the float as a resource. For example, in a lump sum contract, the contractor has the right to own the float. In contrast to a cost-plus contract, the owner has the right to own the float. One of the weakness and drawbacks of this concept is that both parties cannot consume more than the allowed float based on the contractual risk. Although the concept has a ground base for the rational argument of float ownership, it does not specify the methodology of sharing the float between the parties according to their contract risk.
8. Path distribution concept (Pasiphol and Popescu, 1995; Pasiphol, 1994; Pasiphol and Popescu, 1994). It is the concept of allocating the total float to individual activities on the

paths based on their duration to become all the activities as a critical. Although this concept allows the contractor to manage the resource within allowed distributed float, it has many drawbacks. For example, this concept does not discuss the owner's right to own the float in a situation of carrying the project risk. Also, it does not consider the increased of the float as the result of delaying the project.

9. Total Float Management concept (Al-Gahtani, 2006). It is the concept of tracking the changes on project floats due to delay events. In this method, the responsible party will be credited/discredited total float to the affected activity due to increased/decreased of float after the effect and will gain/loss floats of successor activities. One of the weakness and drawbacks of this method is the apportionment of concurrent delay since it only considers the number of delays caused by each party rather than the degree of importance of different paths and (or) activities on which these delays occur. Proper consideration of this degree inequitably apportioning concurrent delays is essential (Ibbs and Nguyen, 2007). Another drawback of this method is the fact that the total owner delays and contractor delays can be more significant than total project delays, which is difficult to accept in the industry (Nguyen and Ibbs, 2008).

The result of analysing the construction delay claims can be affected by the different views regarding the float and float ownership float (Arditi and Pattanakitchamroon, 2006). Also, increasing or decreasing the project float(s) is an issue during the delay analysis process and could lead to another issue in delay analysis, such as pacing delay, concurrent effects, resource levelling and other analysis issues (Kraiem and Diekmann, 1987; Arditi and Robinson, 1995; Chehayeb et al., 1995; Al-Gahtani, 2006). Therefore, to help minimise potential project dispute, there are three questions should be considered during the delay analysis process before any damage can be determined, which are: (1) Who own the original floats? (2) What is the effect that occurs on the floats? Moreover, (3) Who is responsible for the effect?

3.2.7. The Issues of Damages in Recoverable Day

The ultimate objective for the delay-related disputes is to identify and determine who is responsible for any loss or damage (Shrestha and Zeleke, 2018). As such, damages incurred at the time of a delay should be estimated and determined at the recovery period. Scott and Harris (2004) noted that whether the level of damages during the extended period of the project schedule or that at the time of the delaying event should be paid is controversial, which implies that the timing of delays fundamentally matters in apportioning delays and damages. For instance, if an owner and a contractor simultaneously delay two critical activities, it is difficult to accept that their effects on project costs are similar. To understand the damages and recoverable day of that damages, Figure 3-7 visualises this issue.

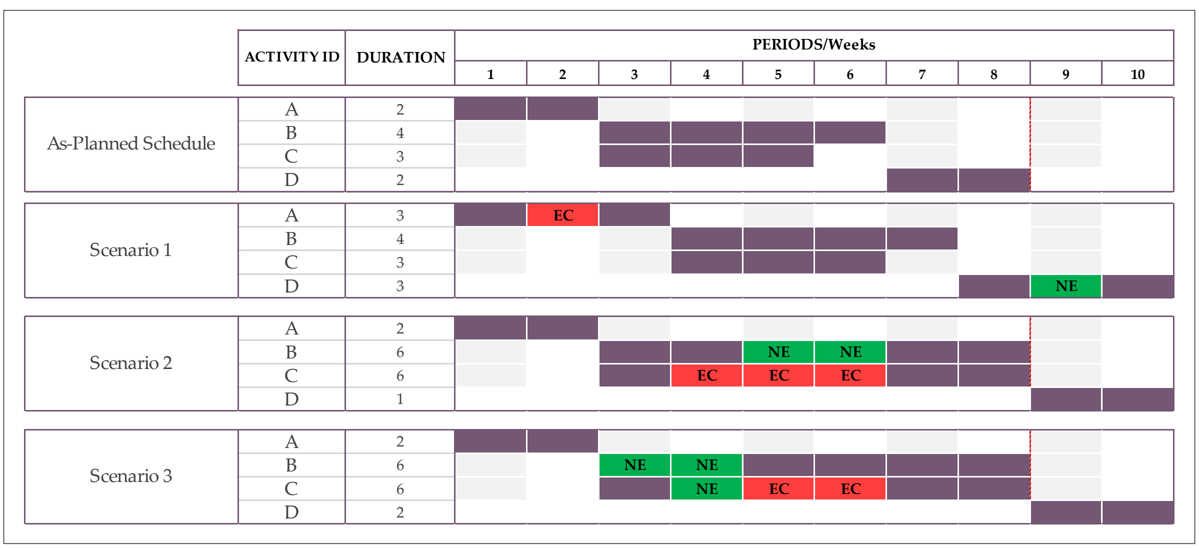


Figure 3-7: Issues of damages and recoverable day

In Scenario 1, there are 2-weeks of delay. The first week is EC delays by the owner and the second week is NE delays by the contractor on Activities A and D, respectively. It is straightforward to divide the 2-weeks of the project delays into 1-week compensability and 1-week inexcusability (Arditi and Pattanakitchamroon, 2008). Due to the fluctuations in the amount of the delay damages that are related to the project time, each week of delay may cause a different amount of damages at different levels. At the project level, the 9th week that caused by EC delay has possibly different damages and losses from the 10th week that caused by NE delay. Also, the damages and losses at the activity-level are not equal. At the activity-level, EC delay has caused the one week of delayed to the duration of activity (A) and pushed the Early Start (ES) of activities B, C and D 1-week. These possible damages and losses are different from the damages and losses that would incur due to NE delay, which only extended the duration of activity D 1-week.

In Scenario 2, two weeks of delay that have occurred on activity B and activity C are a concurrent delay are a concurrent delay (which are inexcusable and compensable delays, respectively). The current practice treats this situation of the concurrent delays as excusable delays, but neither of the project parties entitles to compensation of additional money to recover delay damages. Thus, the contractor will be granted only a time extension, and each party would bear his potential damages and losses. AACEI (2006) mentioned that "The contractor is barred from recovering delay damages to the extent that concurrent contractor-caused delays offset owner-caused delays, and the owner was barred from recovery liquidated or the actual delay damages to the extent that concurrent owner-caused delays offset contractor-caused delays". However, Hughes and Ulwelling (1992) urged that the rule "damages not be apportioned" in concurrent delay situations should be rejected. In the delay claims, a few cases hold that despite the difficulty, the parties should try to segregate damages or costs attributable to each delay cause. James (1991) claims that forfeiture of such damages because of non-apportion-ability is excessively harsh. Therefore, courts often use a jury verdict method to apportion damages to each party (James 1991). The use of this method is very subjective and sometimes incorrect and places the project parties in a passive, reactive position (Ibbs and Nguyen, 2007).

In Scenario 3, the potential damages and losses at the project-level would be in the 9th and 10th week. For the responsibility analysing of any possible damages and losses, the existing DATs would show different results. In additive modelling, the responsibility of the potential damages and losses in the 9th week and the 10th week are due to NE delay (that occurred in 3rd week on activity B) and NE delay (that happened in 4th week on activity B), respectively. In subtractive modelling, the potential damages and losses are due to concurrent effects. In the 9th week, the potential damages and losses would be due to the impact of both delays (NE delay in 3rd week on activity B and EC delay in 5th week on activity C). In the 10th week, the possible damages and losses would be for both delays (NE delay in 4th week on activity B and EC delay in 6th week on activity C). Therefore, the trickiest part in the construction delay cases is how to measure and present evidence on damages (Overcash and Harris, 2005).

The recoverable damages for a delay should be related to the timing of the corresponding delay and its effect on the damage's costs. However, the contracting parties do not have an effective method to provide and demonstrate fair apportionment in front of the courts. Consequently, the outcome of the jury verdict is what the parties will receive, which is highly speculative and can be grossly unfair. The project parties should proactively apportion damages in the project delays, ideally by employing a logical and systematic approach (Duah and Syal, 2017; Ibbs and Nguyen, 2007).

3.2.8. The Issues of Cost Damages for Delay and Acceleration

The context of events of the schedule impacts significantly affects the responsibility. The existing DATs are used to apportion delay days attributable to each contracting party. These techniques solely focus on the criticality of the time for the project activities. It means that 1-day delay at ith day and 1-day delay at the jth day are frequently treated the same. However, each event has a unique effect on the schedule. For example, each impacted activity has a unique cost slope, such as the cost of compression or the savings of decompression per unit of time (Al-Gahtani, 2006). Also, the damages and losses due to the schedule impacts and project delays, which are possible can be recovered for either the contractor or owner, have assumed to be equal, which this assumption is not accurate (Ibbs and Nguyen, 2007).

Arditi and Patel (1989) Proposed a method to apportion owner-directed acceleration costs between the owner and the contractor. The characteristics of this method are:

1. In case of having no delays before the owner-directed acceleration, the owner will carry out the entire acceleration cost.
2. In case all delays before the owner-directed acceleration of the same magnitude are caused by the owner, the owner will carry out the entire acceleration cost.
3. In the case of having the contractor causes all delays before the owner-directed acceleration of the same magnitude; the contractor has two choices. The first is to accelerate the project and incur all acceleration costs to steer the project back on schedule. The second is to continue with the same production speed and pay liquidated damages for the final delay.

4. In the case of that, some of the delays have extended the project completion date due to the owner and the contractor; the acceleration costs can be apportioned between the parties in one condition. The condition is that the unit acceleration costs of the remaining activities (or combination of activities in case of parallel delays on the critical paths) to be compressed are equal for each other.
5. In case of that, some of the delays which have occurred in the completed portion of the project were due to the owner and the contractor. The unit acceleration costs of the remaining activities (or combination of activities in case of having parallel delays on the critical paths) are different from each other. Then apportioning acceleration costs in direct proportion of each party's share in the delays constitutes an unfair practice, since it gives an undue and unjustifiable advantage to the party that caused delays in the earlier parts of the project.

Although the proposed technique rectifies acceleration costs more equitably since each party pays for the delay he caused in chronological order rather than in an arbitrary way, Minimizing the effects of damages and losses of previous delays on the schedule by accelerating any activity on the schedule would not always eliminate the total damages. To understand the issue of cost for delay damages and acceleration, Figure 3-8 and Figure 3-9 visualise this issue. The as-planned schedule of a construction project has four activities A, B, C, D. Case I and II exemplify the as-built schedules under two different acceleration scenarios.

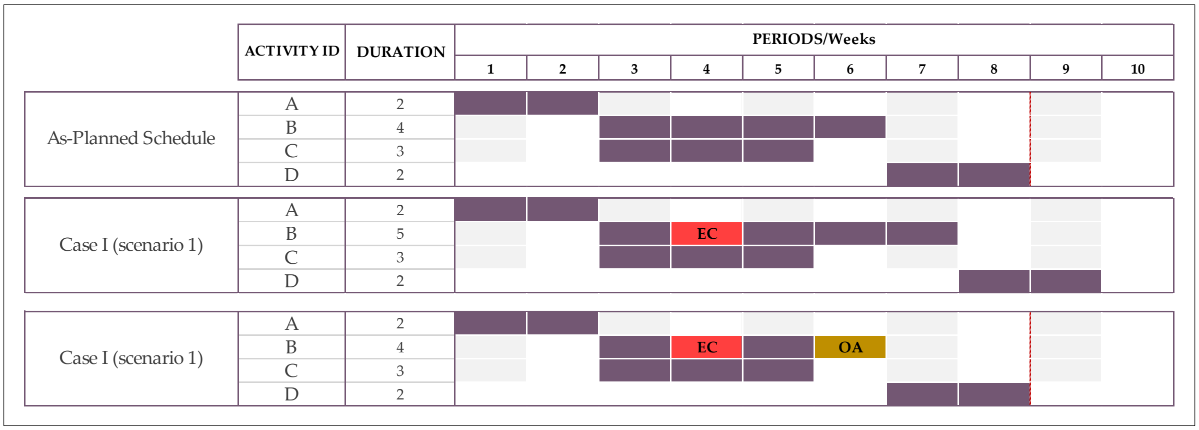


Figure 3-8: Case I for acceleration scenarios.

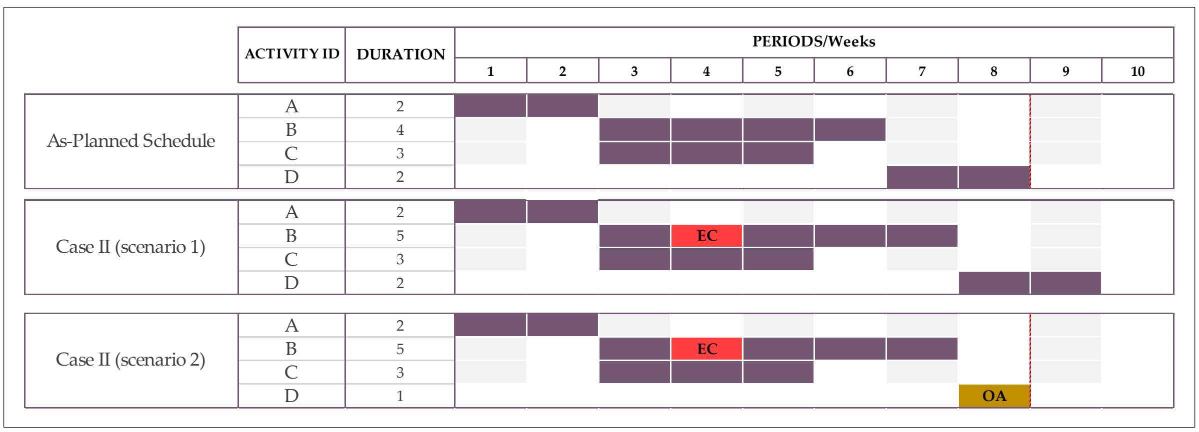


Figure 3-9: Case II for acceleration scenarios.

In case I, there is 1-week of delay by the owner on Activity B. Therefore, the owner-directed acceleration to meet the original completion date and avoid late-completion damages. Arditi and Patel (1989) stated that the owner incurs the entire acceleration cost in such a situation. Before the acceleration event as Case I (scenario 1) showed, there will be possible damages and losses at the project-level in the 9th week and possible damages and losses at the Activity-level (1-week due to extending the duration of activity B and 1-week due to pushing the Early Start (ES) of Activity D). However, the acceleration event steered the project back on schedule and eliminated any possible damages and losses at the project-level in the 9th week. Also, it eliminated any possible damages and losses at the activity-level since the duration of activity B, and ES of activity D remained the same. Therefore, eliminating any possible damages and losses would not happen due to a delay unless the acceleration occurred in the same impacted activity by this delay.

In case II, there is an acceleration occurred in Activity D, which is a different activity from the impacted activity. Although the acceleration steered the project back on schedule and eliminated any possible damages and losses at the project-level in the 9th week; however, the possible damages and losses at the activity-level have not entirely removed. The possible damages and losses due to extending the activity B will remain the same.

3.3 Summary

As discussed in Chapters 2 and 3, DAIs could immensely affect the results of the delay claims analysis, which, in turn, would affect the apportionment of responsibility for any potential damages. These DAIs include the Direct Delay Responsibility (DDR), the impact of Change Order (CO), Acceleration Impact (AI), Resource Levelling (RL), Preventable Force Majeure Delay (PFMD), Productivity Lose (PL), Concurrent Delays (CDs), Concurrent Effects (CEs), Pacing Delays (PDs), Total Floats (TFs), the Impacted Days (IDs) and Acceleration Credit (AC). Some of these issues that have been recognised in the literature will be reviewed in the next chapter, which presents a thorough evaluation of existing DATs, including establishing their capability for producing reliable results in delay claims analysis.

CHAPTER FOUR: DELAY ANALYSIS TECHNIQUES

4.1 Introduction

This chapter offers a comprehensive review of the current Delay Analysis Techniques (DATs) that are widely used in practice. Many DATs have been developed to analyse the delay in construction projects. However, these DATs have different analytical approaches and require varying levels of analysis in the delay assessment process, which may produce different outcome as a result. Therefore, this chapter attempts to investigate the most popular DATs in practical use that are based on the Critical Path Method (CPM). The investigation includes the strengths and weakness of each technique for resolving most of the DAIs defined in Chapter 3 and their capability in presenting robust analyses and accurate results. To review the characteristics of DATs in the analysis processes, DAIs were used as criteria for evaluating the existing DATs.

4.2 Delay Analysis

Delay analysis is referred to the task of investigating the construction project events that cause an impact to the project and the process for determining the responsibilities, among the contracting parties, to any effect on the project cost or time (Braimah and Ndekugri, 2008). For this purpose, Delay Analysis Techniques (DATs) are commonly used to demonstrate how actual schedule impact events on a project happened and interacted in the context of a schedule model, for understanding any deviation from the planned schedule and the role of such deviation in increasing the project time and (or) cost. They all seek to determine the schedule impacts and allocate the impacts' responsibility among the parties (AACEI, 2011).

According to Braimah (2013), the objective of delay analysis is "to calculate the project delay and work backwards to try to identify and recognise how much of it is attributable to each party (owner, contractor, or neither) so that time and (or) cost compensation can be decided". The renowned recommended protocol of the American Association of Cost Engineers (AACE) used the term "forensic schedule analysis methods" instead of "Delay analysis techniques" based on their appropriate use for the investigation and establishment of facts, proof or evidence in a court of law, public discussion or argumentation (AACEI, 2006).

Despite many contributions on the subject of delay claims, proper analysis of delay claims which take into consideration the effect of some scheduling and delay issues is often lacking in practice (Vasilyeva-Lyulina et al., 2015; Pickavance, 2010; Peters, 2007; Hegazy and Zhang, 2005). Existing DATs are widely used in practice to help with successful claim resolutions (Mohan and Al-Gahtani, 2006; Braimah, 2013), but they do not consider many of the DAIs in calculating the responsibility of delay damages and losses. With the increasing size and the complexity in the nature of the construction projects, construction claims have received much attention and more considerable efforts aimed at enhancing DATs. This enhancement includes the need for considering the impact of DAIs and increase the efficiency DATs (Yang and Kao, 2012; Yang et al., 2014; Keane and Caletka, 2015; Burr, 2016).

4.3 Overview of Existing Delay Analysis Techniques

Delay analysis issues are at the centre of the focus of DATs, which, by considering all of them, can provide more robust results in the delay analysis and thus help reduce or avoid disputes amongst claims parties. Instigated by these challenges of DAIs, considerable efforts from researchers and practitioners have been carried out over the years aimed at addressing the issues and enhancing the analysis approaches. As a result, many DATs have been used by researchers and practitioners to form the basis of successful claim resolutions (Magdy et al., 2019; Braimah, 2013; Mohan and Al-Gahtani, 2006). For example, Yang and Kao (2009) identified 19 methods for analysing delay claims, which can be classified from straightforward to very complicated procedure methods. Currently, DATs can be classified into three main categories (process-based, mathematical and computer-based models), as outlined below. This is followed by a review of the most popular DATs, which are known by different names in the literature.

I. Mathematical Models – designed to analyse a single activity on a project in order to calculate the schedule impact (such as from delay events). Under this category, the mathematical methods include the method proposed by Shi et al. (2001), "An equation activity-based calculation"; the method proposed by Oliveros and Fayek (2005), "A fuzzy logic approach for estimating delay duration to improve the delay analysis"; and the method proposed by Lee et al. (2005), which considers lost productivity in analysing schedule delay.

II. Computer-Based Models – developed to collect and record required data to assist in delay analysis. Under this category, Yates (1993) developed a construction decision support system that can determine possible causes for project delays. Aoude (1996) also developed a computer program to help classify and quantify schedule delays in construction projects. Also, Abudayyeh (1997) developed a multimedia system in order to demonstrate the role of information in the management of delay claims.

III. Process-Based Models – these models have different categories to calculate and examine the delay claims based on the project schedule. The methods under this category include the global impact method, net impact method, adjusted As-Built CPM method, As-

Planned expanded method, but-for method, snapshot method, time impact method, windows method, and isolated delay type method (Yang et al., 2006; Yang and Kao 2007). Recently, some techniques under process-based models proved capable of solving some issues of delay claims. Therefore, this study will focus on the techniques under the process-based model. Process-based methods can be further categorised as follows: a concept method, a forward path method, a backward path method, and a dynamic method. Each one has its approach (Yang and Kao, 2009; Al-Gahtani, 2006; Mohan and Al-Gahtani, 2005), as follows:

A. The concept techniques calculate merely delay by examining the final evidence of the as-built schedule. These techniques under this category include:

    1. Reams' systematic approach (Reams, 1989) – this technique is a systematic approach that starts by isolating in time each delay impact, then identifies the delay type after determining its impact on the overall project schedule.
    2. Global impact technique (Alkass et al., 1995) – this method represents all the delays on the project schedule, then calculates the total delay by summarising all delaying events.
    3. Net impact technique (Alkass et al., 1995) – this technique calculates the difference in the completion date between the as-planned and the as-built schedule. The net impact of all the delays is distinguished from the global impact technique.
    4. Dollar-to-time relationship (Zafar, 1996) – this technique analyses the relationship between the extra cost and time. However, analysing the impact of the delay from the extra cost is not an easy task.

5. Bar chart analysis (Zack, 2000; Callahan et al., 1992) – this technique uses the as-planned bar chart with an As-Built bar chart, then compares the extended bars.
6. CPM update review (Zack, 2000) – this technique analyses each update in the project schedule by identifying the delay caused.
7. As-planned versus As-Built analysis (Zack, 2000) – this technique compares the as-planned with the As-Built schedule to analyse the extra time by subtracting the expended time from the actual schedule.
8. Linear schedule analysis (Zack, 2000) – this method compares the As-Planned schedule with actual linear progress. It is only used for linear type projects.

B. The forward-path techniques systematically calculate the delay by starting adding the events to the as-planned schedule and analysing it forwards to the as-built schedule. These techniques under this category include:

1. After-the-fact and modified CPM schedule (Zafar, 1996) – this technique uses the same approach used by the impacted as-planned method; the only difference is that this method uses a new baseline schedule or modified as-planned schedule, instead of the original As-Planned schedule.
2. Bordoli and Baldwin's delay analysis method (Bordoli and Baldwin, 1998) – this technique uses simulation to express the effect of the events that have been identified; also, it uses a technique of critical path and straightforward, step-by-step methodology.
3. Impacted as-planned method (Trauner, 1990; Zack, 2000) – this technique adds the delay events one by one to the As-Planned schedule, then demonstrates the extended time to the completion date.

4. But-for (Schumacher, 1995) – this technique concentrates on a specific delay event, rather than the period of the delay event. It calculates the delay responsibility by imposing each type of delay event in the as-planned schedule.
5. Total float management (Al-Gahtani and Mohan, 2007) – this technique uses day-by-day analysis, which starts from the as-planned schedule. It uses the concept of total float consumption during the analysis.

C. The backward path techniques systematically calculate the delay by starting subtracting the events from the as-built schedule and analysing it backwards to the as-planned schedule. These techniques under this category include:

1. But-for (Schumacher, 1995) – this technique starts by removing only one of the contract party's delays from the as-built schedule to collapse it while leaving the other contract party's delays.
2. As-Built Technique (Callahan et al., 1992; Bubshait and Cunningham, 1998) – this method uses the As-Built schedule as a baseline for analysis to compare the actual start and finish dates for each activity against the as-planned dates.

D. The dynamic techniques systematically calculate the delay value in specific time frames based on the analysis methodology such as forward or backward analysis for the as-planned and as-built schedules. These techniques under this category include:

1. Snapshot technique (Alkass et al., 1995) – this technique starts by dividing the As-Built schedule into some consecutive periods and imposing all delay types (without classifying the delay types) in each period in an updated as-planned schedule.

2. Isolated delay type (Alkass et al., 1995) – this technique uses the classification of delay types in each consideration. The whole process of this method is similar to the snapshot technique.
3. Modified but-for (Schumacher, 1995) – this technique uses the window concept to track the critical path during the project in order to determine the real-time delay status. Simultaneously, it uses the but-for or the collapsed concept to determine the delay impact for each window analysis.
4. Windows analysis (Schumacher, 1995) – this technique first adopts the as-planned schedule as its baseline and then breaks the schedule into window periods. On each window, the analysis starts by examining the effects of the delays for each contracting party as the delays occur, and then finally summarising all recorded values.
5. Apportionment delay method (Ng et al., 2004) – this technique apportions the actual delay amount according to the ratios of EC delays, NE delays, and EN delays to the total delays. It is a compromise between two methods, which are; the net impact and But-for techniques.

The above review serves as a precursor to a critical evaluation of the techniques (in the sections following) regarding their suitability for producing acceptable results in delay claim analyses.

4.4 Evaluating Delay Analysis Techniques

Although various available DATs have been introduced in the field of delay claims, there are no standard techniques approved by the courts for analysing delay events (Magdy et al., 2019; Arditi and Pattanakitchamroon, 2006). By reviewing the existing DATs, these techniques and methods range from inaccurate techniques to a technique that has weakness and depends on their capabilities and limitations in practical use (Al-Gahtani et al., 2016; Alkass et al., 1996; Pinnell, 1998; Alkass et al., 1995; Korman and Daniels, 2003; Bubshait and Cunningham, 1998; Stumpf, 2000). For example, global impact technique is a natural model and a simple method to assess schedule impacts by summing up the total duration of all delays. However, practitioners resist the use of this technique because it wrongly assumes that each delay has an equal impact on the schedule. Thus, the results of delay analysis may be affected by the method selected, and therefore the selection of an appropriate DAT is essential to all parties concerned (Khandel and Soliman, 2019; Alena et al., 2015; Al-Gahtani, 2006).

The Process-Based Models which apply the CPM are the most widely used in delay claims analysis. Mohan and Al-Gahtani (2005) reviewed ten techniques that are used in the US for construction delay claims. Six of them have been reviewed by Braimah (2013) and Arditi and Pattanakitchamroon (2006) have also reviewed some of these techniques for selecting a suitable method in resolving construction claims.

These techniques that are based on the CPM are regarded in the literature as suitable for producing more rigorous results and include the following: As-planned technique, As-Built technique, Impacted as-planned technique, Time impact technique, But-For technique, Windows Analysis technique and total float management technique (Reams, 1990; Alkass and Harris, 1991; Kallo, 1996; Finke, 1999; Kartam, 1999; Baram, 2000; Shi et al., 2001;Lucas, 2002; Wickwire and Groff, 2004; Ng et al., 2004;Al-Gahtani and Mohan, 2007; Yang and Teng, 2017).

In order to evaluate the existing DATs more thoroughly, a hypothetical example of a schedule of a construction project and a scenario of a schedule delay was designed as shown in Figure 4-1. It involves the construction of a project consisting of 10 activities which were affected by all the events of the schedule impacts. The idea behind designing this case-study is based on the fact that there is no existing case study that possesses all the types of DAIs represented as possible scenarios of delay claims, which are usually experienced in real-life projects. Further, it is because the delay analyses of real-life projects involve a considerable amount of processes and information that would exceed the limited space for this thesis as well as the calculation procedures that would be difficult to handle manually. Designing a case study as an example to illustrate a specific scenario of delay claims is popular in the literature that is relevant to delay claims analysis (see, e.g. Kraiem and Diekmann, 1987; Al-Gahtani, 2006, Ibbs and Nguyen, 2008). Therefore, this example was found appropriately suited to be used in assessing the process of existing DATs. In Chapter 8, this example will also be used to evaluate the proposed technique and compare its results with the results of the existing DATs that will be introduced by the end of the analysis in this chapter.

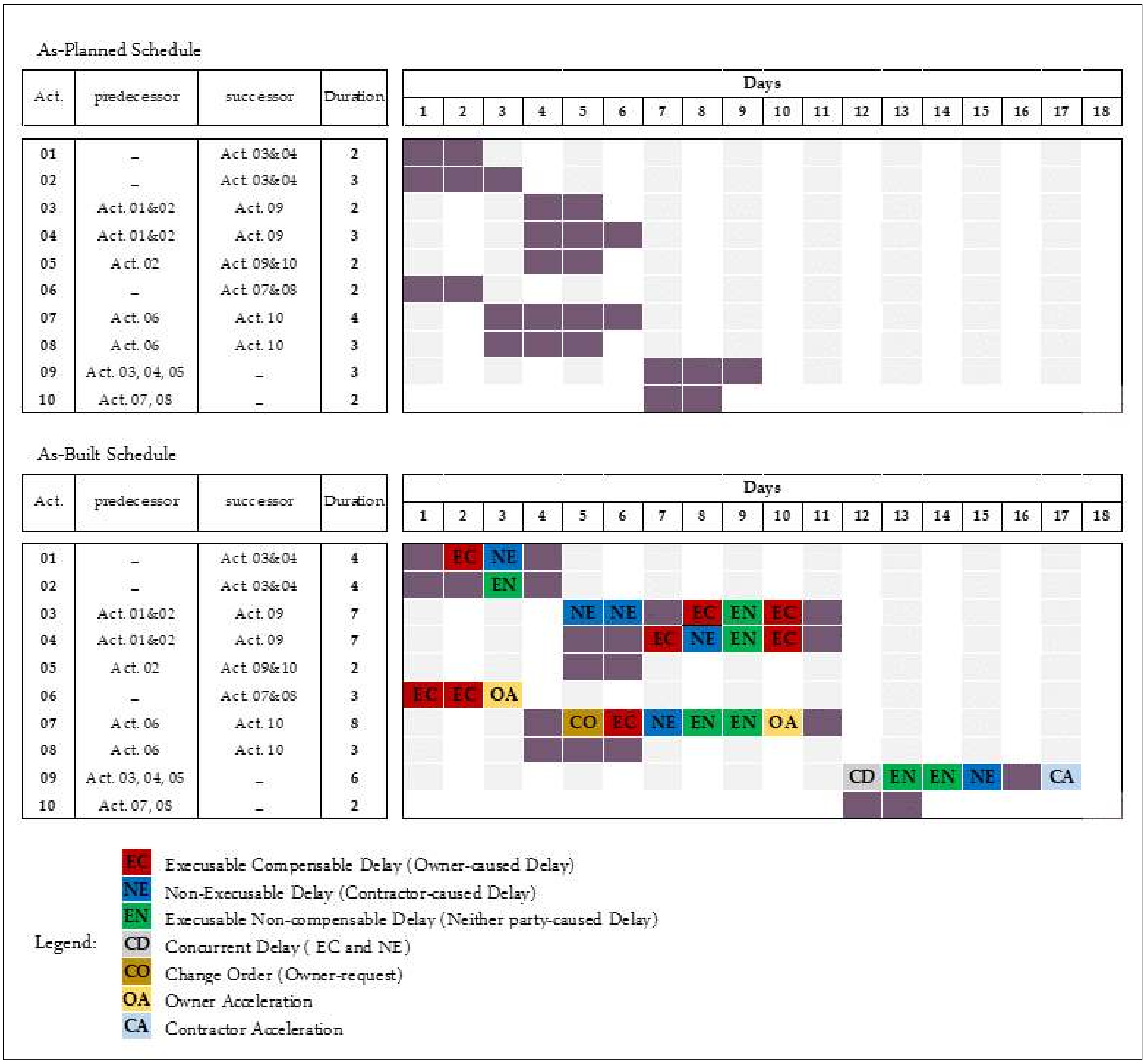


Figure 4-1: Case study schedules, as-planned schedule and as-built schedule

As shown in Figure 4-1, the as-planned schedule is indicating a total project duration of 9 days. The project started as planned, but progress was affected by different types of schedule impacts events forcing the total project duration to be extended up to 17 days. The following sections evaluate the most popular DATs that rely on CPM in determining the responsibility of the delay damages, which depends on some DAIs to be tackled during the analysis process. The sections include a review of the strengths and weaknesses of each DATs in resolving the DAIs and the capability in presenting robust analyses and accurate results. The detailed analysis of these techniques as well as the procedure flowcharts can be found elsewhere in the literature (see for example Al-Gahtani, 2006; Braimah, 2013; AACEI, 2007; Yang and Kao, 2009). Also, the summary for the detailed analysis of the case by these techniques is included in Appendix (I).

4.4.1. As-Planned Technique

As-planned, or as it has been labelled "What If" technique is one of the CPM-based methods that use the as-planned schedule as a baseline for conducting the analysis (Schumacher, 1997). The determination of the owner damages can be achieved by impacting the as-planned schedule with only contractor-caused delays (NE delays). In contrast, the contractor damages are calculated by impacting the as-planned schedule with only owner-caused delays (NE delays). Under this method, the determination for each party's damages is based on the difference of the completion date before and after the impact. It uses the time-effect method for determining each party's responsibility in extending the overall project duration (Callahan et al., 1992; Schumacher, 1995; Bramble and Callahan, 2010).

This technique is an additive modelling method that consists of comparing the as-planned schedule before and after the impacts. In this technique, the analysis can be implemented by using two methods (Bubshait and Cunningham, 2004). The first method is Gross of Measure, which uses a gross measurement in which both owner-caused delays and contractor-caused delays are impacted the As-Planned schedule at once. The second method is the Unit of Measure, which measures the impact of each event on the As-Planned schedule to determine their effects. The analysis results by using Gross of Measure and Unit of Measure are as shown in Table 4-1 and 4-2, respectively.

Table 4-1: The analysis results of the As-planned technique by gross of measure approach

Responsibility	**Completion Date**		**Project Delay**
	Before Impacted	**After Impacted**	
Owner (EC&OA)	9	12	3
Contractor (NE&CA)	9	11	2
Neither Party (EN&SA)	9	13	4

Table 4-2: The analysis results of the as-planned technique by the unit of measure approach

Activity	**Impacted Type**	**Completion Date**		**Project Delay**
		Before	**After**	
A	EC	9	9	0
G	EC	9	10	1
B	EC	9	10	1
C	EC	9	11	2
H	EC	9	10	1
M	EC	9	10	1
G	OA	9	9	0
H	OA	9	9	0
Total Owner Responsibility				**6**
A	NE	9	9	0
B	NE	9	10	1
C	NE	9	10	1
H	NE	9	10	1
M	NE	9	11	2
M	CA	9	9	0
Total Contractor Responsibility				**5**
B	EN	9	9	0
C	EN	9	10	1
D	EN	9	10	1
H	EN	9	11	2
M	EN	9	11	2
Total Neither Party Responsibility				**6**

Although this type of delay analysis model is accepted for measuring the schedule impacts (AACEI, 2007), the technique has many shortages and weakness (Al-Gahtani, 2006). It fails to address several issues of DAIs. The evaluation of this technique confirmed the following:

1. The amount of responsibility at the project-level exceed the total delayed period, which is 8 days (from day 10 up to day 17). The responsibility by this technique shows 9 days by using gross of measure and 17 days by using a unit of measure. Thus, the responsibility for the real-time of the delayed period has not been addressed correctly in this technique. This issue of ignoring the real-time happened due to the analysis methodology in which has not considering all the events in the analysis at once.
2. The issue of change order responsibility, concurrent delays analysis, concurrent effects analysis, acceleration analysis, and pacing delay analysis has not considered in this technique. Due to this, the responsibility for the delay damages at the project-level cannot be presented inaccurate and rigorous assessment.
3. The cost of delay damages and losses was not tackled in this technique. For example, delay damages and the recoverable day was not adequately defined at the project-level. Also, the damages and losses at the activity-level that create more harm to the innocent party cannot be measured at all by this technique.

4.4.2. As-Built Technique

As-built, or as it has been labelled “Net Impact” technique, is also one of the CPM-based methods that use the as-built schedule as a baseline for conducting the analysis. (Alkass et al., 1996). Under this technique, the analysis starts by comparing the total float of the as-planned schedule with the impacted schedule events in each activity. A negative value of As-Built’ TF indicates that the event has affected the overall project completion by some days equal to that negative value (Callahan et al., 1992; Bubshait and Cunningham, 1998; Al-Gahtani, 2006).

Therefore, this technique is a subtractive modelling method and consists of comparing the TF of the as-built schedule before and after the impacts. It uses the as-built schedule as a baseline for conducting the analysis (Bubshait and Cunningham, 2004). Table 4-3 and 4-4 show the detailed analysis by this technique.

Table 4-3: The analysis result of the as-built technique

Act.	As-Planned			As-Built			Events		TF	Project Delay
	ES	EF	TF	ES	EF	TF	Day	Type		
01	0	2	1	0	4	0	1	EC	0	0
							1	NE	0	0
02	0	3	0	0	4	0	1	EN	-1	1
03	3	5	1	4	11	0	2	EC	-1	1
							2	NE	-1	1
							1	EN	0	0
04	3	6	0	4	11	0	2	EC	-2	2
							1	NE	-1	1
							1	EN	-1	1
05	3	5	1	4	6	5	-	-	-	-
06	0	2	1	0	3	0	2	EC	-1	1
							-1	OA	2	-2
07	2	6	1	3	11	0	1	CO	0	0
							1	EC	0	0
							1	NE	0	0
							2	EN	-1	1
							-1	OA	2	-2
08	2	5	2	3	6	5	-	-	-	-
09	6	9	0	11	17	0	1	CD	-1	1
							2	EN	-2	2
							1	NE	-1	1
							-1	CA	1	-1
10	6	8	1	11	13	4	-	-	-	-

Table 4-4: The total responsibility using the as-built technique

Activity	Delay Type	Project Delays
03	EC	1
04	EC	2
06	EC	1
	OA	-2
07	OA	-2
Total Owner Responsibility		**0**
03	NE	1
04	NE	1
09	NE	1
	CA	-1
Total Contractor Responsibility		**2**
02	EN	1
04	EN	1
07	EN	1
09	EN	2
Total Neither Party Responsibility		**5**

Although this type of delay analysis model is accepted for measuring the schedule impacts (AACEI, 2007), the technique has many shortages and weakness (Braimah, 2013: Al-Gahtani, 2006). The As-Built Techniques fails to address and consider several issues of DAIs. The evaluation of this technique confirmed the following:

1. This technique does not consider the real-time of the delayed period. Therefore, the amount of responsibility at the project-level shows 7 days, while the real-time is 8 days (from day 10 up to day 17). Thus, the responsibility for the real-time of the delayed period has not been addressed correctly in this technique. This issue of real-time happened due to the analysis methodology in which the analysis of the schedule impacts considers individually.

2. Although this technique considers the issue of an acceleration event, the issue of concurrent delays analysis, concurrent effects analysis, acceleration analysis, and pacing delay analysis has not considered in this technique. Due to this, the responsibility for the delay damages at the project-level cannot be presented by accurate and rigorous assessment.
3. The cost of delay damages and losses were not tackled in this technique. For example, delay damages and the recoverable day has not adequately defined at the project-level. Also, the damages and losses at the activity-level that create more harm to the innocent party cannot be measured at all by this technique.

4.4.3. Impacted As-Planned Technique

The impacted as-planned technique is the method of analysing the effect of the event that happened on the critical path(s) of as-planned only and measuring their effects on extending the completion date. The difference between the completion date before and after the impact can determine the responsibility of each party (Trauner, 1990; Al-Gahtani, 2006).

This technique is an additive modelling method consists of comparing the critical path(s) of the as-planned schedule before and after the impacts. The analysis starts by impacting each activity on the as-planned critical path with the events and quantifying the impacts before and after the impact. The analysis result of the impacted as-planned technique is shown in Table 4-5 and 4-6.

Table 4-5: The analysis result by using the impacted as-planned technique

Impacted Schedule	Activity	Events		Project Completion		Project Delay
		Type	Day	Before	After	
1	02	EN	1	9	10	1
2	04	EC	1	10	11	1
3		NE	1	11	12	1
4		EN	1	12	13	1
5		EC	1	13	14	1
6	09	CD	1	14	15	1
7		EN	2	15	17	2
8		NE	1	17	18	1
9		CA	1	18	17	-1

Table 4-6: The total responsibility using the impacted as-planned technique

Activity	Delay Type	Project Delays
04	EC	2
Total Owner Responsibility		**2**
04	NE	1
09	NE	1
	CA	-1
Total Contractor Responsibility		**1**
02	EN	1
04	EN	1
09	EN	2
Total Neither Party Responsibility		**4**

Although this type of delay analysis model is accepted for measuring the schedule impacts (AACEI, 2007), this technique has many shortages and weakness (Braimah, 2013; Arditi and Pattanakitchamroon, 2006). The Impacted As-Planned Techniques fails to address and consider several issues of DAIs. The evaluation of this technique confirmed the following:

1. This technique is not considering the real-time of the delayed period. Therefore, the amount of responsibility at the project-level shows 7 days, while the real-time is 8 days (from day 10 up to day 17). Thus, the responsibility for the real-time of the delayed period

has not been addressed correctly in this technique. This issue of ignoring the real-time happened due to the analysis methodology in which the analysis of the schedule impacts ignores the critical path.

2. Although this technique considers the issue of acceleration event only on the as-planned critical path, the issue of concurrent delays analysis, concurrent effects analysis, acceleration analysis, and pacing delay analysis has not considered in this technique. Due to this, the responsibility for the delay damages at the project-level are not presented by accurate and rigorous assessment.

3. The cost of delay damages and losses has not tackled in this technique. For example, delay damages and the recoverable day has not adequately defined at the project-level. Also, the damages and losses at the activity-level that create more harm to the innocent party cannot be measured at all by this technique.

4.4.4. Time Impact Technique

Time impact, or as it has been labelled "Updated Impact or Contemporaneous Impact" technique, is one of the CPM-based methods that use the as-planned schedule as a baseline for conducting the analysis. This technique uses the as-planned schedule to measure the effect of each responsible party on each activity. The responsibility of each party can be obtained by measuring the difference between the completion date before and after the impact (Callahan et al., 1992; Alkass et al., 1996; Bramble and Callahan, 2010).

This technique is an additive modelling method consists of comparing the impact of each activity on the as-planned schedule before and after for the delays of each party-caused. It is a comparison technique between the as-planned and as-built schedule for the activities before and after the impact. For analysing the responsibility of any schedule impact, the analysis starts by determining the start and finish date of the activities in the as-planned schedule and updating the analysis with the as-built data. The difference between the dates is the effect of schedule events that had on the project. The analysis result of the time impact technique is shown in Table 4-7 and 4-8.

Table 4-7: The analysis result by using time impact technique

No.	**Activity**	**Delay**		**Project Completion Date**		**Project Delay**
		Type	**Day**	**Before**	**After**	
1	06	EC	2	9	10	1
		OA	1	10	9	-1
2	01	EC	1	9	9	0
		NE	1	9	10	1
3	02	EN	1	10	10	0
4	07	CO	1	10	10	0
		EC	1	10	11	1
		NE	1	11	12	1
		EN	2	12	14	2
		OA	1	14	13	-1
5	03	NE	2	13	13	0
		EN	1	13	13	0
		EC	2	13	14	1
6	04	EC	2	14	14	0
		NE	1	14	14	0
		EN	1	14	14	0
7	09	CD	1	14	15	1
		EN	2	15	17	2
		NE	1	17	18	1
		CA	1	18	17	-1

Table 4-8: Total project delays by using time impact technique

Activity	Delay		Project Completion Date		Delay
	Type	Day	Before	After	
06	EC	2	9	10	1
01	EC	1	9	9	0
07	EC	1	10	11	1
03	EC	2	13	14	1
04	EC	2	14	14	0
06	OA	1	10	9	-1
07	OA	1	14	13	-1
Total Owner Responsibility					**1**
02	NE	1	9	10	1
07	NE	1	11	12	1
03	NE	2	13	13	0
04	NE	1	14	14	0
09	NE	1	17	18	1
09	CA	1	18	17	-1
Total Contractor Responsibility					**2**
02	EN	1	10	10	0
07	EN	2	12	14	2
03	EN	1	13	13	0
04	EN	1	14	14	0
09	EN	2	15	17	2
Total Neither Party Responsibility					**4**
Total Project Delays					**7**

Although this type of delay analysis model is accepted for measuring the schedule impacts (AACEI, 2007), this technique has many shortages and weakness (Arditi and Pattanakitchamroon, 2005). Although this technique considers the real-time of the delayed period, the Time Impact Techniques fails to address and consider several issues of DAIs. The evaluation of this technique confirmed the following:

1. This technique fails to address the issue of concurrent delays analysis, concurrent effects analysis and pacing delay analysis. Due to this, the responsibility for the delay damages at the project-level cannot be presented inaccurate and rigorous assessment.

2. The cost of delay damages and losses has not tackled in this technique. For example, delay damages and the recoverable day has not adequately defined at the project-level. Also, the damages and losses at the activity-level that create more harm to the innocent party cannot be measured at all by this technique.

4.4.5. But-For Technique

But-For, or as it has been labelled "Collapsed As-Built" technique, is one of the CPM-based methods that use the as-built schedule as a baseline for conducting the analysis (Trauner, 1990). It is the most accepted method for delay analysis in US construction delay claims (Zack, 2000). This method uses two comparisons for implementing the method. The first method is to collapse from the as-built schedule all the event that belongs to the contractor-caused delay (NE delays) to obtain the owner responsibility by comparing the completion date before and after the collapsed. The second method is collapse from the as-built schedule all the event that belongs to the owner-caused delay (EC delays) to obtain the contractor responsibility by comparing the completion date before and after the collapsed (Zack, 2000). This technique is a subtractive modelling method consists of comparing the completion date before and after the collapsed of each party's delays from the as-built schedule. Under this technique, two methods can be applied, which are Gross of Measure and Unit of Measure. The analysis results of both methods are shown in Table 4-9 and 4-10, respectively.

Table 4-9: The analysis result of the But-For technique by using Gross of Measure

Activity	**Project Completion Date**		**Delay**
	Before Collapsed	**After Collapsed**	
Owner	17	15	2
Contractor	17	16	1
Neither Party	17	14	3
Total Project Delays			**6**

Table 4-10: Total project delays by using time impact technique

Activity	Project Completion Date		Delay	
	Before Collapsed	**After Collapsed**	**Type**	**Days**
06	17	17	EC	0
07	17	17	EC	0
01	17	17	EC	0
03	17	17	EC	0
04	17	15	EC	2
Total Owner Responsibility				**2**
01	17	17	NE	0
07	17	17	NE	0
03	17	17	NE	0
04	17	16	NE	1
09	16	15	NE	1
Total Contractor Responsibility				**2**
02	17	17	EN	1
07	17	17	EN	0
03	17	17	EN	0
04	17	16	EN	1
09	16	14	EN	2
Total Neither Party Responsibility				**4**
Total Project Delays				**8**

Gross of measure is a grossly collapsed method that measures the impact of one project party at one time by collapsing all the related events from the as-built schedule. In contrast, the unit of measure is the method of collapsing each of the events individually. In each method, the difference between the dates before and after the collapsed is the effect of events that had on the project. Although this type of delay analysis model is accepted for measuring the schedule impacts (AACEI, 2007), this technique has many shortages and weakness (Arditi and Pattanakitchamroon, 2005). Although this technique does not consider the real-time of the delayed period, But-For Techniques also fails to address and consider several issues of DAIs. The evaluation of this technique confirmed the following:

1. This technique fails to address the issue of concurrent delays analysis, concurrent effects analysis, acceleration credit and pacing delay analysis. Due to this, the responsibility for the delay damages at the project-level cannot be presented inaccurate and rigorous assessment.
2. The cost of delay damages and losses has not tackled in this technique. For example, delay damages and the recoverable day has not adequately defined at the project-level. Also, the damages and losses at the activity-level that create more harm to the innocent party cannot be measured at all by this technique.

4.4.6. Window Analysis Technique

The traditional window (or window snapshot) technique is the most popular method of window analysis methods (Alkass et al., 1996). Under this technique, the total project duration of as-planned schedule is divided into several periods (snapshots or windows) usually based on significant changes in planning, specific types of delays or significant project milestones. In each window, the schedule impacted with the event that occurred during this time to reflect the actual durations, while the remaining duration of the schedule is maintained. The impacts of the events in each window can be determined by comparing the completion date before and after the impact. The responsibility of each party computed based on the impacted events in each window (Baram, 2000; Galloway and Nielsen, 1984).

Under this type of method, there are other techniques performed by the same methodology with different processes. For example, the window-But-For method uses the same procedure with the collapsed method, which can be a combination of As-Built technique and But-For Technique. Under this method, the type of each Party-caused delay considered separately to determine other party damages (Baram, 2000). Also, the daily window analysis method is another technique that used window procedure in the daily base to measure the impact of delay event that happened within the same day on the total project duration (Hegazy and Zhang, 2005).

This technique is an additive modelling method consists of comparing the completion date of each determined window before and after the impacted events. Daily window analysis is the most accurate analysis techniques among window techniques (Braimah, 2013; Hegazy and Zhang, 2005). It uses a daily window analysis to determine the effect on the project by comparing the completion date before and after the impact. The analysis result of the daily window analysis technique is shown in Table 4-11.

Table 4-11: Total project delays by using Daily window analysis technique

Window Day No.	Schedule Update	Completion Date	Delay			
			EC	NE	EN	Concurrent
0 (start)	0	8	-	-	-	-
1	8	9	-	-	-	-
2	9	10	1	-	-	-
3	10	10	-	-	-	-
4	10	10	-	-	-	-
5	10	10	-	-	-	-
6	10	11	-	-	-	1
7	11	12	-	1	-	-
8	12	13	-	-	1	-
9	13	14	-	-	1	-
10	14	14	-	-	-	-
11	14	14	-	-	-	-
12	14	15	-	-	-	1
13	15	16	-	-	1	-
14-17	16	17	-	-	1	-
Total Project Delays			**1**	**1**	**4**	**2**

Although this type of delay analysis model is accepted for measuring the schedule impacts (AACEI, 2007), the technique has short-comings (Al-Gahtani, 2006; Arditi and

Pattanakitchamroon, 2005). Although this technique considers the real-time of the delayed period, Daily Window Analysis Techniques fails to address and consider several issues of DAIs. The evaluation of this technique confirmed the following:

1. It fails to address the issue of concurrent delays analysis, concurrent effects analysis, acceleration credit and pacing delay analysis. Due to this, the responsibility for the delay damages at the project-level cannot be presented inaccurate and rigorous assessment.
2. The cost of delay damages and losses has not tackled in this technique. For example, delay damages and the recoverable day has not adequately defined at the project-level. Also, the damages and losses at the activity-level that create more harm to the innocent party cannot be measured at all by this technique.

4.4.7. Total Float Management Technique

Total float management technique is a daily analysis undertaken to continually account for the changes in total floats of the network activities (Al-Gahtani and Mohan, 2007). This method starts with the as-planned schedule to run a day-by-day analysis of events. In a daily process, any change of the total float is considered, which used as an indication and significant sign that the schedule has been impacted on the completion date or not. The analysis results consist of the responsibility of each contracting parties (owner, contractor and neither party) in extending the project duration.

This technique is an additive modelling method consists of analysing each day of the schedule in impacting the completion date by tracking the total project floats. It follows a daily analysis approach to determine the impact on the project by tracking the total floats consumption. Under this technique, there are two rules of analysis, which are the easy rule and Fair rule.

While the easy rule does not allow for apportioning the responsibility between the owner and contractor, the fair rule does. The analysis result of this technique is shown in Table 4-12.

Table 4-12: The analysis result by using total float management technique

Day	Activity	Delay							Total Float	
		Easy Rule				Fair Rule			Owner	Contractor
		EC	NE	EN	CD	EC	NE	EN		
1	06	-	-	-	-	-	-	-	-	-
2	01	-	-	-	-	-	-	-	-	-
	06	-1	-	-	-	-1	-	-	-	-
3	01	-	-	-	-	-	-	-	-	-1
	02	-	-	-1	-	-	-	-1	-	-
	06	+1	-	-	-	+1	-	-	-	-
5	03	-	-	-	-	-	-	-	-	-
	07	-	-	-	-	-	-	-	-1	-
6	03	-	-	-	-1	-	-0.5	-	-	-
	07	-	-	-		-0.5	-	-	-	-
7	04	-	-	-	-	-	-	-	-1	-
	07	-	-1	-	-	-	-1	-	-	-
8	03	-	-	-	-	-	-	-	-1	-
	04	-	-	-	-	-	-	-	-	-1
	07	-	-	-1	-	-	-	-1	-	-
9	07	-	-	-1	-	-	-	-1	-	-
10	03	-1	-	-	-	-1	-	-	-1	-
	04		-	-	-		-	-	-1	-
	07	+1	-	-	-	+1	-	-	-	-
12	09	-	-	-	-1	-0.5	-0.5	-	-	-
13	09	-	-	-1	-	-	-	-1	-	-
14	09	-	-	-1	-	-	-	-1	-	-
16	09	-	-1	-	-	-	-1	-	-	-
17	09	-	+1	-	-	-	+1	-	-	-
Total Delays		**0**	**-1**	**-5**	**-2**	**-1**	**-2**	**-5**	**-5**	**-2**

Although this technique considers the real-time of the delayed period and concurrent delay, Total Float Management Techniques fails to address and consider several issues of DAIs. The evaluation of this technique confirmed the following:

1. It fails to address the issue of concurrent effects and pacing delay. Also, resolving the acceleration credit was entirely arbitrary. Due to this, the responsibility for the delay damages at the project-level cannot be presented inaccurate and rigorous assessment.

2. The cost of delay damages and losses has not tackled in this technique. For example, delay damages and the recoverable day has not adequately defined at the project-level. Also, the damages and losses at the activity-level that create more harm to the innocent party cannot be measured at all by this technique.

4.5 Summary

The DATs that have been relied on during the resolutions of construction delay claims have not successfully reduced the high incidence of disputes. The primary source of that lies with the limitations and capabilities of the techniques in their practical use and their ability for resolving the DAIs. As shown in Section 4.4, the evaluation of seven DATs confirmed that the various techniques yield different analysis results, which are summarised in Table 4-13. The result of the total Project Delays (TPDs) should be eight days, and the difference is mainly due to the methodology and procedures that are adopted in each technique.

Table 4-13: The analysis results by using the existing DATs

No.	DATs	Project Delays					TFs	
		EC	NE	EN	CD	TPD	EC	NE
1	As-Planned (Gross of Measure)	3	2	4	-	9	-	-
	As-Planned (Unit of Measure)	7	5	5	-	17	-	-
2	As-Built	0	2	5	-	7	-	-
3	Impacted As-Planned	2	1	4	-	7	-	-
4	Time Impact	1	2	4	-	7	-	-
5	But-For (Gross of Measure)	2	2	4	-	8	-	-
	But-For (Unit of Measure)	2	2	4	-	8	-	-
6	Window Analysis	1	1	4	2	8	-	-
7	Total Float Management (Easy Rule)	0	1	5	2	8	5	2
	Total Float Management (Fair Rule)	1	2	5	-	8		

Section 4.4 has evaluated the popular DATs and confirmed that the most suited DAT in analysing the delay claims are window analysis and total float management, mainly due to their approach in addressing two issues from the DAIs. However, there are other DAIs that have not been addressed by these techniques which would affect delay analysis results. As shown in Table 4-14, the issues that are often ignored in the DATs are as follows: concurrent delays, concurrent effects, pacing delays, cost of delay damages and acceleration, delay damages and recoverable day and the damages at project and activity-levels. The limitations of the evaluated DATs are discussed as follows.

Table 4-14: Comparison of existing DATs in considering the DAIs

DAIs	**Delay Analysis Techniques (DATs)**						
	As-Planned	As-Built	Impacted As-Planned	Time Impact	But-For	Window Analysis	Total Float Management
Real Time	×	×	✓	✓	×	✓	✓
Concurrent Delays	×	×	×	×	✓	✓	✓
Concurrent Effects	×	×	×	×	×	×	×
Pacing Delay	×	×	×	×	×	×	×
Cost of Delay Damages and Acceleration	×	×	×	×	×	×	×
Delay Damages and Recoverable Day	×	×	×	×	×	×	×
The Damages at Project Level	×	×	×	×	×	×	×
The Damages at Activity-Level	×	×	×	×	×	×	×

Form Sections 4.4.1 and 4.4.2, as-planned and as-built techniques have many limitations. The analysis by these methods cannot determine the real-time of the total project delays. Further, the methods ignored the issues of acceleration, pacing delay, concurrent delay and concurrent effect, which will affect the delay analysis results. Based on this, the as-planned and as-built techniques are not suitable for determining the responsibility of the delay damages in most practical situations of the delay claims.

Form Sections 4.4.3 and 4.4.4, impacted as-planned and time impact techniques have many limitations. Although these techniques can determine the real-time for the total project delays, these methods ignored the issues of acceleration, pacing delay, concurrent delays, and concurrent effects, which will affect the delay analysis results. Based on this, the impacted as-planned and time impact techniques are not suitable for determining the responsibility of the delay damages in most practical situations for the delay claims.

Form Section 4.4.5, the but-for technique has also many limitations. Although this technique can address the concurrent delays issue, this method ignored the issues of acceleration, pacing delay, real-time of the total project delays, and concurrent effects, which will affect the delay analysis results. Based on this, the but-for technique is not suitable for determining the responsibility of the delay damages in most practical situations for the delay claims.

Form Section 4.4.6 and 4.4.7, window analysis and total float management techniques have also many limitations. Although these techniques can address the issues of real-time and concurrent delays, these methods ignored many other issues, which will affect the delay analysis results. These techniques cannot address the issues of acceleration, pacing delay, and concurrent effects. Based on this, window analysis and total float management techniques are not suitable for determining the responsibility of the delay damages in most practical situations for the delay claims.

The above evaluation result provides a better understanding of the shortages and limitations in the existing DATs. Further, it offers critical issues that need attention to improving the delay claim analysis. At the project-level, considering the issues of concurrent effects and pacing delays are crucial to ensuring fairness and an amicable result for allocating the delay damages between the project parties, which have been not addressed by any of the existing DATs. Additionally, the cost of delay damages and acceleration is another essential issue in delay analysis that should not be neglected during the delay analysis. The cost of delay damage is not equal to the acceleration in the most delay scenarios unless the delay and acceleration have occurred in the same activity. Although the acceleration can eliminate any damage at the project-level by accelerating the project completion date, this acceleration cannot eliminate the damages at the activity-level unless it occurred at the same effected activity. Further, this consideration has not addressed by any of the existing DATs. Therefore, determining the recoverable day of damages at the project-level and the recoverable day of damages at the activity-level are also two factors that can be used to reduce the delay claims resolution difficulties.

Based on this, there is a need to develop a technique to overcome the above shortcomings in the existing DATs. Developing a new delay analysis technique would require rigorous data that can be achieved based on a suitable methodology. Thus, the following sections will focus on finding the best suitable methodology that can be adopted to achieve the research aim. It also needs to be validated to test its applicability and reliability for producing accurate results of delay analysis claims through reliable validation processes.

CHAPTER FIVE: RESEARCH METHODOLOGY

5.1 Introduction

The review of the literature shows a lack of consensus regarding the appropriate technique for use in construction delay analysis. The fairness in delay claims analysis and resolution is being tied significantly in resolving some crucial issues related to delay claims analysis that has subsequent disruptive effects on delay responsibility, which is often missed in the existing delay analysis techniques. This chapter intends to discuss the research methodologies in the construction engineering and management field and describes the methodology that is adopted in this research to capture the data needed to achieve the research objective. The contents of this chapter are as follows. It begins by introducing general research methodologies followed by reviews of different researches in construction delay claims analysis. The research philosophy, approach and strategy are briefly discussed in Section 5.2. The methods adopted for various stages of this research are then presented and justified in Section 5.3.

5.2 Overview Research Methodologies

Kagioglou et al. (2000) proposed a nested approach to research modelling that provides a holistic and integrated understanding of research methods. Figure 5-1 illustrates how research philosophy, approaches and techniques are interrelated in nested research methodology, as follow:

- The research philosophy created by the outer ring guides and energises the essential and inner research approaches and techniques.
- The research approaches incorporate qualitative and quantitative methods.

- Research techniques consist of data collection tools such as literature review, Interviews, Observations, experiment, Questionnaires and Surveys, Documents and Records, Case Studies, and Focus Groups.

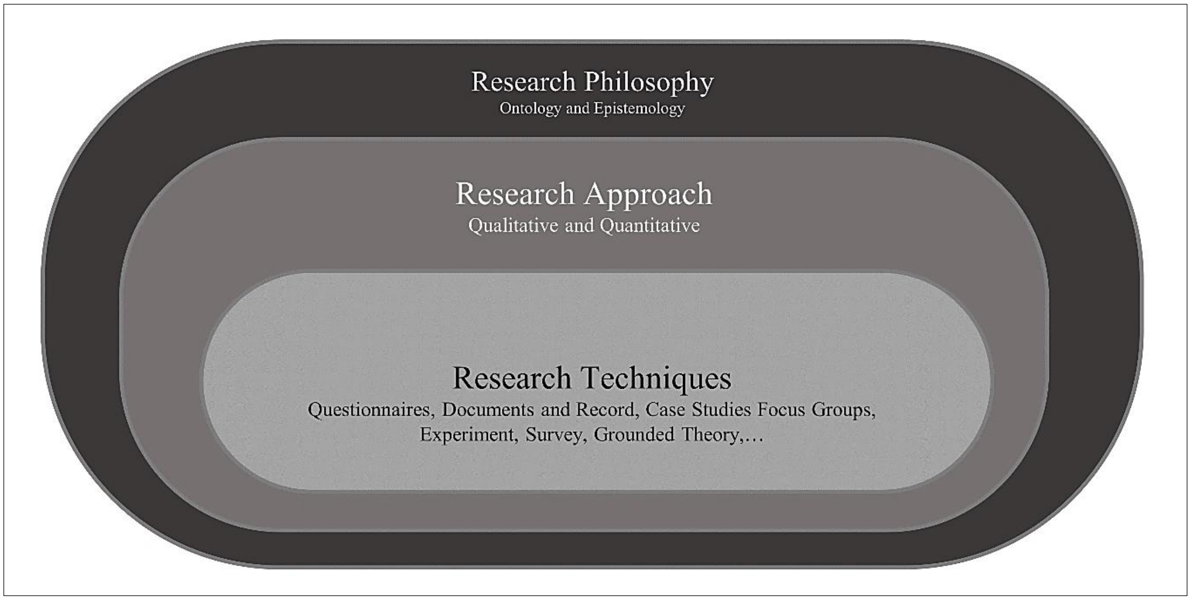


Figure 5-1: Nested Research Methodology (reproduced from Kagioglou et al. 2000)

Saunders et al. (2003) equate the approach of the research to an 'onion', where the outer ring layer is research philosophy. Saunders et al. (2003) developed a model that coincides with the three-stage hierarchical model of Kagioglou et al. (1998). Kagioglou et al. (1998) proposed a nested methodology that flows from the research philosophy up to the research approach and then to data collection methods. However, Saunders et al. (2003) have enhanced this model by recognising further two layers within the research process, as shown in Figure 5-2. Beyond the research philosophy, the research approach lies that leads the researcher into the research strategy in the third layer. After the research strategy, the researcher would be able to move to the stage of data collection by determining and realising 'the time horizons' for the research.

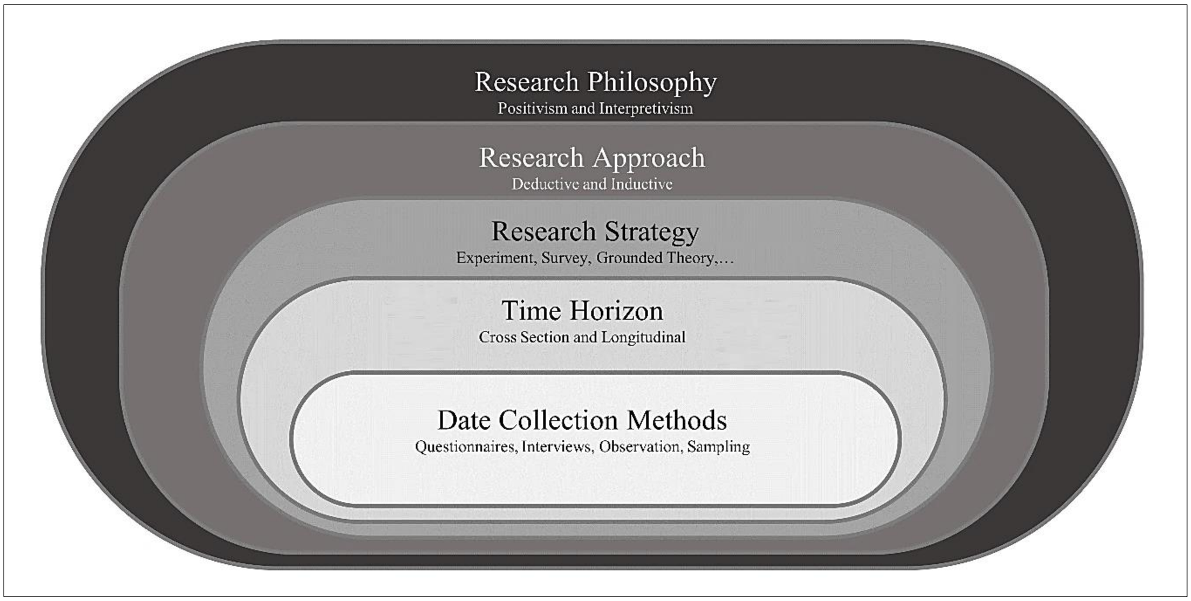


Figure 5-2: Onion Research Methodology (reproduced from Saunders et al. 2003)

5.2.1 Research Philosophy

Understanding the philosophy of a research study is essential as it forms the base for understanding the research methodology. Research philosophy can help to get the research work into perspective and ensure that it avoids making unsuitable claims for its results (Thomas, 2004). Thus, research studies have different positions on the nature of research philosophy (Easterby-Smith et al. 2002). Therefore, there are two main philosophical schools of thought in physical and social researches: ontological and epistemological (Bryman, 2016).

Ontological philosophy is “the theory of what there is” (Trigg, 2001) and deals with reality and the nature of the world (Flew, 1984). Epistemological philosophy further seeks to answer questions about; "how we may come to know, what constitutes knowledge, what relationships exist between the knower and the knowable, and how reality maybe is known" (Tuffin, 2005). The epistemology has been defined by Carson et al. (2001) as “the relationship between the researcher and the reality of how this reality is captured or known". Also, Hudson and Ozanne (1988) stated that Ontology is the nature of reality.

As shown in Table 5-1, both ontological and epistemological can each be categorised into the two most distinguished research philosophies, which are positivism and interpretivism (Easterby-Smith et al., 2002). Positivism refers to a search for general laws and cause-effect relationships by rational means (Sexton, 2003). The positivist ontology always believes that the world is external and that there is only a single objective reality and fact to any research phenomenon or situation, with regardless of the researcher's perspective or belief (Hudson and Ozanne, 1988; Carson et al., 2001). Thus, the researcher takes a controlled and structural approach in researching by identifying a precise research topic, constructing appropriate hypotheses and by adopting an appropriate research methodology (Churchill, 1996; Carson et al., 2001). Interpretivism refers to a search for explanations of human action (Sexton 2003). The position of interpretivism considers that reality is multiple and relative (Hudson and Ozanne, 1988). Lincoln and Guba (1985) explain that these various realities also depend on other systems for meanings, which make it even more challenging to interpret regarding fixed that based on facts of realities (Neuman 2000). The knowledge obtained in this discipline is socially constructed rather than objectively determined (Berger and Luckman, 1967; Hirschman, 1985; Hudson and Ozanne, 1988; Carson et al., 2001, p.5).

Table 5-1: The differences between the paradigms of the research (Adopted from Carson et al., 2001: p. 6)

	Positivist	Interpretivist
Ontology (Nature of 'being' / Reality)	- Have direct access to the real world. - Single external reality.	- Have direct access to the real world. - No single external reality.
Epistemology (The grounds of knowledge or the relationship between reality and research)	- It can be used to obtain hard and secure objective knowledge. - Research focuses on abstract concepts and general ideas. - Thought governed by hypotheses and stated theories.	- It can be understood through 'perceived' knowledge. - Research focuses on specific and concrete background. - Seeking to understand a specific context.
Methodology (Focus of research/ Role of the researcher/ Techniques used by the researcher)	- It concentrates on description and explanation. - Detached, external observer. - It is a clear distinction between reason and feeling. - Aim to determine external reality rather than creating the object of study. - Strive and endeavour to use a rational, consistent, verbal, logical approach. - Seek to maintain a clear difference between facts and value judgments. - A difference between science and personal experience. - It formalised statistical and mathematical methods predominant.	- It concentrates on understanding and interpretation. - Researchers want to investigate what they are studying. - Allow feeling and reason to govern actions. - Partially create what is intended to be studied, the meaning of phenomena. - Use of pre-understanding is essential. - A difference between facts and value judgments less clear. - Accept the influence of both science and personal experience. - Primarily non-quantitative.

5.2.2 Research Approach

A research approach is a way of unfolding a specific style and employment of different methods in doing research. It is a strategy of enquiries which moves from philosophical assumptions to research design and data collection (Myers, 1997). The research approach or strategy can be categorised in various ways. For example, it can be divided into the inductive approach and deductive approach. Easterby-Smith et al. (2002) argue that the positivist research is more biased towards deductive approach. A researcher can use a deductive approach in which he can develop a theory and hypotheses and design a research strategy to test the hypothesis (Saunders et al., 2009). However, the interpretive researches are more biased towards the inductive approach. In an inductive approach, the researcher will collect data and develop a theory as a result of his data analysis (Saunders et al. 2009).

5.2.3 Research Strategy

A research strategy in the literature is identified as a road map that provides the overall direction to achieve the goal of the research, including the process by which the research is conducted. Action research, case study, survey, experiment are examples of such research strategies (See Saunders et al., 2003; Yin, 2003; Easterby-Smith et al., 2002; Gill and Johnson, 2002). The strategy for research is chosen according to the characteristics of the problem. According to Yin (2003), there are many ways to conduct research, which are governed by the relationship between research questions and research strategy. He suggests three conditions for defining the research strategy, as shown in Table 5-2, which are: (1) the type of research questions, (2) the extent of control an investigator has over actual behavioural events, and (3) the degree of focus on contemporary as opposed to historical events. Therefore, each of these conditions will determine the strategies that would be adopted in this research.

Table 5-2: Relevancy of research strategies- adopted from Yin (2003)

Strategy	A form of the research question (1)	Requires control over behavioural events? (2)	Focuses on contemporary events? (3)
Experiment	how, why	Yes	Yes
Questionnaires and Surveys	Who, what, where	No	Yes
Case study	how, why	No	Yes
Documentary and Archival analysis	who, what, where, how many, how much	No	Yes/No

In this study, the research questions start with "what". Also, this study is on contemporary events and without any control of the behaviours. Thus, questionnaires survey strategy and archival analysis are more appropriate strategies for this study to meet the research objectives.

5.2.4 Time Horizons

Before data collection, it is essential to determine whether the objective of the research is to study a phenomenon in a snapshot of time (cross-sectional) or to study an on-going and longitudinal phenomenon (Saunders et al. 2003). The research could be a time-constrained or "snapshot" research, which is called a cross-sectional study. Also, it could be with more extended time duration, which is called a longitudinal study. Both the cross-sectional and longitudinal studies are observational. This means that researchers record information about their subjects without manipulating the study environment (Saunders et al., 2009).

In general, the research should drive the design. However, the progression of the research helps determine which design is most appropriate. Cross-sectional studies can be done more quickly than longitudinal studies. That is why the researchers might start with a cross-sectional study to first establish links and associations between individual variables. Then they would set up a longitudinal study to study cause and effect.

5.2.5 Techniques and Procedures

Techniques and procedures of the research data are usually collected through qualitative and quantitative methods (bell and Bryman, 2003). Quantitative method is the method that focuses on numbers and frequencies rather than on meaning and experience. It focuses more on counting and classifying feature and constructing statistical models and figures to explain what is observed. Thus, it can be used to measure the incidence and prevalence of phenomena. In contrast, a qualitative method concerns in-depth responses of opinions and thoughts about phenomena. It relies heavily on words and verbal responses from participants. Qualitative research is more subjective and is based on interpretive. Therefore, it produces results from words, rather than numbers (Cohen et al., 1994). Table 5-3 presents a summary of the features of quantitative and qualitative research techniques.

Table 5-3: Features of quantitative and qualitative research- Adapted from Park and Mauch (2003)

Quantitative Research	Qualitative Research
Aims to provide full and accurate descriptions of phenomena in all their complexity	Aims to reveal or establish cause-and-effect relationships in or among experiences or occurrences
Fact-finding based on evidence or records	Attitude measurement based on opinions, views and perception measurement
Relies on deduction; testing of theory	Relies on induction; generation of theory
Structured Questionnaires/ Experiments	Unstructured or semi-structured interviews
Nature of data is hard and reliable	Nature of data is rich and deep
Statistical of the data analysis	Thematic of the data analysis
The relationship between researcher and subject is a distant	The relationship between researcher and subject is a close
The relationship between theory/concepts and research is testing/confirmation	The relationship between theory/concepts and research is emergent/development
Findings are conclusive, can be generalised and used to recommend a final course of action	Findings are not conclusive, cannot be generalised and usually exploratory and investigative

Depending on the need and requirement, the researcher can devise data collection methods such as analysis of secondary data, observations, interviews and questionnaires within the selected research strategy. In the section above the research philosophies, research approaches and research strategies are discussed in detail. The next section formulates an appropriate methodology to fulfil the aim of the research on delay claims analysis.

5.3 Research Design

The nature of a research subject, its aim and objectives and the available resources are mainly used to determine its design (Creswell, 2003; Gill and Johnson, 2002). This research was designed to address the problem identified in Section 1.3 and achieve the objectives mentioned in Section 1.4. It was considered essential to develop a complete understanding of the study by setting out the various elements in a logical sequence, to avoid misunderstandings about any point in the research. The problem, aim, objectives and questions of the research were therefore stated at the outset. These mainly formed the research methodology developed for carrying out this research.

Burrell and Morgan (1979) identified realism and nominalism as two assumptions of ontological, and two epistemological assumptions, which are positivism and interpretivism (subjectivism). In construction management research, the positivist paradigm is based on realist ontology and objectivist epistemology, and usually takes the form of deductive research and makes use of quantitative techniques. On the other hand, the interpretive paradigm is based on nominalist ontology and subjectivist epistemology, and typically takes the form of inductive research and makes use of qualitative techniques. A combined or pragmatic paradigm methodology means both the positivist and interpretive paradigms are applied in one piece of research.

Figure 5-3 shows this research design through the concept of research onion. The research philosophy adopted the interpretive paradigm that is based on nominalist ontology and subjectivist epistemology, and takes the form of inductive as the research approach and makes use of qualitative techniques. Also, the research adopted questionnaires survey and archival and documentary research as the research strategy. As like most academic research, this research is a cross-sectional study.

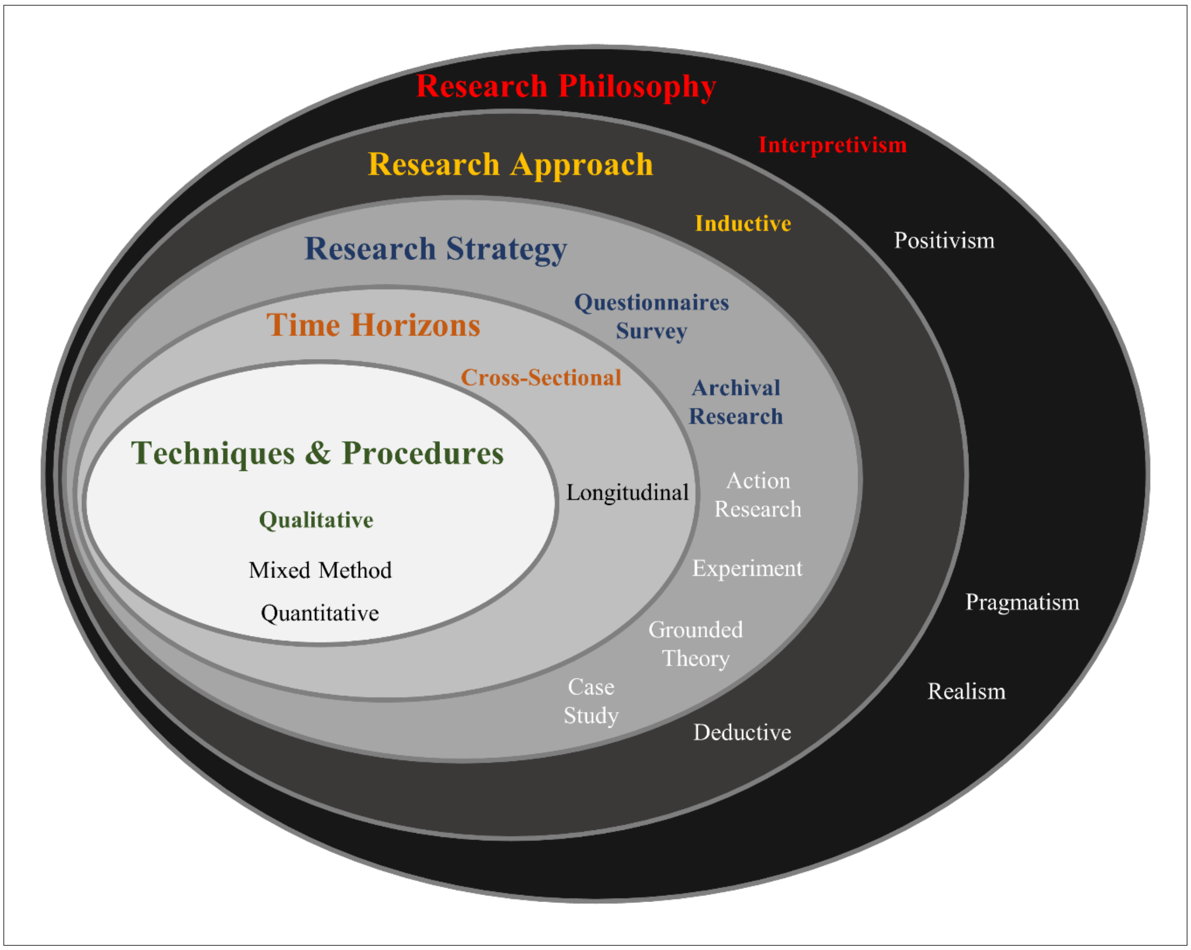


Figure 5-3: The research design through the concept of research onion

In order to achieve the aim of the research, it was decided to conduct six stages of the study, as shown in Figure 5-4. The first was a comprehensive review of the relevant literature, starting with an overview of construction delay claims, for shedding light on theories of delay analysis in general in construction delay claim environments. The second stage was to conduct a documentary analysis of court cases relating to delay claims, to test the problems in current practice, identify the issues of delay analysis and highlight the shortcomings of current techniques in delay claims analysis. The third stage was to explore the best practice of delay claims analysis by questioning experts from carefully selected groups. The fourth stage was to build a reliable framework based on the results obtained from the second and third stages. The fifth stage was to develop a technique that offers an equitable analysis for the delay damages claims and capable of considering the DAIs. The last stage was to test and ensure the validity of the purposed method.

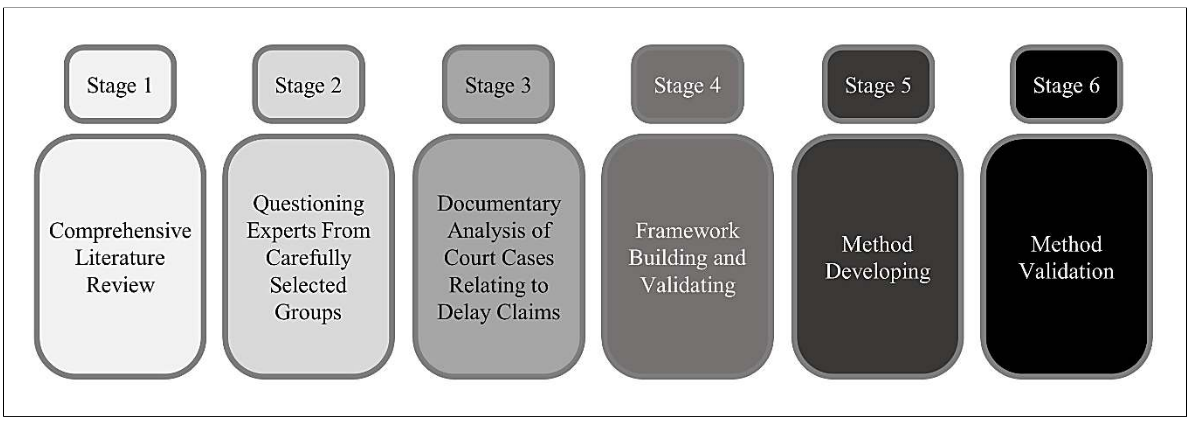


Figure 5-4: Stages of the research

5.3.1 Literature Survey

After the identifying of the problem, the primary concern throughout the review stage was to understand the concept of delay claims analysis and to explore the available approaches, therefore identifying the broader parameters that are likely to feed and affect the secondary method and primary method of the data collection in stages two and three, respectively. The literature divided into three substages: studying the literature on construction delay claims, the current delay analysis issues, and the existing delay analysis techniques. The literature was thus set out to address the following points:

- Provide insight to whether the research is viable and will also not lead to repetition;
- Compare the research aim to existing knowledge in the chosen field;
- Present the research topic to reflect current trends in the chosen field;
- Identify an appropriate methodology for undertaking the research;
- Identify and suggest routes about delay claims analysis; and
- Assist in generate other ideas and further refinement of the research objectives and questions.

5.3.2 Primary Data Collection

Due to limited studies in some DATs and DAIs, there was a need for conducting a questionnaire survey as a primary method of data collection. This survey aims to determine the DAIs that are often ignored by the previous studies or the existing DATs and find out the most effective approach for considering each of the determined DAIs during the delay claim analysis. Thus, the questionnaire is adopted in this research as an appropriate strategy to overcome this limitation, based on the conditions that are stated in Section 5.2.3.

For meeting the research aim, a qualitative approach will be adopted in designing the survey questions to collect the required data. This is because the qualitative method concerns investigations into more in-depth details of phenomena, such as the phenomena of delays in construction projects. Further, it relies both on the opinions and thoughts that are used during the analyses and disputes and also on words and verbal responses from participants, which is more subjective in producing results from words, rather than numbers (Cohen et al. 1994).

Based on this, the primary method for collecting the required data in this research is a questionnaire that takes a qualitative approach. It aims to explore an appropriate technique that can address the DAIs and overcome the shortcomings in the current practice, thereby meeting the research objectives.

5.3.2.1 Design of The Survey Questionnaire

As the result of the research questions as well as the sources of the data that are required for answering the questions, it became apparent at the very early stage of the research that the data would be qualitative. Therefore, this study adopted a qualitative method to give an in-depth and precious data from specific samples of researchers and practitioners to gain significant insights about the problems and issues underlying the delay analysis issues and techniques in the construction industry (Tanur, 1982; Babbie, 2005).

The qualitative method applied the most common types of questionnaires, which are self-administered questionnaire such as mail questionnaire, and in the form of closed-ended question among focus groups to support and validate the survey instrument designed for data collection from selective experienced practitioners in construction delay claims. This type of questionnaire will enable accurate data to be collected consistently, which will mean the received data is reliable (Saunders et al., 2009).

Also, good questionnaire design is crucial in order to generate data that are helpful to achieve the research goals (Oppenheim, 1992; De Vaus, 2002; Parfitt, 2005). Questionnaire format, sequence and wording, the inclusion of classification, behavioural, knowledge and perception questions, and questionnaire length and output, need to be considered to ensure reliability, validity and sustained engagement of the participant (Bird, 2009). Therefore, the survey was carefully designed to ensure that it elicits useful responses to various questions and overcome the limitations of the questionnaire survey. This design was achieved by following the recommended best practice supported, such as Moser and Kaltron (1986) and Baker (2003). Such method includes making sure the questionnaire is precise and accurate, easy to read and understand, as short as possible and able to complete within a matter of minutes and prepared to flow smoothly without any hidden bias. Similarly, the wording of the questions was carefully considered to prevent as far as possible any misperception or vagueness.

Therefore, the set of questions is designed to investigate into six areas that formed the DAIs. The questions in each delay issue have structured based on three areas. The first area is the questions that are related to recognising the issue in the delay claims. The second area is the questions that are related to proving its potential in changing the analysis results. The third area is the questions that are related to identifying the best analysis to overcome the issue. The questionnaire survey is included in Appendix (II).

5.3.2.2 Sampling

Other than selecting a research subject and appropriate research design, no other research task is more essential to creating credible research than obtaining an adequate sample. In qualitative research studies, the number of participants depends on data saturation. Saturation is reached when the researcher gathers data to the point of diminishing returns—when nothing new is being added or when the researcher is no longer learning very much (if anything) from each subsequent interview, observation or others (Marshall et al., 2013). Guest et al. (2006) propose that saturation often occurs around 12 participants in homogeneous groups. Further, Latham (2013) stated that saturation in qualitative research occurs at approximately 11 participants. For a particular group, saturation often occurs between 12 and 15 (Crouch and McKenzie 2006). Therefore, the estimation of the appropriate sample size for this study is directly related to the concept of saturation.

While qualitative methodologists are improbable to agree on exact sample sizes needed for qualitative studies, the experts commonly agree that a number of factors can affect the number of participants in the focus groups or interviews that are required in order to achieve saturation, such as a particular level of understanding or quality of experience in the area of research (Strauss and Corbin, 1990; Sandelowski, 1995; Morse, 2000; Patton, 2002). Therefore, the characteristics of participants in this survey have been selected thoroughly throughout specific criteria to fit the survey requirements. The first criterion is that the participants must have knowledge contribution to the topic of project delays, project disruptions, or schedule analyses. The second criterion is that the participants must have a relatively high level of skill, knowledge, or experience into construction claims. Therefore, it is logical and sufficient to collect information to be more credible from the researchers, academics, and practitioners who are fully understood the subject of construction delay claim analysis.

Accordingly, a list of 105 experts has been determined, which represents the experts and authors who are well-known in the area of construction delay and have a contribution to the delay claims analysis. The experts in this list have been selected based on their contributions in the subjects of DAIs and DATs, which were collected from construction delay claims books and journals, Forensic Schedule Analysis by ACCE, and Delay and Disruption Guidelines by SCL. Based on the concept of saturation, the questionnaires were emailed to 50 experts. Out of 50 questionnaires sent out to the selected experts, only 15 questionnaires were returned, of which 13 were adequately completed and useful for the future analysis. Due to the low response rate, the questionnaires have been improved and sent back again to another 45 participants who had knowledge of delay claims. Out of 45 questionnaires sent out to the selected participants, 24 questionnaires were returned, of which 21 were adequately completed. Thus, the total of the completed questionnaires was 34 out of 95 that had been sent to the selected experts. Figure 5-5 shows that this represents a 35.7% response rate for this survey, which is quite suitable since surveys within the construction industry typically achieve between 20% and 40% response rate (Furtrell, 1994).

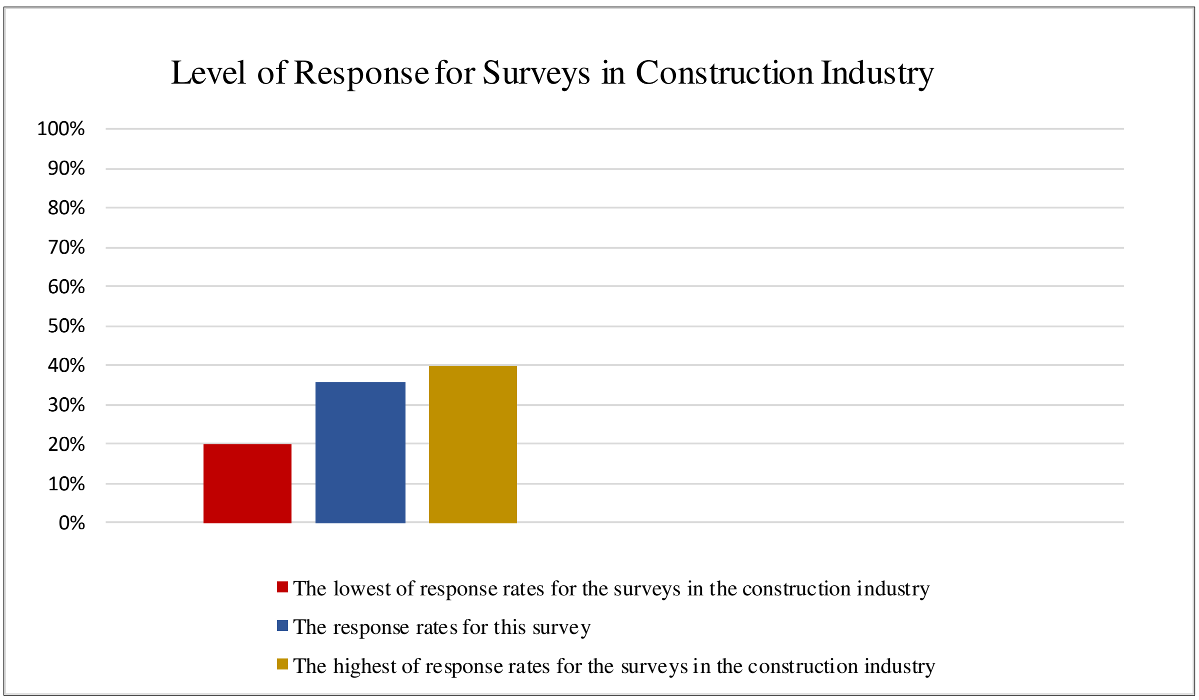


Figure 5-5: The percentage of response rates

Most of the respondents have spent more than 20 years in delay claim analysis, and it indicated that 85% of respondents had experience of more than 20 years, followed by 15% with 15–19 years of experience. There were no respondents who had experience between 1–14 years. It can be summarised from the results that the vast majority of the respondents had more than

20 years (20–40) of knowledge and experience in construction delay claims analysis and litigation, indicating a high level of experience, which showed that the given data are deep, rich and relevant for the reliability and validity for measuring the research quality. Therefore, the sampling's type and size for this research would be sufficient and accurately reflects the reliability of the outcomes.

5.3.2.3 Pilot Study

Among the experts sampling, the process involved first selecting a total of 10 participants for a pilot test. According to Weisberg et al. (1996), questionnaire design is typically an art, much of which is learned through practice, and that it is so tricky that researchers rarely conduct a questionnaire without first pretesting it. Therefore, the sampling first has been determined for a pilot test that included the researcher and practitioner who has relevant experience between 12-45 years. The selected respondents were construction litigation attorneys, university professors with expertise in construction delay claims, and experts in mitigation, analysis and resolution, or defender of construction disputes.

5.3.2.4 Primary Data Collection

For the questionnaire method, a total of twenty-eight questions in each questionnaire survey were addressed to the experts in construction delay claims, along with covering letter explaining the purpose of the survey. A copy of the final draft of the questionnaire, along with the cover letter, is indicated in the Appendix (I). The questionnaire was constructed to produce answers to several questions about the research objectives.

The two primary modes of obtaining the data are: (1) sending a survey out by post, fax or internet to the respondents with a self-administer; (2) using an interviewer to administer the survey either by telephone interviews or face to face (Rea and Parker, 1997; Burns, 2000; Creswell, 2003). Due to a worldwide spreading of the participants, it was decided that the best way to send the questionnaires through an online survey. Also, emails and internet surveys have acceptable reliability enough to be used for administering the survey (Braimah, 2008).

5.3.2.5 Data Analysis

The data obtained from the survey are ordinal in nature as most of the responses were ratings measured on the Likert scale. Such data cannot be treated using parametric statistics methods unless precarious and, perhaps, unrealistic assumptions are made about the underlying distributions (Siegel and Castellan Jr., 1988, p.35). It was therefore found appropriate to analyse it using non-parametric statistics involving descriptive statistics analysis. This involved the use of percentages for presenting description finding of the data collection. This technique was employed for analysing data related to the characteristics of the respondents and open-ended questions/comments.

5.3.3 Secondary Data Collection

In this research, the method of analysing the existing documentary records such as court cases and protocols related to delay claims was adopted as a secondary method and valuable method for data collection. Documentary methods differ from primary research data where the researcher is responsible for the entire research process from the design of the project to collecting, analysing and discussing the research data (Stewart, 1984). Judd, Smith and Kidder (1991: 289) distinguish three common characteristics of documentary methods such as:

- they rely entirely on the analyses of data collected for purposes other than those of particular studies in social relations;

- documentary studies often call for ingenuity in translating existing records into quantifiable indices of some general concepts;
- documentary studies are particularly susceptible to alternative interpretations for the natural events and their effects.

The literature reveals the disadvantages and weaknesses of documentary data (Bailey, 1982; 1994; Treece and Treece, 1982; Stewart, 1984; Webb et al., 1984; While 1987; Hakim, 1993). Documentary analysis is limited by the availability of material, missing or incomplete data, inaccuracies in real and inherent biases. Webb et al. identify the significant sources of bias in documentary evidence when they describe the two problems of 'selective deposit' and 'selective survival' (Webb et al., 1984: 114).

The advantages include: 1) Data readily available; 2) Inexpensive and economical form of data; 3) Save time; 4) Nonreactive records unbiased by the data collection process; 5) Researcher does not have to be present during data collection; and 6) Useful for problem formulation. However, the disadvantages include: 1) Limited by the availability of data; 2) Inaccuracies in the original material; 3) Bias - 'selective deposit'; 4) Bias – 'selective survival' - missing/incomplete data; 5) Total document or part of the document?; 6) Data studied out of context; and 7) Preparation before analysis (Ahmed, 2010).

Therefore, the analysis of the documents concerned a critical analysis of the specific information such as court cases relating to force majeure delays in the construction industry. This analysis is aimed to provide a background in the context upon the research objectives that covered a wide range of issues. These issues include (1) investigate the construction delay claims in general, the types of the schedule impacts, and the problems that related to project time and cost overruns; (2) explore the theoretical and legal principles underpinning the effect of the schedule impacts and DAIs (detailed in Chapter 3); and (3) examining the existing DATs in considering the identified DAIs (reported in Chapter 4). Therefore, application of the appropriate set of criteria to select secondary data to be used in the study plays a vital role in increasing the levels of research validity and reliability.

The documentary analysis is a particular analysis that can help in investigating the issues of delay claims and examining the process of delay analysis. Other than the data that collected for the general topic of delay claims that have mainly covered in chapter 2, the documentary records and studies include various research strategies such as archival of delay claims and court cases. The documentary analysis was considered as the most effective method for collecting the data in deciding upon the most appropriate approach for this research. The documentary analysis includes these publications that range from journal papers, conference papers, court cases, case research studies, and online documents, which can assist in understanding all the related issues of delay claims.

In the systematic analysis of the documentary, a critical study of existing court cases related to the DAIs and DATs was conducted. Also, particular data from both technical and legal materials in the field of delay claims and construction delays disciplines have provided suitable information for determining the research objective in the practices used. The technical documents included technical papers and articles in construction delay claims and mathematical formulas for computing delay claims. Legal materials researched covered case law, construction delay claims and legal textbooks. The purpose of the analysis is to establish, among others, A state-of-the-art on the subject of the research objective, by addressing the following issues. (1) the effect of the schedule impacts; (2) the problems of the delay claim analysis; and (3) an appropriate framework for addressing these issues in delay analysis process that can help claims analysts, judges and jury members, lawyers, contractors, and owners in the construction industry.

5.3.4 Developing the Framework and Building the Technique

Building the technique is an essential step for achieving the research objectives. Information gathered from the literature review was used to develop the most appropriate framework and build the technique for delay claims analysis. The processes commenced with developing an Initial presentation of the conclusion for each DAI in the delay analysis process independently and Separately; this conclusion was linked with the data obtained from the document's analysis of delay claims. Therefore, the information gathered from the literature review, documentary analysis, and questionnaires, will be used to draw the framework and the proposed technique, as well as the conclusions concerning the research objectives.

The framework construction was based on identifying the impact on the project schedule by the unit of performance measurement. The framework has classified the delay as non-performance in the unit of measurement and the disruption as less or more productivity in the unit of measurement. Thus, the effect types, whether loss of money or loss of time, will determine the claim type, whether disruption claim or delay claim.

The technique building was based on analysing the delay claim by (1) calculating the responsibility for any potential damage at project-level and activity-level; (2) employing a procedure to determine any effect on the early start of the scheduled activities as well as the project completion date; and (3) considering the most DAIs during the delay analysis.

5.3.5 Validation of the Framework and the Technique

Two validation methods have adopted in this research for validating the proposed framework and technique. The first validation method is a comparison between the existing DATs and the proposed technique. In this method, the case study that is used in Chapter 4 will also be used by the proposed technique in Chapter 8 to compare analysis results. Three criteria will be set to compare the proposed technique with the existing DATs, which are as follows: the approach in analysing the schedule impacts, the accuracy in producing accurate results, and the capability in considering the DAIs.

The second validation method is the validity of the proposed technique by using the experts' opinions in the delay claims analysis. In this method, a video was designed on an online page (YouTube) to explain the processes of the proposed framework and technique. This method has been selected to determine the capability of the proposed technique for overcoming the DAIs and its efficiency in producing a reliable result. The validation questionnaire will be designed based on some criteria to ensure the proposed technique accuracy, completeness, comprehensibility and cost-effectiveness. Further, the previous list used in the primary data for selecting the participants will be used in the validation. The use of the same list will ensure assessment accuracy and the level of familiarity with this research. Following this, the results will be analysed quantitatively and qualitatively to validate the proposed technique.

5.4 Summary

This chapter explored the philosophy, methods, techniques, and types of research methodologies that are suitable for the field of construction delay analysis. It also explained the data collection methods used and adopted in this research. The research uses the empiricism philosophy: realist ontology and subjectivist epistemology, practical method; it is mostly qualitative, and, regarding the research type, it is considered to be exploratory research.

Six essential stages were designed to achieve the objectives of the research: 1) reviewing the literature; 2) analysing the documentary of the delay claims; 3) conducting the questionnaire survey; 4) developing the framework; 5) proposing the technique; 6) validating the framework and the proposed technique. The following chapter will focus on the data that are needed to meet the research aim, which are collected from the documentary analysis and the questionnaire.

CHAPTER SIX: DATA COLLECTION AND ANALYSIS

6.1 Introduction

The previous chapter discussed different research methodologies and approaches and justified the adopted research methods used for collecting the required data. Thus, this chapter aims to present the collected data and the findings that have resulted from analysing this collected data. The collected data have been processed based on the adopted framework that has three fundamental and requirement factors. These fundamental factors will form the entitlement, based on the resulting injury, the causation and the liability. In this chapter, these requirements will be collected by using the two adopted methods for collecting the data—the documentary analysis and the questionnaire survey. Further, each of these requirements will be discussed and analysed to determine the missing information and fill the resulting gap. The primary purpose for collecting the required data from the court cases is to extend the knowledge to create sufficient comprehension of the delay claims analysis. This includes the following: (1) how the resulting injury has been presented in the court cases and which causation has been adopted to prove such damage in each case; (2) how the responsibility for the DAIs has been specified and what the entitlement that has been allocated in each case. The cases presented in this chapter have been sought from different resources such as the Board of Contract Appeals and Court of Appeals in the USA, UK, Canada and other countries. Furthermore, many of these court cases have been investigated by construction delay experts in many sources, such as construction claims books, journals and websites. In effort to fine a specific case, the investigation was conducted based on keywords that are related to the issue of a claim. The relevant keywords that were included in the research consisted of the following: construction delay claims, construction acceleration, loss of productivity in construction delays, force majeure in construction delays, disruption and delay in construction projects, excusable delays, non-excusable delays, compensable delays, and other related words in the subject of delay analysis claims and issues. While the data from the documentary analysis of the court cases have been used in all the three fundamental factors, the data from the questionnaire survey have been used only for investigating the liability in Category C. This is due to the fact that the analysis of the liability in construction delay claims requires further considerations in how the responsibility should be assigned for any DAI, which needs a reliable assessment, such as the expert opinion.

6.2 Data Processing

The purpose of data collection in this research aims to achieve the research objectives and answer the research questions as stated in Section 1.5, toward developing a framework and technique that can be used to analyse the construction delay with considering the most DAIs. The reliability and validity of the data collected are based on two facts. First, the primary data collection will be based on a high level of experts in construction delay claims analysis. Second, the secondary data collection will be based on reliable results for the documentary analysis of court cases in construction delay claims. Therefore, the data from both adopted methods will be profound, rich, and relevance with the research aim and objectives.

In this research, the required data have been organised based on the process of delay claims analysis. The foundation of a claim or request in analysing the schedule impacts is rooted in three categories of proofs: liability proof, causation proof, and the proof of resulting injury. Liability is the contractual entitlement to recover for an issue. Causation is the cause-and-effect relationship between an action or inaction by a party on the issue under investigation and the resultant injury or impact to another. Resulting injury is the quantification of impact to the injured party resulting from the cause-and-effect connection on an issue. These elements are typically considered together and referred to as an entitlement. Thus, the innocent party must prove liability, causation, and the resultant injury (*See, e.g. Wunderlich Contracting Co. v. the United States, 1965*). In Wunderlich, the U.S. Court of Claims stated that:

> *"although a contractor did not need to prove damages with mathematical exactitude, this leniency as to the actual mechanics of computation does not relieve the contractor of its essential burden of establishing the fundamental facts of liability, causation and resultant injury."*

Also, the U.S. Court of Claims has applied these elements in the case of Acme Missiles & Constr. Corp., (1963) and stated that:

> *"Certainly, there has been nothing to establish a doctrine that the ordering of a reasonable number of changes on an ordinary construction contract is proof, per se, that the contractor suffers impact costs. In order to recover a contractor must bear an essential burden of establishing the fundamental facts of liability, causation and resulting injury."*

Based on that, the data needed to meet the research goal has been classified into three categories of proofs, as shown in Table 6-1. This classification will help to manage the data that are needed to accomplish the research aim and objectives by verifying the collected data in each category, which is consequently essential for analysing delay claims in the construction industry. Data collected from the adopted methods will be presented and discussed for each category in the following sections.

Table 6-1: The categories for proving the construction delay claims

Category	The Proofs	The process	The result
A	Resulting Injury	Quantify the losses and damages.	Entitlement (compensable or excusable)
B	Causation	Defining the effect.	
		Determining the cause.	
		Linking the cause and the effect.	
C	Liability	Analysing the responsibility	
		Identifying the responsible party.	

To collect the data that are required for this research, this study adopted the three fundamental facts mentioned above, which form the basis of proving any construction delay claims. Collecting the required data based on these factors will help to eliminate any doubt to achieve the research aim that is established on the basis of rigorous sequencing for the data processing, similar to the required processes in the construction delay claims. Thus, the following sections will begin by discussing the resulting injury first followed by the work that was being performed when it occurred to try to identify the causation and the liability for such losses and damages. The discussion of the data collection analysis for the three fundamental facts in delay claims will be as follows.

6.3 Category A: Resultant Injury

The resulting injury due to the schedule impacts is the claim of cost overrun or damages. The plaintiff must offer clear proof of the damages that suffered as a result of the schedule impact caused by the defendant. In *Coates Industrial Piping, Inc.*, the VABCA rejected one contractor's claim because of its inability to prove resultant injury by stating that

> *"there is no evidence of what the impact was, how it impacted the work, or at what cost to the contractor."* The problem was that *"the quantity of loss is, in effect, offered as proof of the loss for which the owner is liable."*

As a result, courts and boards often discuss resultant injury simultaneously with causation. In *Bechtel Nat'l, Inc.,* (1989) the board stated that the record supported the fact that the Government's RFIs cause loss of productivity; but denied the claim because the contractor offered no contemporaneous documentation to substantiate the extent of the cumulative/indirect impacts claimed.

As discussed in Chapter 2 (Section 2.2), the types of resulting damages that are experienced by a contractor or owner because of specific events, actions or inactions are likely to vary, but typically include one or more of the following: delay-related costs, scope change-related costs, acceleration-related costs, disruption-related costs, and termination-related costs (Arcuri and Hildreth, 2007). One type of the damage category will rarely exist without at least one or more of the others. As such, in most cases, the contractor or owner who has suffered damages will typically experience and claim several different types of damages in arbitration, unless a total cost claim is being presented. Total cost claims can capture several types of damages in one comprehensive calculation (Jones, 2001).

As evidenced by some court cases relating to recovering the losses and damages due to the schedule impacts, impacting the project cost can be directly recovered through disruption claim; while impacting the project cost indirectly by impacting the project time can be recovered through delay claim. It means, the potential damages due to the schedule impacts can be recovered through; 1) disruption claims if the damages directly have resulted from impacting the project cost, without impacting the project time, or 2) delay claims if the damages have resulted from impacting the project time. For example, the scope changes may result in losses and damages for owner and contractor in different manners. A scope change that increases costs could impact the owner directly by increasing the overall budget, or the change could require a variation to a follow-on contractor which may require some design modification that increases the project time and thus increase the project cost. Likewise, a scope change could impact a contractor by increasing the overall budget, or it could modify the as-bid work plan necessitating more time to complete the project and affect the project cost. These are all practical impacts that nonetheless may affect the overall project costs and schedule in some manner (see, e. g. *Centex Bateson Constr. Co. v. West, 2000*; *Rice v. the United States, 1942; DTC Engineers & Constructors, 2012*).

Regardless of how such claims are characterised, a consistent approach must be developed to how the loss should be identified, how the impact occurred, and to whom it should be allocated. Thus, determining whether to proceed under a direct or indirect impact through a theory of disruption or delay claim can be difficult for any claimant party. The distinction is mostly a matter of quality of proof of quantum and entitlement. Thus, the following sections discuss the distinction between disruption claim and delay claims.

6.3.1 Disruption Claims

Disruption can lead to an increase in the project costs without any project delay. According to Cushman at al. (2001), Disruption claims (or cumulative impact claims) include direct impacts for additional costs that are used to perform extra work; increased costs for inefficiency caused by altered work conditions; increased equipment cost, and increased material costs.

These direct impacts can contribute to a cumulative or indirect impact such as loss of productivity. For example, extraordinary numbers of change orders are factors that contribute to loss of labour productivity and lead to other indirect impacts (Jones 2011). If the net effect of disruption that happened on the schedule directly or indirectly would affect the project cost without affecting the project time, the losses and damages cannot be recovered through the delay claim based on Delay and Suspension clauses because the project time had not affected partially or entirely (See e.g. FIDIC 2005; Burke, T. R, 1991).

Therefore, the disruption claims use different proofs that differ from delay claims for proving any loss or damage. For example, the summary of case Sauer, Inc. v. (2000) stated that:

> *"Although numerous changes can cause delays, a cumulative impact claim differs from a claim for delay in that the contractor need not prove that contract performance was extended beyond the planned completion date in order to recover."*

Because of the similarity in the proof of claiming the direct disruption and the cumulative/indirect disruption, contractors must be careful in choosing how to proceed. Some boards have rejected cumulative disruption claims because the contractor has offered the same proof of entitlement and damages to demonstrate direct disruption (See, e.g., Southwest Marine Inc. v. United States (1994). The distinction between direct disruption claim and indirect disruption claim will be discussed as follow:

6.3.1.1 Direct Disruption Claims

Direct disruption claims are necessary for claiming items that could have been recovered at the time a particular impact (e.g. change order) was executed (i.e., they were foreseeable), but for one reason or another, the contractor did not claim the costs at that time (Nelson, 2011). A direct disruption claim covers the direct effect of changed work, rather than the work conditions that will indirectly affect the consistent work. In generality, direct disruption claims include the direct damages that result directly from changes order, acceleration, or direct disruption, without impacting the project time partially or entirely (Sauer, Inc. v. Danzig, 2000).

Absent the issues of waiver, reservation of right and accord and satisfaction; boards generally appear to be more receptive to direct disruption claims because of the direct and visible link between cause and effect. Therefore, direct disruption claims can be more straightforward to prove provided the contractor can show precisely how a particular change order or group of change orders affected specific base contract work (See, e.g. Southwest Marine, Inc., 1994). The U.S. Court of Claims has recognised a general right to recover the losses and damages that result from a change order as a direct impact of disruption when it can be recognised when the change order is issued. Courts and boards have recognised the existence of disruption claim by the impact of change orders as a compensable change under the Changes clause since the abrogation of the Rice doctrine in 1968 (Rice v. the United States, 1942).

Also, the direct disruption claims also include the processes for claiming the cost of acceleration. For example, the case of Great Eastern Hotel Company v. John Laing Construction Ltd., (2005) dealt with resisted liability for acceleration costs expended by the employer to overcome the breach. The High Court in England recognised the damages due to acceleration can be recovered under the direct disruption claim as a form of mitigation. Also, if a contractor is behind the schedule and the owner acts reasonably under the terms of a contract provision allowing it to demand the contractor accelerate, the contractor will not be entitled to recover its resulting costs that are necessary to get the project back on schedule. This entitlement is the only result when the contractor will dispute its obligation for accelerating the project schedule to overcome the delays. (See, e.g. A.E. Gigxon Co. & Amulco Asphalt Co., 1970; Siefford v. Housing Auth., 1974).

6.3.1.2 Indirect Disruption Claims

Indirect or cumulative disruption can occur as the result of either direct disruption or delay, which can increase the project cost without affecting the project time partially or entirely. Thus, for recovering losses or damages due to cumulative or indirect disruption through disruption claims, the project cost must be impacted without affecting the project time partially or entirely (Finke 1997; Jones 2001).

Unlike the direct disruption claim, the associated of additional costs with the cumulative or indirect disruption are related to the work that is not as readily foreseeable, or if foreseeable, is not as readily computable as the direct disruption costs. For example, the cumulative impact of change order could lead to a claim for lost productivity on constant work, which is not foreseeable at the time the change order is issued. (See e. g. Pittman Construction Co., 1983; Haas & Haynie Corp., 1984).

Although the direct impact of disruptions by change orders or accelerations may directly add, subtract, or change the type of work being performed in one particular area of a construction project, it also may affect other areas of the work that are not addressed by this impact and impact the productivity or/and the resource allocation. In Coates Industrial Piping, the Veterans Affairs Board of Contract Appeals (VABCA) explained that:

> *"it is a change order's unforeseeable impact on [this] unchanged work that lies at the core of the cumulative impact claim."* According to this theory of recovery*, "the issuance of an unreasonable number [or unusual kind] of*

change orders creates a synergistic disruptive impact such that the total disruption caused by the changes exceeds the sum of the disruptive impacts caused by the individual change orders when looked at independently."

In case *Centex Bateson Constr. Co. v. West (2000)*, the VABCA summarised the relationship between loss of productivity and impact costs that result from disruption as that:

"Impact costs are additional costs occurring as a result of the loss of productivity; loss of productivity is also termed inefficiency. Thus, impact costs are simply increased labour costs that stem from the disruption to labour productivity resulting from a change in working conditions. Productivity is inversely proportional to the working-hours necessary to produce a given unit of product. As is self-evident, if productivity declines, the number of working-hours of labour to produce a given task will increase. If the number of man-hours increases, labour costs obviously increase."

Nonetheless, the decisions have been inconsistent at best regarding defining cumulative impacts and explaining the causes of such impacts. The distinction is mostly a matter of quality of proof for determining the cause of cumulative or indirect impact. As the cumulative or indirect impact could be the result of a direct impact, the delay also may cause a cumulative or indirect impact. Also, considering the effect that leads to cumulative or indirect impact will determine the theory of recovering for losses and damages. In case Rice v. the United States (1942), the losses and damages that associated with the cumulative impact as a result from direct impact (change order) is the only costs that can be recovered, but not from the delays. The case stated that:

> *"a contractor that incurred costs associated with delays in performance or with disruption of contract work as the result of contract change was entitled, under the terms of the standard Changes clause, only to the increased costs of the changed work and to a time extension equal to the delay period."*

The elimination of the "Rice" Doctrine has been accomplished primarily by adding constructive change clause for claiming cumulative impacts and explaining what is necessary to maintain such a claim. Courts and boards have repeatedly recognised the existence of cumulative impact claims as a separate constructive change compensable under the Changes clause since the abrogation of the Rice doctrine in 1968 (Kelleher et al., 2010).

Courts and boards have articulated a host of differing definitions for claiming a cumulative impact based on constructive change or suspension of work clause. Also, it should be noted that providing a specific definition suitable for every situation is an extremely difficult task. In fact, in some cases, boards have neither defined nor even mentioned the words "cumulative impact," but awarded such costs anyway (See, e.g., Charles G. Williams Constr., Inc., 1989).

6.3.2 Delay Claims

According to Burke (1991), delay claims usually include indirect costs such as extended overhead, increased equipment duration, and financing costs. In typical delay claims, the plaintiff must show that the other party was responsible for the delay and that this delay caused the plaintiff to suffer a monetary loss. The amount of damages to which a plaintiff is entitled is determined by a set of judge-made rules which form part of the common law. Therefore, the potential damages that would be occurred at the project-level or the activity-level are the only damages that can be measured by using the schedule analysis, as discussed in Chapter two. For accommodating any potential damages resulted from delays, this Section will discuss how the losses and damages would be recovered through a delay claims process.

If the net effect of delay has affected the project time, the potential damages can be recovered through the delay claim because the project time had affected. In order to recover any loss or damage through a delay claim, the plaintiff needs to prove that contract performance was extended partially due to extending any activity in the schedule or entirely due to extending the project completion date solely due to the defendant (see e.g. L.O. Brayton & Co., 1970; J.L. Malone & Assocs., Ine. V. United States, 1989; B-E-C-K Construction., 1971)

The overall contract time does not need to be extended to recover the costs of delay damage (See, e.g. AIA 2007; Bramble and Callahan 2010). For example, a delay may not extend the overall completion date; but it may work in extending a particular task and increase its related cost. Authority for recovering these types of costs may be found under the U.S. federal design contract suspension clause, which provides that the delay only needs to affect the performance cost to recover its damages. This also can be found under change order clauses, in which the owner may be obligated to pay the cost associated with performing the changed work. Therefore, the innocent party may recover any delay cost, whether the delay has delayed the overall project completion date or not (L&A Contracting Co. v. Southern Concrete Servs., 1994).

Based on that, there is no doubt of recovering losses and damages from any delay caused by one of the contracting parties if this delay has caused losses or damages to another party. However, the theory of losses or damages through delay claims is based on how a specific delay or group of delays have occurred on the schedule and the effect that is caused to the project time (See, e.g. Southwest Marine Inc., 1994).

The following Section intends to discuss two types of delay that potentially resulted in losses or damages. The first type is a direct delay that directly attributed to one of the contracting parties. The other is a delay which is hard to be attributed directly to one of the contracting parties. As discussed early in Section 6.3.1.2, when a direct delay occurred on the schedule, it could lead to a cumulative/indirect impact. Also, it may cause indirect delays such as the delay caused by loss of productivity, resource constraints and allocation, or push the project into a period of PFMD. This classification for the direct delay and indirect delay will help to establish the process for analysing their liability and determined the entitlement.

6.3.2.1 Direct Delay Claims

Depending on the terms of the construction contract, direct delays include the delays that are directly attributed to the owner, contractor, or/and neither party. Also, the losses or damages that caused by the direct delay are directly arising out due to a direct impact of the schedule. In a direct delay claim, the responsibility can be admitted straight away because the cause or fault of a direct delay is easy to perceive and directly attributed (Bramble and Callahan 2010). As the case in most delay claims, the claimant must prove liability of delay, the duration of the delay, and losses or damage of delay (See, e.g. Groves-Black JV., 1985; pathman Costr. Co. v. the United States, 1981).

For example, the losses or damages caused by force majeure delay is typically recognised as a direct delay, which entitles contractors only to time extensions, but neither of the contracting parties is entitled to monetary compensation to recover delay damages (FIDIC 1999, Clause 19). However, if the owner extended the project completion date and pushed the project performance into a period of the force majeure, then the case would be treated as indirect delay claims, and the entitlement is entirely different (Alshammari et al. 2017).

Concerning the direct delay claims, the disputes regarding the damages that have caused by direct Government's delays and change orders have exposed that the contractors were awarded the right to recover any loss. The following is some cases regarding direct delay claims:

- A claim of Pittman Construction Co., v. United States, (1983), the contractors were awarded the right to recover the losses and damages from the direct Government's delay.
- The contractors have the right in change orders to recover the costs resulting from this change order include those costs directly related to the accomplishment of the changed work (See, e.g. Triple "A" South, 1994).

In theory, the owner is entitled to claim any loss or damage through the clause of liquidated damages that stated in construction contracts, which such damages are designed to alleviate uncertainty over the extent of the parties' potential liability without relying on the courts. In practice, the owner is entitled to claim any actual losses and damages that are caused by a contractor delay (See, e.g. Priebe & Sons, Inc. v. the United States, 1947; P & D Contractors, Inc. v. the United States, 1992; Melwood Constr. Corp. v. State, 1984).

6.3.2.2 Indirect Delay Claims

The recovery of delay damages will depend on the facts surrounding the claim, precise measurements for determining the real delay cause, and proper analyses for allocating its responsibility. Also, a plaintiff must show that the defendant was responsible for the delay and that this delay caused the plaintiff to suffer a monetary loss (Yates and Epstein 2006).

In a typical delay claim, the direct delay is consequentially caused a further delay or indirect delay, due to lost productivity, resource shortages/allocation or constraints, and push the project performance into PFMD. In construction delay claims analysis, delay that could have been avoided by the due care of one party is compensable to the innocent party suffering injury or damage as a result of the delay (See e.g. Sotiros Shipping Inc. v. Sameiet Solholt, 1983; TCN Channel Pty. v. Haden Enterprises Pty. Ltd., 1989).

For example, force majeure delay is an excusable risk which entitles contractors only to time extensions, but neither of the contracting parties is entitled to monetary compensation to recover its damages. However, if the force majeure delay occurred after the original completion date and resulted solely from extending the project performance due to owner' delay or contractor, the force majeure would be compensable (See, e.g. Alshammari et al. 2017).

This issue of recovery of delay damages on account of an adverse weather delay claims has notably been addressed by the Armed Services Board of Contract Appeals (ASBCA) in the Appeal of DTC Engineers & Constructors (2012). DTC's claim was based on severe weather delays, for which the standard remedy under the force majeure clause is time extension, but not money. Consequently, the ASBCA found that the adverse weather claim was "not grounded" in the force majeure clause, but instead was based on a constructive suspension of work by the Government under the Suspension of Work clause. Finally, the ASBCA held open the possibility of money damages, stating that:

> *"government delays which pushed a contractor's performance into periods of adverse weather can be a cause of additional delay for which a contractor may be compensated."*

A similar case was advanced in Charles G. Williams construction claims (1991). In this case, the government characterised the claim as one based on unusually severe weather for which no responsibility for monetary compensation was due. The contractor argued the theory that the weather delays were indirectly caused by the government's delay, which is to say that:

> *"had the government not suspended work on the project, the weather delays would not have occurred. "*

The Board, however, found that weather interfered with work that would have been completed earlier under better weather conditions and that the government's delay caused the delay. The ASBCA agreed with that analysis, finding that the suspension of work was the direct cause of the additional weather-related delays, and therefore granted money damages to the contractor.

Also, the direct delay can form a sequential impact that may cause a further delay due to loss of productivity and resource constraints and allocation. Delay due to productivity lost or resource practically is a sequential delay caused by advance impact to the project time. Although direct delay, change orders, and acceleration can cause a cumulative impact and impacting the productivity and resource allocation and cause low performance, they also lead to indirect delay by affecting the productivity or resource allocation and cause non-performance. When the delay is the result of some action or negligence on the part of the owner, it will generally be found excusable (See, e.g., Exton DriveIn Inc. v. Home Indem. Co., 1969).

6.3.3 The Summary of Category A

Section 6.3 has demonstrated two types of claims for recovering the resulting injury from construction delays—the disruption claims and the delay claims. This includes the determination of each DAIs type that can be claimed through each type of claim.

The summary of Sections 6.3.1 and 6.3.2 indicated that delay and disruption in construction claims could occur directly or indirectly in the schedule. The direct delay includes the schedule impacts that are caused by a change order and acceleration as a direct disruption and may lead to loss of productivity as an indirect disruption. However, direct delays include the schedule impacts that are caused by change orders and critical or non-critical delays. These schedule impacts may lead to indirect delays caused by productivity loss, resource constraints or PFMD.

The above summary will assist in forming accurate procedures that are needed in defining the disruption and delay claims, which will not only be based on only the types of DAIs but also on their direct effects. For example, a change order can be claimed through the process of delay and disruption claims. However, the direct effect of the change order on the schedule, whether to be a disruption effect, such as loss of productivity, or a delay effect, such as PFMD, will help to determine the type of claim, which will be a delay claim, or a disruption claim, respectively.

While the data in the resulting injury (Section 6.3) is used as the first fundamental fact for proving the entitlement has determined the claim type, there is a need to determine the causation as the second fundamental fact for proving the entitlement. The following section will discuss the causation based on the claim types.

6.4 Category B: Causation

The second fundamental fact that needs to be proofed in the delay claim for proving the damages resulting from the schedule impacts is to establish the causation. Causation is the cause-and-effect relationship between an action or inaction by a party on the issue under investigation and the resultant injury or impact to another. Without proof of a causal link between schedule impacts and the resulting injury, there is no entitlement to recovery (Finke, 1997).

As the claimant must perform the burden of proof for any causation of delay claim, the claimant must establish a causal link between the breach (the cause) and the loss (the effect). However, establishing such connection is not an easy task because the causation is the most challenging element to prove; as noted by one of courts and boards of contract appeals that "causation can be an elusive commodity" (see e. g. Contributory Negligence,1990). For example, the existence of a substantial number of changes is insufficient evidence of causation (see e. g. Freeman-Darling, Inc., 1989; Bechtel Nat'l, Inc., 1990).

In Centex Bateson Construction Co., (2000), the VABCA required proof of a causal connection showing that:

> *"the undifferentiated group of contract changes affecting the changed and unchanged contract work resulted in the loss of productivity on that work."*

The board suggested that causation could be established by demonstrating that:

> *"there were no other reasons for a loss of productivity for which the Government is not responsible."*

Centex Bateson requires the contractor to prove a negative by showing that the contractor was not the cause of the increased labour costs.

The board in Centex Bateson concluded that

> *"cases awarding recovery had done so as the result of subjective conclusions rather than through objective analysis."*

Another example of how not to prove cause and effect can be found in Southwest Marine, Inc., (1994), in which the Department of Transportation Board of Contract Appeals (DOT BCA) rejected the contractor's claim because the contractor only provided evidence that fifteen of 202 government change requests disrupted the work. In this case, the contractor sought to recover for 14,022 craft hours of cumulative disruption allegedly resulting from more than 200 government-issued changes. The contractor based its claim on the testimony of its scheduling expert and exhibits prepared by the expert to support the adverse effect of the remaining 187 changes. The DOT BCA concluded that the exhibit did not prove the link between the change orders and the disruptions.

Another example can be founded in Bechtel Nat'l, Inc., 90–3 BCA ¶ 22,549, at 113,177, which the court board stated that:

> *"the record supported the fact that the Government's changes caused loss of productivity but denied the claim because the contractor offered no contemporaneous documentation to substantiate the extent of the cumulative impacts claimed."*

In the case of Wunderlich Contracting Co. v. the United States, (1965), although the change orders have created liability without a causal link between the change orders and the loss of productivity, it concluded that since there is no causation and therefore no entitlement (See also Triple "A" South, 1994). Thus, contractors often seek to relate the loss of efficiency with cost overruns and unanticipated schedule delays (see, e.g. Howard W. Wright & James P. Bedingfield, Government Contracts Accounting 341, 1979).

6.4.1 Disruption Claims

In the disruption claims, factual causation for any direct or indirect disruption on the schedule is not easy to be proved because it is based on impacting the project cost only, without impacting the project time. Therefore, courts and boards are not always consistent in their treatment of disruption claims. Because the theoretical bases for the claim have changed over time, claimants must be prepared to proceed under several different theories that have discussed in Chapter 2. The claim may be brought as a direct impact claim for the loss of money if the causation between a specific change and the loss of money can be established directly, or as an indirect/cumulative impact which the causation in case can be more difficult to be proved (see e. g. Jones, 2001).

6.4.2 Delay Claims

In the delay claims, causation is the most challenging element to prove in the delay claim. The first hurdle that must be overcome is to show a connection between the effect of time lost and the damage (factual causation). For example, a claimant is not entitled to any related money claim for the time loss unless it can satisfy the more stringent ‘but for’ test of causation by showing that, absent the defendant delay event relied upon, the postulated losses or damages due to time loss would not happen. If factual causation is satisfied, the claimant must then show that the defendant is legally responsible for the damage that has suffered. This question of legal causation may involve consideration of the effect of intervening acts occurring between the defendant's delay and the claimant's damages (See, e.g. Bechtel Nat'l, Inc., 1990; Acme Missiles & Constr. Corp.,1963).

6.4.3 The Summary of Category B

Section 6.4 indicates that any schedule impact may lead to a direct effect on project cost or time. Without affecting the project time, the loss of money as a direct effect on the project can be claimed through a disruption claim only. The is because the causation for the cost overruns cannot be built on any loss of time on the schedule. However, to claim the cost overrun that resulted from the time overrun, the claim will be reviewed through the process of delay claim, which will be based on the loss of time that must occur on the schedule.

In the delay claims, the direct effect may also lead to an indirect effect, which will produce another delay or/and disruption and can be more difficult to prove in construction claims. Thus, the burden of proof for any direct or indirect effect of the schedule impact is always on the party that is claiming the benefit. However, proving the actual extent of the loss can be very tricky because it is integrally linked to the causation. It is difficult to separate causation from resultant injury because proof of one often entails showing proof of the other. As a result, boards often discuss resultant injury simultaneously with causation (see, e.g. Lisbon Contractors, Inc. v. the United States, 1987).

The above result will form the processes that are needed to develop a consistent framework in delay claims analysis, which will be built on sequence facts. For example, the effect of the change order that led directly to increasing only the project cost, without increasing the project time, can be recovered only by disruption claims, while the effect of the change order that led indirectly to increasing the project cost, based on extending the project time, can be recovered only by delay claims. Therefore, time and money loss, as two facts for any direct effect of any schedule impact, should not be neglected in any approach for the project schedule analysis.

As the above summary (Section 6.4 as well as Section 6.3) forms the framework that is required to be adopted to meet the research aims, the following section will discuss the liability based on the direct effect. However, the direct effect could concurrently occur with other direct effects resulting from different causes and different responsible parties, which the analysing in this situation can be a challenging task. This case is a part of the DAIs, such as concurrent delay and concurrent effects. Therefore, the liability that will be discussed in the following section is based on the DAIs.

6.5 Category C: Liability

The identification of the liability of any schedule impact on the project relies significantly upon the language of the contract itself. However, every cause of the schedule impact can be classified as being the responsibility of risk assumed by either the government, the contractor, or neither party, which is typically stipulated by contractual terms. Therefore, the fundamental fact for determining the liability of any schedule impact must be proved by identifying a specific reason that caused a specific effect and showing that the cause is excusable or compensable (Hughes and Ulwelling, 1992).

As mentioned earlier, the potential losses and damages would be the result of disruption or delay. In this case, the innocent party must prove the liability of the cause first. For example, in the case of H. W. Detwiller Co., Inc., (1985), it stated that:

> *" ……… It is well established that in order to recover for alleged compensable delay a contractor must demonstrate that delay was caused by the Government*

and, with a reasonable degree of accuracy, the extent of such compensable delay."

In the disruption claims, establishing the liability that based on impacting the project cost is a subject of dispute (See, e.g., Southwest Marine, Inc. v. the United States- 1994). For example, if the cause and the effect were foreseeable, then it will be considered as a direct impact, and the innocent party has the right to claim the damages. However, if the cause or the effect was not foreseeable, then it will be considered as an indirect impact and the right to recover from the indirect impact is reserved, or the possibility of recovery exists for the innocent party (See, e.g. Pittman Constr. Co. v. the United States, 1983).

In the delay claims, the case is entirely different. The liability is established based on impacting the project time and determined by using the analysis of the project schedule, which can be affected in different manners. In the situation where there is a single cause for any time loss, establishing the entitlement for any damage can be relatively straightforward. As often the case in construction delay claims, the difficulties arise from losing time by different delay causes such as the concurrent delays, which the position of the analysis in such delay claim become more complicated.

The context of delays in construction delay claims plays a vital role in the apportionment of delay responsibility and damages liability. Quantifying the costs associated with the schedule impacts requires a causation analysis (or a cause-and-effect analysis) for addressing the responsibility for both direct schedule delay and indirect schedule delay. Therefore, the DAIs need to be kept in mind during the analysis for considering the liability. Due to that, the following Sections intends to discuss the liability based on the DAIs and from the two adopted methods of the data collection to highlight, as follow:

6.5.1 Concurrency of Delays

There is no apparent legal authority defining what should be considered as the meaning of concurrency or concurrent delay. That makes this already complicated issue further complicated. It appears that much of the controversy surrounding the term 'concurrent delay' is whether the events leading to delay must be simultaneous in occurrence or merely offsetting in effect. Thus, the liability for the concurrency of delays will be discussed based on the documentary analysis and questionnaire survey as follows:

Views expressed from the documentary analysis: -

According to some academic and professional work, the issue of concurrency in delay claims can be described as a situation in which two or more delays (include change orders) are occurring at the same time during all or a portion of the delay periods being considered, which is known as concurrent delays (Wickwire et al. 2003). Also, it can be described as a situation related to two or more delay events arise at different times but the effects of them are felt at the same time, which is known as concurrent effects (SCL, 2017). For example, Finke (1992) mentioned that:

> *"It must be noted that the Boards of Contract Appeals (BCAs) have the unfortunate tendency to use the term concurrent to describe both time-of-occurrence and true causal concurrency. Indeed, this mixed-use of the term seems to have misled some BCAs into giving incorrect definitions of concurrency. In an attempt to avoid this confusion, it distinguishes between the two by referring to delays that merely occur at the same time as concurrent and delays that cause the same impact (and are therefore truly causally concurrent) as offsetting".*

Some case authorities in the UK and the US courts seem corroborating with concurrent effects. For example, in the UK jurisdiction, the existence of such sequential 'causes' of concurrent delay 'effects' was accepted by Judge Seymour in The Royal Brompton Hospital (2001) when he considered an argument that two delays happening at different times were the concurrent delays. In the US, in Raymond Construction of Africa (1969), the court determined that three consecutive delays be concurrent. Similarly, in Williams Enterprises (1990), the federal court determined the consecutive delays as concurrent delays. In denying a contractor's claim for delay damages, the Agriculture Board of Contract Appeals (AGBCA) in John Murphy Construction Company (1979) stated that:

> *"It does not appear from the record that But-For the government caused delays [the contractor] could have completed the work [on time] …… [The contractor] was at least concurrently responsible for the delay."*

Similarly, in Fischbach &Moore International Corp., (1991), it was stated that:

> *"[it is axiomatic that a contractor asserting a claim against the government must prove not only that it incurred the additional costs making up its claim but also that such costs would not have been incurred but-for government action."*

Therefore, the conclusion that concurrency-in-time is not a required element of offsetting delays makes sense when it is remembered that delay damages are a function of only one variable-the extent to which overall project completion was delayed and that delays to the critical path extend overall project completion to the same extent regardless of when they occur (Finke, 1992). Rider (2013) stated that:

"The concurrent delay is a vexed and complex and legal issue. The challenge is to determine equitably the following. 1) the contractor's entitlement to a time extension as a result of an owner-responsible delay event (liability) and recover of the contractor's extended time-related costs (damages) that result from such delays. 2) the owner's recovery of its actual delay or liquidated damages when the contractor fails to complete its work by a contractually stipulated completion date as a result of a contractor-responsible delay event that is concurrent to the owner-responsible delay event."

Considering the foregoing, unless expressed otherwise in a contract, it may be safe to consider both true concurrency of two or more delay events at the same time, and 'concurrent effects', which is related to two or more delay events that arise at different times but the effects of them felt at the same time, equal status and effectiveness. The increasingly popular Delay and Disruption Protocol of the Society of Construction Law has considered this approach in its core principles (the SCL Protocol, 2002, ref. item 1.4, and 'Figure 9').

Based on US case law, the general view on concurrent delays in which the employer and the contractor are both responsible for delays to project completion. The entitlement is that neither party will recover financial recompense unless and to the extent that they can segregate delay associated with each competing cause (Marrin, 2002). Kraiem and Diekmann (1987) somehow described this view as the 'easy rule' and 'fair rule', as shown in Table 6-2.

Table 6-2: Remedies for concurrent delays (adopted from Kraiem and Diekmann 1987)

Loss of time-based on the concurrency between:		**Remedy**
EC	EN	Time Extension
NE	EN	Time Extension
EC	NE	Time Extension (**Easy Rule**) Apportionment (**Fair Rule**)

Based on that, the concurrent delay plays a vital role in analysing the delay responsibility and damages liability. The reason for that is because of the resulting injury was based on the effect of two different parties. The liability in a case of concurrency delay needs further investigation to cover all the possible scenarios in the practice use. This need can be covered in this research based on seeking the experts' opinion as following.

Views expressed by the questionnaire survey: -

For ensuring more reliable results for delay claims analysis, the survey questionnaires have asked the respondents to assess the issue of concurrent delays and concurrent effects during the delay analysis process. As a visual aid, the respondents were asked to indicate the extent to which they agree or disagree on two days of delays happened on the schedule as shown in Figure 6-1, which are day 20 and 21. The result was as follow:

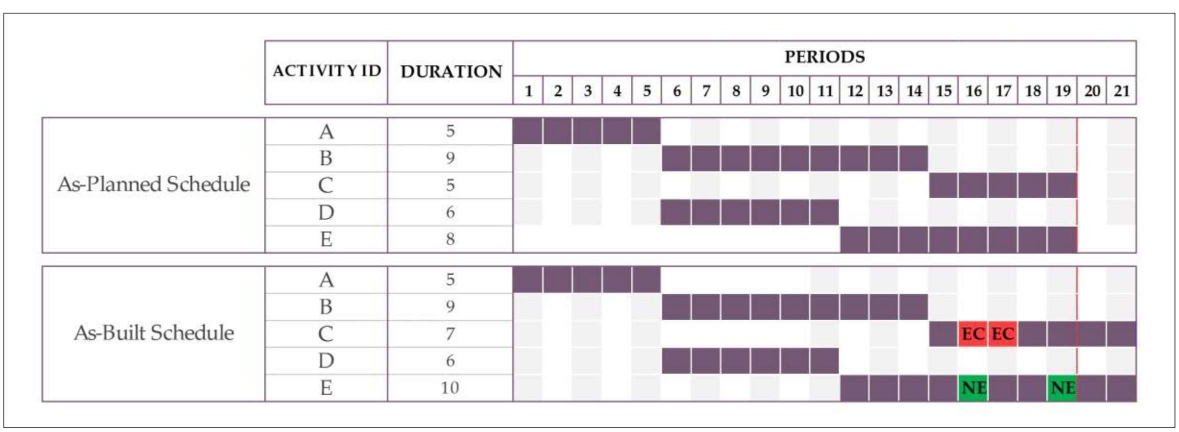


Figure 6-1: The issues of concurrent delays and concurrent effects in delay claims

- 100% of the experts agreed that the project had been extended up to day 20 caused by concurrent delays (EC and NE) that happened on day 16.
- 50% of the experts agreed on the concept of that courts in both the UK and the US often consider the EC delay on day 17 and NE delay on day 19, which happened in a different timeframe, as concurrent delays based on their effect.
- 83.33% of the experts agreed on that considering the EC delay on day 17 and NE delay on day 19 as a concurrent effect will resolve the issue of total float consumption and the issue of pacing delay.
- 75% of the experts agreed that the project delay (on day 21) is the responsibility of both EC delay and NE delay on day 17 and 19, respectively.
- 100% of the experts agreed on that concurrent delays, and concurrent effects pose a significant source of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties.

Based on analysing the questionnaire survey for the concurrency delay, there are two situations of delay that could happen concurrency and have been recognised in delay claims. First is the situation which two or more delays happened on the same timeframe and their effect felt on the same timeframe. This situation, as shown in Figure 6-1, is concurrent delays between EC delay and NE delay on day 16, which their effect felt on day 20. Another situation for the concurrency of delays is the situation which two or more delays happened on a different timeframe, but their effect felt on a different timeframe. This situation, as shown in Figure 6-1, is concurrent effects between EC delay on day 17 and NE delay on day 19, which their effect felt on day 21. Therefore, considering both situations during the delay claim analysis will help for resolving four DAIs, which are: concurrent delays, concurrent effects, total float consumption, and pacing delay.

6.5.2 Apportionment of Delays and Damages

Apportionment is a rule of law which allows a court to reduce a plaintiff's damages by the degree to which he is responsible for his loss. However, the rules with respect the apportionment of delay remain unsettled. Several decisions in delay claims adhere to the "rule against apportionment." (See, e.g. Sunshine Constr. & Eng'g, Inc. v. the United States, 2005; accord PCL Constr. Servs., Inc. v. the United States, 2002; Acme Process Equip. v. the United States, 1965; the United States v. United Eng'g & Constructing Co., 1912).

For example, in case Schmoll v. the United States (1940), the board had utilised a "rule against apportionment" to prohibit either party from recovering delay damages where both parties caused any project delay and liquidated damages provision was annulled because delays were attributable to both parties. Also, when there are overlapping or concurrent compensable and non-compensable causes, a contractor possibly could be denied recovery if there is no "clear apportionment" of the damages. See, e.g., Pittman Constr. Co. v. United States (1983), finding that:

> *"numerous government changes resulted in delay and impact costs but reasoning that because the contractor could not separate these effects from those caused by the contractor's deviations from the sequence of work, the contractor could not recover."*

In the case of Southwest Marine, Inc. v. United States (1994), the court board concluded that:

"Where both parties contribute to delay, neither can recover delay damages unless there is a clear apportionment of the delay and expense attributable to each party."

This analysis "but for" requirement necessarily resulted in the creation of the doctrine of concurrent delay. As was stated in Cline Construction Co., (1984):

"Concurrent delay does not bar extensions of time, but it does bar monetary compensation for daily fixed overhead costs of the type claimed by [the contractor] because such costs would be incurred on account of the concurrent delay even if the government-responsible delay had not occurred."

In counterpoint to the rule against apportionment, tribunals also advocate the "clear apportionment" rule. Decisions like Blinderman Construction Co. v. the United States encourage apportionment and hold that

"Where both parties contribute to the delay 'neither can recover damage, unless there is in the proof a clear apportionment of the delay and the expense attributable to each party'."

In this context, the tribunal will not simply nullify a remedy-granting contractual provision in the face of competing delays but will engage in analysis of the competing delays and apportion responsibility accordingly. (See, e.g., Blinderman Const. Co. v. the United States, 1982; Coath & Goss, Inc. v. the United States, 1944; Sauer Inc. v. Danzig, 2000; William F. Klingensmith, Inc. v. the United States, 1984; Blinderman Constr. Co. v. the United States, 1982; Interstate Gen. Gov't Contractors, Inc. v. West, 1993).

In case of City Inn Ltd v. Shepherd Construction Ltd., (2010) concerned how to assess the issue of a fair and reasonable extension of time, under clause 25 of the JCT standard form, in a case of delay caused by concurrent delay (for which there would be an entitlement to an extension of time) and matters for which the contractor was responsible. The majority of the Inner House held that, where there was a delay caused by two concurrent causes and only one of which was a ‘relevant event’, the decision-maker may apportion the delay.

For the owner claims to apportion the concurrent delay, some courts and boards of contract appeals have criticised the rule against apportionment, and as long as there is delay by both the government (owner) and the contractor, the liquidated damages clause will not be enforced and there will be no apportionment of delay. The court further noted that some courts and boards apportioned the concurrent delay in assessing liquidated damages (See, e.g. E.C. Ernst, Inc. v. Manhattan Construction Co., 1977 modified 1978).

More recent decisions, however, have criticised the “rule against apportionment” as harsh and outdated. Thus, many courts have moved toward an approach that permits the award of liquidated damages to owners, or delay costs to contractors, where the party seeking recovery can apportion responsibility for delays to the critical path (PCL Constr. Servs., Inc. v. the United States, 2002). This rule is often referred to as the “clear apportionment rule.” In case of Sauer Inc. v. Danzig (2000), the board have applied the “clear apportionment rule” to award the Government liquidated damages for the entire delay on the project; less the two days of delay apportioned to government acts and omissions.

Based on the above, the analysis should consider the apportionment of delays and damages between the responsible parties. This is because the damage to each party will be differed and are not an equal amount in most of the delay scenarios. Therefore, the issue of damages apportionment in the concurrent delays and the concurrent effects should not be neglected for more accurate results of delay claims analysis.

6.5.3 Pacing Delay

Pacing delay is a delay in an independent activity as conscious and contemporaneous decision to pace progress due to receiving Extension of Time (EoT) or compensation. Without receiving the EoT, there will not be a pacing delay issue. However, the benefit of an EOT is that it establishes a new contract completion date (SCL, 2002). In delay claims analysis, the EoT may affect the liability. AACE (2011) stated that:

> *"If time extensions have been granted, they should be considered both at the time they were granted and at the end of the analysis. Time extensions should be considered at the time granted when the reasons for delayed performance are identified through the comparison as well as identification of the as-built critical path. Time extensions will change the overall delay to the project and may, therefore, override apparent delays to specific activities."*

The courts and boards of contract appeals have addressed the pacing delay issue. For example, The Corps of Engineers Board of Contract Appeals addressed this issue in the case of *John Driggs Company, Inc., ENGBCA No. 4926, 87-2 BCA 19833 (1987)* as follows:

> *"When a significant owner-caused, construction delay.....occurs, the contractor is not necessarily required to conduct all of his other construction activities exactly according to his pre-delay schedule, and without regard to the changed circumstances resulting from the delay. The occurrence of a significant delay generally will affect related work, as the contractor's*

attention turns to overcome the delay rather than slavishly following its now meaningless schedule."

Also, the General Services Agency Board of Contract Appeals similarly addressed the issue in the case of *Utley-James Inc., GSBCA No. 5370, 85-1 BCA 17,816, aff'd, Utley-James, Inc. Vs. the United States, 14 CL. Ct. 804 (1988)*, as follow:

"Where the government causes delays to the critical path, it is permissible for the contractor to relax the performance of the work to the extent that it does not affect project completion."

A contractor has a burden to demonstrate that the pacing delay is related to an earlier owner-caused delay. The board's holding in John Driggs Co. imparts an equally significant obligation on an owner seeking to overcome that showing, without contemporaneous records documenting the decision to pace a critical or near-critical activity based on the owner's delay, a pacing delay appears very much like a simple contractor-caused delay. Absent records evidencing the contemporaneous decision to pace, testimony, even if accurate, may seem like after-the-fact justification (See, e.g., John Driggs Co., 1987; Orlosky Inc. v. the United States, 2005).

Based on that, the pacing delay plays a vital role in analysing the delay responsibility and damages liability. The reason is that the resulting injury was based on the effect of two different causes that occurred in a different timeframe. The liability in a case of pacing delay is similar to the case of concurrent effects. However, it needs further investigation to cover all the possible scenarios in the practice use. This need can be covered in this research based on seeking the experts' opinion as following.

6.5.4 Preventable Force Majeure Delay

Preventable Force Majeure Delay (PFMD) is a new type of composite delays situation that has defined and recognised recently (Alshammari et al., 2017). Thus, the liability for the PFMD will be discussed based on the documentary analysis and questionnaire survey as follows:

Views expressed from the documentary analysis: -

The liability issue due to force majeure delay has notably been addressed by the Armed Services Board of Contract Appeals (ASBCA) in the Appeal of DTC Engineers & Constructors (2012). In DTC's claim, the ASBCA found that the adverse weather claim was "not grounded" in the force majeure clause, for which the common remedy under the force majeure clause is time extension, but not money. Instead, it was based on a constructive suspension of work by the Government under the Suspension of Work clause. Finally, the ASBCA held open the possibility of money damages, stating that

> *"government delays which pushed a contractor's performance into periods of adverse weather can be a cause of additional delay for which a contractor may be compensated."*

Also, a similar case was advanced in Charles G. Williams construction claims (1991). The government characterised the claim as one based on unusually severe weather for which no responsibility for monetary compensation was due. The contractor argued the theory that the weather delays were directly caused by the government's delay, which is to say that:

> *"had the government not suspended work on the project, the weather delays would not have occurred".*

However, the Board found that weather interfered with work that would have been completed earlier under better weather conditions and the delay was caused by the government. Thus, the ASBCA agreed with this analysis, finding that

> *"the suspension of work was the direct cause of the additional weather-related delays, and therefore granted money damages to the contractor."*

Alshammeri et al., (2017) reviewed the force majeure delays during the delay analysis claims and found that the liability of force majeure delay during the original contract period is Unavoidable Force Majeure Delay (UFMD), which the entitlement is typically an extension of time only as the usual and the only remedy for force majeure delays. However, force majeure delay after the original contract period is Preventable Force Majeure Delay (PFMD). PFMD would occur on the schedule only due to the extension of the original contract period. Since the original contract time for the project was supposed to be completed before the period of PFMD, one of the contracting parties at least is therefore responsible for pushing the performance into PFMD period. Thus, the innocent party suffering damages has the right to claim against any delay that resulted from the negligence or tardiness of the other party. In this case, the attitude typically expressed by the innocent party is,

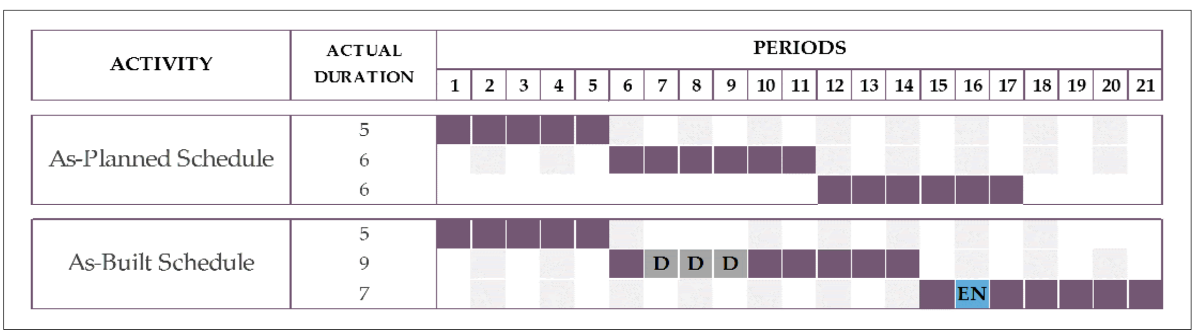
> *"why should I carry such expenses or lost profit when the other party's action has extended the project performance into this period of delay?" …………The argument, when analysed in the legal context of delays, is that completing the project during the original contract time would avoid such delay damages."*

Based on the above court cases, the force majeure that occurred after the original completion date is a preventable delay, which has the potential to be a compensable delay. Therefore, the

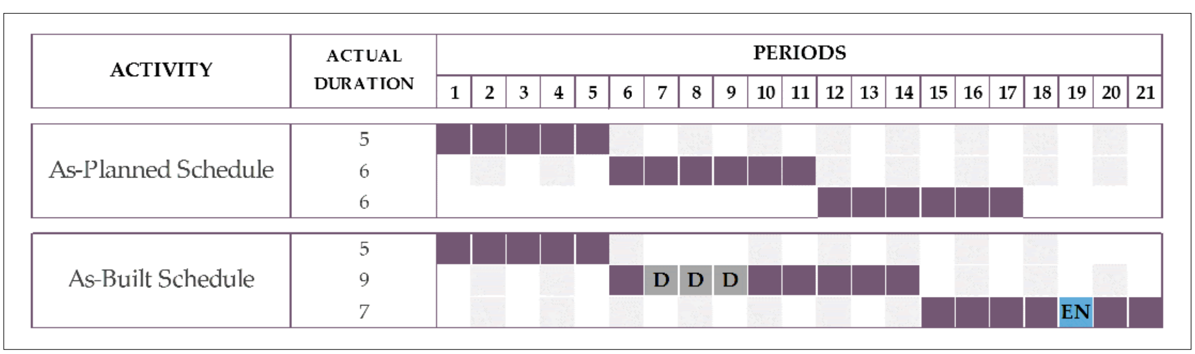
PFMD has the potential to change the results of damages' responsibility, which requires to be considered during the delay analysis.

Views expressed by the questionnaire survey: -

For ensuring more reliable results for delay claims analysis, the survey questionnaires have asked the respondents to assess the issue of force majeure during the delay analysis process. As a visual aid for considering the rights of the contracting parties, the respondents were also asked to indicate the extent to which they agree or disagree of the liability for the force majeure delays in scenario A and scenario B as shown in Figures 6-2 and 6-3, respectively. In scenario A, the force majeure is UFMD that happened during the initially agreed period on day 16, while in scenario B, the force majeure is PFMD that happened during the extension period on day 19.



Figures 6-2: Scenario A, force majeure happened during the original contract period



Figures 6-3: Scenario B, force majeure happened after the original contract period

As shown in Figure 6-4, 100% stated that the force majeure in scenario A is an unavoidable delay that classified during the delay analysis claims as excusable but non-compensable. For scenario B, 91.2% agreed on that the delay events on days 7, 8, and 9 have contributed to extending the project performance into a period after the original date of project completion, on which the force majeure event occurred on day 19. Therefore, the delay in Day 19 is a preventable delay that the innocent party suffering damages have the right to claim compensation.

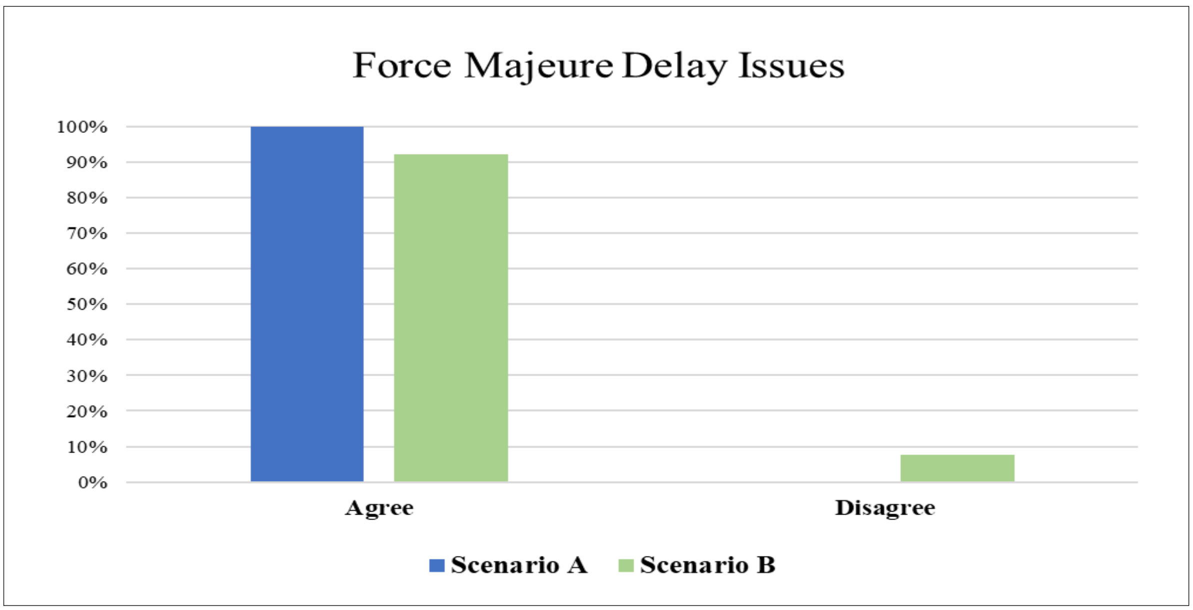


Figure 6-4: Percentage distribution of participants according to their views about the issue of force majeure during the delay analysis

Therefore, and through the data that obtained from the literature survey, documentary analysis, and the survey questionnaire, the schedule impacts may cause a further delay to the project by extending the original project completion date into PFMD. It is noteworthy that the need to consider the issue of PFMD during the delay analyses is becoming an increasingly vital requirement.

6.5.5 Productivity Loss

Primary challenges associated with loss of productivity claims are identifying the root cause of productivity lost issues, quantifying associated productivity losses, corroborating the cause-and-effect relationship, and establishing entitlement to damages. (see, e.g. *Wunderlich Contracting Co. v. the United States, 351 F.2d 956, 968 (Ct. Cl. 1965)* and *Luria Bros. & Co. v. the United States, 369 F.2d 701 (Ct. Cl. 1966).*

Based on that, the loss of productivity plays a vital role in analysing the delay responsibility and damages liability. The reason is that the resulting injury could be the only effect for losing time as the result of productivity loss. Thus, it needs further investigation to cover all the possible scenarios in the practice use. This need can be covered in this research based on the court cases of productivity loss in the construction delays claims and seeking the experts' opinion as following:

1) <u>Views expressed from the documentary analysis: -</u>

All the schedule impacts; include delay, change order and disruption, are the source for loss of productivity, which may result as a direct impact or indirectly as a cumulative impact. In Coates Industrial Piping, the Veterans Affairs Board of Contract Appeals (VABCA) explained that:

> *"Cumulative impact is unforeseeable disruption of productivity, resulting from the 'synergistic' effect of an undifferentiated group of changes. The issuance of an unreasonable number [or unusual kind] of change orders creates a synergistic disruptive impact such that the total disruption that*

caused by the changes, which exceeds the sum of the disruptive impacts that caused by the individual change orders when looked at independently.

In case of that, the productivity loss has caused by an impact that happened directly; liability can be established with proof that the Government or private owner breached its contractual obligation by initiating a substantial number of contract changes, modifications, or design clarifications. For example, in Bechtel National, Inc. (1989), the NASA Board of Contract Appeals found that:

> *"because the contractor needed to submit large numbers of RFIs to the Government to correct defects in its specifications, the Government was liable for any resulting cumulative impact."*

Also, the productivity loss can be occurred by the delay. For example, in the case of *Net Construction, Inc. v. C & C Rehab and Construction, Inc., 256 F. Supp. 2d 350, 354 (E.D. Pa. 2003)*,

> *"The court found that the delays caused the contractor to work under unanticipated winter conditions, with a resulting loss of productivity. Therefore, the contractor recovered disruption damages associated with the loss of its productivity."*

The liability for loss of productivity could not be an issue; if the owner actions or inactions obstructed the progress in the project based on this general rule of law. In Centex Bateson Construction Co. (2000), the board found that:

"liability was not an issue because neither side disputed that all of the events allegedly giving rise to the cumulative impact claim arose out of certain supplemental agreements for which the Government was responsible."

2) *Views expressed by the questionnaire survey: -*

To ensure a more accurate assessment for the delay claims and more reliable results for delay analysis, the respondents in the survey questionnaires survey were asked to assess the issue of disruption and productivity loss in construction delay claims. As shown in Figure 6-5, 100% stated that disruption, as well as productivity loss, pose a significant source of difficulties and thus represent potential sources of conflict among contracting parties.

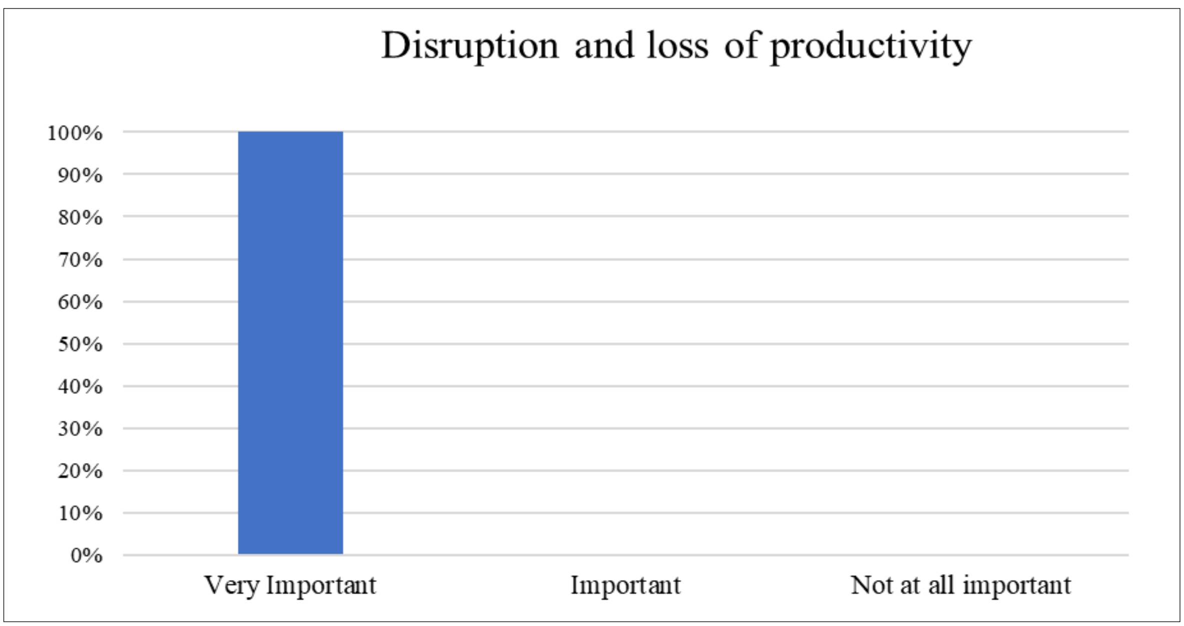


Figure 6-5: Percentage distribution of participants according to their views about the issue of disruption and loss of productivity during the delay analysis

Based on the collected data, the loss of productivity will happen only as a cumulative impact or indirect cause of other impacts on the schedule, which the damages will be as an indirect effect also. In this case, the analysis of the liability for the loss of productivity is as an indirect liability. In indirect liability, the analysis can be a very complicated task, which poses a significant source of difficulties in the construction claims. This fact is also recognised from the view of the participants in responding to the productivity loss issue in a construction dispute.

6.5.6 Resource Allocation

Delay and disruption can cause an impact on project performance. Through the data obtained from the research methods conclude that the schedule impacts can cause unrealistic impact to the resource that may cause a further delay to the project. Thus, it needs further investigation to cover all the possible scenarios in the practice use. This need can be covered in this research based on the court cases of the impact on resource allocation in the construction delays claims and seeking the experts' opinion as following:

1) Views expressed from the documentary analysis: -

Where additional resources are required on a project to accommodate the delay or disruption, the question must be asked: "why they are needed?" If it is because without the additional resources, the project will not finish on time, then these additional resources indeed constitute acceleration resources and are not claimable unless there is an explicit or implied instruction to accelerate. On contrast, if the resources are required for specific delay or disruption, the additional resources would be better priced as specific preliminaries associated with a variation (Baker, 2012; Tweeddale, 2004).

It is noteworthy that the need to consider the issue of resource allocations during the delay analyses is becoming an increasingly vital requirement. Also, the liability for losses or damages due to impacting the resource allocation requires to consider the resource allocation. In the UK case of McAlpine Humberoak Ltd vs. McDermott Inc. (1992),

> *"the judge disapproved of the plaintiff's delay claim submissions based on not considering how resource usage was planned for and how they were actually utilised during construction."*

2) *Views expressed by the questionnaire survey: -*

For ensuring more reliable results for delay claims analysis, the survey questionnaires have asked the respondents to assess the issue of resource allocation during the delay analysis process. As shown in Figure 6-6, 100% stated that resource allocation poses a significant source of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties.

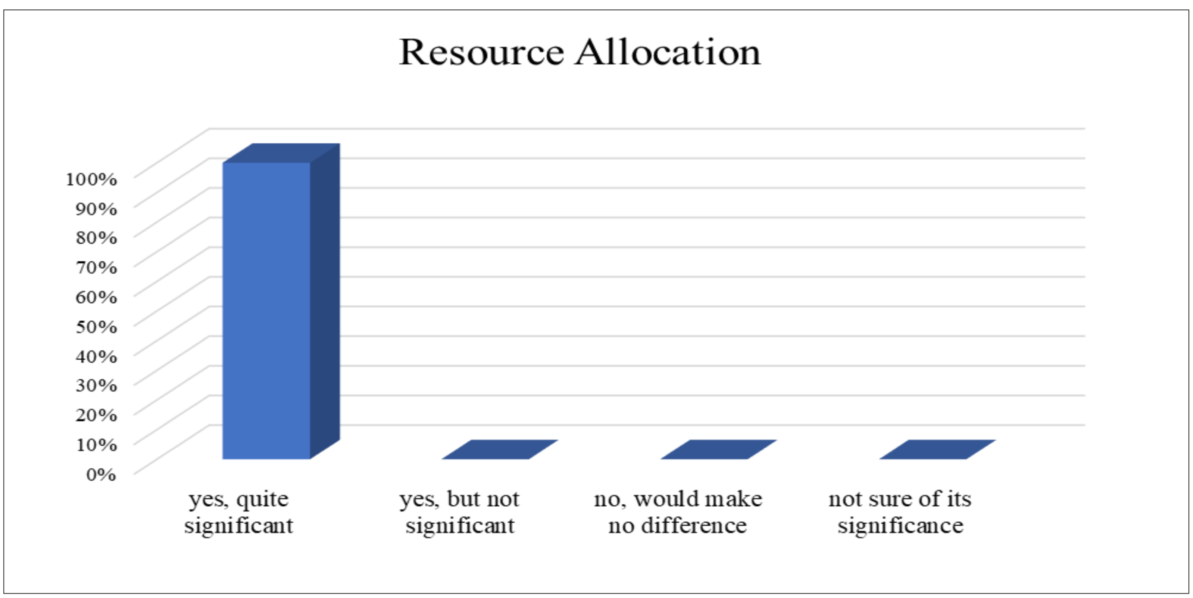


Figure 6-6: Percentage distribution of participants according to their views about the importance of resource allocation during the delay analysis

The same case in the productivity loss, the impact on the resource allocation will happen only as a cumulative impact or indirect cause of other impacts on the schedule. In this case, the damages would also happen as an indirect effect. Also, the analysis of the liability is as an indirect liability, which the analysis would be very complicated. This fact is also clarified form the participants responses, which poses a significant source of difficulties in the construction claims.

6.5.7 Acceleration

The responsibility for acceleration costs frequently arises in the delay claims. In that context, the law has segregated acceleration into three primary types, which are: directed by the owner, constructive by the contractor, voluntary by schedule (See, e.g., Conti Corp. v. Ohio Dep't of Admin., 1992). Thus, it needs further investigation to cover all the possible scenarios in the practice use. This need can be covered in this research from the court cases based on the acceleration issue in the construction delays claims, as well as from seeking the experts' opinion as following:

1) Views expressed from the documentary analysis: -

For an acceleration effort to be compensable, the owner/Government must order the contractor to speed up its efforts on the site in an attempt to complete the work in a shorter period (See e. g. Norair Eng'g Corp. v. United States, 1981; Fru-Con Corp. v. State, 1996; Contracting & Material Co. v. City of Chicago,1974).

Arguably a claim might be supportable when acceleration measures are implemented upon expiry of the time limit. In the case of the JCT SBC, any 'impediment, prevention or default' of the employer or certifier is recognised as a compensable event, which means a contractor might even be able to justify a claim for acceleration costs as direct loss and expense (JCT, 2016).

Most disputes arise in the context of constructive acceleration. A claim of constructive acceleration ordinarily arises when the government requires the contractor to adhere to the original performance deadline outlined in the contract even though the contract provides the contractor with periods of excusable delay that entitle the contractor to a more extended performance period. The Federal Circuit described the doctrine of constructive acceleration in Azure Construction Co. v. United States (1997), as follows:

> *"A claim of acceleration is a claim for the increased costs that result when the government requires the contractor to complete its performance in less time than was permitted under the contract. The claim arises under the changes clause of a contract; the basis for the claim is that the government has modified the contract by shortening the time for performance, either expressly (in the case of actual acceleration) or implicitly through its conduct (in the case of constructive acceleration), and that under the changes clause. Thus, the government is required to compensate the contractor for the additional costs incurred in effecting the change."*

To recover for acceleration, the contractor must have requested a time extension. If the contractor did not request a time extension (and have that extension denied), it is difficult to determine if the owner either directly or constructively accelerated the work. However, this requirement may be waived if the owner has instructed the contractor during the project that no extensions of time will be considered (Gibbs Shipyard Inc., 1967).

Also, a constructive acceleration claim might succeed if presented as a common-law mitigation claim (Bailey, 2011). This approach assumes that the contractor's acceleration is implemented to minimise time-related for the project overhead costs. This acceleration may be due to delays from the employer's influence, with refusing to grant time extensions, or the original employer's breach of contract giving rise to the time extension request (See e. g. British Westinghouse Electric and Manufacturing Co Ltd v Underground Electric Railways Co of London Ltd., 1912).

AACEI (2011) and SCL (2002) discusses the use of different analysis model for identifying acceleration, such as: single base and additive model; multiple bases and additive model; single base and subtractive model; and multiple base and subtractive model. AACEI supports the use of the single base and additive model as the most model that can be used for analysing acceleration, such as As-Planned Analysis and Time Impact Analysis.

2) Views expressed by the questionnaire survey: -

For ensuring more reliable results for delay claims analysis, the survey questionnaires have asked the respondents to assess the acceleration effects during the delay analysis process. As a visual aid, Figure 6-7 shows an EC delay happened on day 16 that extended the original completion date up to day 21 and formed one extra day of total float in paths (A, D, E). The contractor noticed that and decided to decrease the amount of the work (NE delay on day 18 and 19). However, the owner decided to accelerate the original critical path; so that the original completion date be met. In most delay analysis techniques, the owner would still be responsible for delaying the project up to day 21 due to EC delay on day 16. The respondents were asked to indicate the extent to which they agree or disagree on the responsibility for extending the project one day up to day 21. The result was as follow:

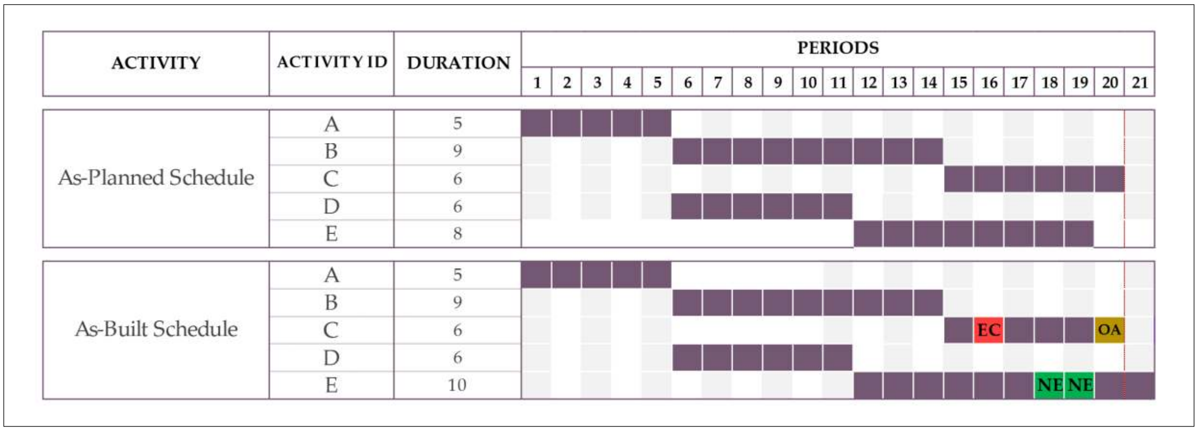


Figure 6-7: The issue of schedule Acceleration

- 100% of the experts agreed on that without the acceleration on day 20, the delay in Day 21 day 21 is the responsibility for the concurrent effects of EC delay in Day 16 and NE delay in Day 19.
- 100% of the experts agreed that the delay in Day 21 is the responsibility for NE delay in Day 19.
- 100% of the experts agreed on that acceleration poses a significant source of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties.

Based on the collected data, the acceleration should affect the recovering day of delay to be credited to the directed party. Also, the acceleration could affect the liability for any schedule delay. For example, day 21 was the responsibility of the EC delay that happened on day 16. However, and by the acceleration that directed by the owner on day 20, day 21 become the responsibility of the NE delay that happened on day 19. Therefore, the acceleration should be analysed at the activity-level and at the overall project-level for identifying the liability for each schedule delay.

6.5.8 Floats Consumption

In the delay claims, Total Floats (TFs) float ownership plays a role in the results for the delay claims analysis. Thus, it needs further investigation to cover all the possible scenarios in the practice use. This need can be covered in this research based on the court cases of float consumption in the construction delays claims and seeking the experts' opinion as following:

1) <u>Views expressed from the documentary analysis: -</u>

Also, the issue of whether compensation is justified when the float is consumed and used is another complicated issue (see e. g. Weaver Bailey Contractors Inc. v. the United States, 1990; U.S. Fid. & Guar. Co. v. Orlando Utils. Comm'n, 1983). Regarding the float ownership, all the protocols and specifications such as SCL (2002) and the AACEI (2011) have formally addressed this issue. The AACEI states that the project owns the "Float" (Subsection 4.3.E). That means that the contractor might not have to recover compensation for the owner's non-critical delay. The SCL protocol states that:

> *"the time can only be extended if the owner affects the path which has zero total floats, and the contractor is entitled to compensation if the owner uses the float."*

However, Scott et al. (2004) conducted a survey with the practitioners in the UK for the issue of the float. The three essential issues of the float from that study are (1) who owns the float; (2) who is responsible for the delay if the contractor consumes float first; and (3) who is responsible for the delay if the owner consumes the float first. For the first question of who own the floats, the majority of respondents in Scott et al.'s survey believes that the contractor should have exclusive control of float. However, the SCL (2002) position on float ownership is that if the clause stating the entitlement of float is not specified in the contract, the float should be belonging to the project or the concept of the first-come-first-served principle.

Regarding the second and third question, there are two possible effects could be occurred due to two possible schedule impacts. The amount of the floats would be decreased due to delaying the critical path or accelerating non-critical path. In contrast, delaying the non-critical path or accelerating the critical path will increase the number of floats. Therefore, the effect on the folate in each case should be determined and assigned to the responsible party. Therefore, the issues that associated with the floats due to the schedule impacts are as shown in Table 6-3.

Table 6-3: The impacts on the total floats

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">The schedule events</th><th colspan="2">The impact on the TF</th><th rowspan="2">The issues</th></tr>
<tr><th>Increase</th><th>Decrease</th></tr>
<tr><td>1.</td><td>Direct or Indirect delay that happened on the critical project path</td><td rowspan="2">✓</td><td rowspan="2">-</td><td rowspan="2">• Who owns the increased float?
• Who is responsible for increasing this float?
• What is the impact on the project?
• Who is responsible for the impact?</td></tr>
<tr><td>2.</td><td>Accelerate events on the non-critical path</td></tr>
<tr><td>3.</td><td>Direct or Indirect delay that happened on the project non-critical path</td><td rowspan="2">-</td><td rowspan="2">✓</td><td rowspan="2">• Who owns the consumed float?
• Who is responsible for consuming this float?
• What is the impact(s)?
• Who is responsible for the impact?</td></tr>
<tr><td>4.</td><td>Accelerate events on the critical path</td></tr>
</table>

Therefore, the increased or decreased of project floats that formed after the impact on the project schedule and were not initially in the as-planned schedule must be analysed equitably due to their effect on resolving the analysis issues and delay liability, as shown in Table 6-4.

Table 6-4: The issues of float consumption in three different concepts of float ownership

Effect	Impacted event		Float Ownership Concept		
			Owner	Contractor	Project
Increase	Delay	EC	-	Owner Credit	Owner Credit
		NE	Contractor Credit	-	Contractor Credit
		EN	-	-	-
	Acceleration	OA	-	Owner Credit	Owner Credit
		CA	Contractor Credit	-	Contractor Credit
		SA	-	-	-
Decrease	Delay	EC	-	Owner Discredit	-
		NE	Owner Discredit	-	-
		EN	-	-	-
	Acceleration	OA	-	Owner Discredit	-
		CA	Owner Discredit	-	-
		SA	-	-	-

2) *Views expressed by the questionnaire survey: -*

For ensuring more reliable results for delay claims analysis, the survey questionnaires have asked the respondents to assess the issue of acceleration effects during the delay analysis process. As a visual aid for considering the rights of the contracting parties, Figure 6-8 shows that EC and NE delay events both happened on day 18. However, they are not concurrent delays because the NE delay has not affected the overall project duration. Also, the EC delay on day 18 and the NE delay on day 19 have both affected the original project duration independently of each other. However, they are not concurrent delays because the delays must be "inextricably intertwined" and must overlap each other. In this Scenario, EC delay (on day 18) has extended the path (A-B-C) up to day 21. Also, NE delays (on days 18 and 19) have contributed to extending path (A-D-E) up to day 21. Therefore, the schedule should be accurately analysed (among which of these delay events) to assign the right party who is responsible for extending the original completion date (one day) up to day 21. The result was as follow:

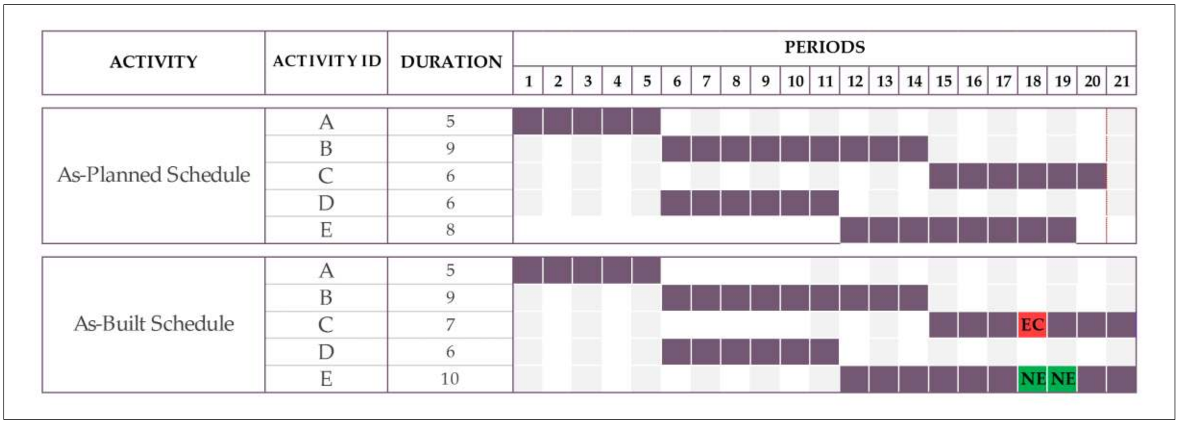


Figure 6-8: The issue of total float consumption

- 82.35% of the experts agreed on that float in Day 21 formed by EC delay that occurred in Day 18, and contractor should be discredited for consuming this float by NE in Day 19.
- 82.35% of the experts agreed on that the contractor (due to delaying the path [A-D-E] on day 19) has to share the damages in Day 21 with Employer who formed the extra day of total float (in Day 21) due to EC delay in Day 18.
- 58.82% of the experts agreed on that the responsibility for the project delay on day 21 is the responsibility of both parties if the contractor has not granted an EoT, which this sound of analysis will help to resolve the pacing delay issue.
- 100% of the experts agreed on that total float consumption pose a significant source of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties.

Based on the collected data, the float consumption affects the recovering day of the impact. Also, the float consumption could affect the liability due to any schedule impact. In the case, the float consumption will also affect the responsibility of total project delays. Therefore, the float consumption should be analysed only at the overall project-level for identifying the liability for total project delays.

6.6 Summary

The chapter considered the first question of the research, which relates to understanding the current practice of schedule impacts and delay claims. Table 6-5 shows the conclusion for the liability, the causes, and the effects of any schedule impact, whether it occurs directly or indirectly, along with the responsibility for determining its liability. The summary of the results of this chapter is as follows:

Table 6-5: The liability for any cause and effect of the schedule impact based on the data analysis

Cause and effect		**Liability of the schedule impacts**			**The liability of the effects**	
		Owner	**Contractor**	**Neither party**	**Direct Effect**	**Indirect Effect**
The liability of the causes	**Direct Cause**	Delays, disruptions, change orders, or accelerations that are happened directly as the result of owner action.	Delays, disruptions, and accelerations that are happened directly as the result of contractor action.	Delays, disruptions that are happened directly as the result of neither party action	Loss of time or money	Cumulative Impacts
	Indirect Cause	Disruption or loss of productivity that happened indirectly as the result of owner action	Disruption or loss of productivity that happened indirectly as the result of contractor action	Disruption or loss of productivity that happened indirectly as the result of neither party action	Loss of time or money	Cumulative Impacts
		Resource impact that happened indirectly as the result of owner action	Resource shortages that happened indirectly as the result of contractor action	Resource shortages that happened indirectly as the result of neither party action	Loss of time or money	Cumulative Impacts
		PFMD or delay that happened indirectly as the result of owner action	PFMD or delay that happened indirectly as the result of contractor action	PFMD or delay that happened indirectly as the result of neither party action	Loss of time or money	Cumulative Impacts
The liability for losses	**Losses due to delay**	The contractor entitles to a time extension due to critical delays for extending the project completion date and compensates for any potential damages.	The owner entitles to the liquidated damages due to critical delays for extending the project completion date and any potential damages.	The contractor entitles to a time extension only due to critical delays for extending the project completion date.	Loss of Time	The analysis should be retaken to evaluate the schedule impacts
	Losses due to disruption	The contractor entitles to monetary compensation for any losses or damages	The owner entitles to monetary compensation for any losses or damages	None	Loss of Money	

1. The investigation through the adopted research methods shows that the losses and damages can be recovered through the processes of disruption claims or delay claims based on the effect type. The type of direct effect on the schedule impact, whether loss of time or loss of money, will determine the type of claim (delay claim or disruption claim). Impacting the project cost without impacting the project time is a part of the disruption claim process. However, impacting the project time, leading to cost overrun or/and loss of time is a part of the delay claim.
2. There are some events relative to schedule impact that can be only claimed through a delay claim process and not through disruption claims and vice versa. Further, there are some events of schedule impact can be claimed through both delay and disruption claims such as change order, based on the type of direct effect. Thus, determining the type of schedule impact will not help to select the claim process.
3. Some of the claims will be shifted from a delay claim to a disruption claim and vice versa based on the indirect impacts (the cumulative impacts).
4. Some events could indirectly affect the schedule due to other schedule impacts, leading to further delays and disruption. For example, a change order which has impacted the schedule may impact the resource, which may not lead to a direct effect in terms of losing time or money but impact productivity. In this case, the loss of productivity is an indirect cause for the indirect effect of the change order. The indirect cause event includes PFMD, resource allocation and loss of productivity, which cannot occur without another effect.
5. The type of effects, whether direct (loss of time or money) or indirect (other impacts), may determine the type(s) of claim to be sought— delay or disruption claim.

6. In the case of claiming indirect effect, the process should follow the proceeding: 1) the impact type should be determined; 2) determine the responsibility of its indirect cause for its occurrence; 3) determine its effect.
7. The determination of the liability and entitlement for the schedule impacts are based on three factors: 1) the type of the schedule impact; 2) the type of the cause; 3) the type of the effect. For example, the claim for loss of productivity could be caused by a delay or disruption. Thus, it is an indirect cause for the schedule impact and must be caused by another impact. Also, the effect of the loss of productivity that the contractor would claim could be a direct loss or indirect effects, such as further delay or disruption. Thus, determining the type of the schedule impact, its cause, and its effect will determine its liability and entitlement.
8. The losses and damages that result from the schedule impact would occur at the project-level by impacting the Project Completion Date (PCD) or/and at the activity-level by impacting the Early Start (ES) or Duration (D) of any activity.

The results obtained from Chapter 6 represent the basis for identifying the criteria for analysing the schedule impacts, which can be used in claiming the losses and damages. These criteria are as follows: 1) the type of schedule impact; 2) the type of cause; 3) the type of effect. Also, for determining the liability type of any schedule impact, whether a direct liability or indirect liability, determining the type of the cause and the effect is one of the criteria used for analysing the liability. These criteria will be used in the next chapter, which will help to form the research aim and meet the research objectives.

CHAPTER SEVEN: DISCUSSION OF RESEARCH FINDINGS

7.1 Introduction

This chapter discusses the findings obtained from the collected data in Chapter 6, which formed the basis in proposing a framework and technique for the delay and disruption claims analysis. The proposed technique is a new systematic approach that uses the theory of the CPM logic-driven approach, which based on measuring the effect before and after the impact on the schedule. In an effort to create more rigorous results of the schedule analysis, the proposed technique aims to track any potential damages or losses for delay claims and determine the responsibility between owner and contractor. The outputs by the proposed technique provide the following: 1) the responsibility for the project delay period, 2) the responsibility for any potential damage or loss at the project-level, 3) the responsibility for any potential damage or loss at the activity-level. To ensure more reliable results, the proposed technique will consider the most DAIs. The following sections present the findings that were adopted for developing the framework and therefore proposing the technique in detail.

7.2 Framework Developing

Concepts or theories are developed to explain phenomena in a field, or to provide a structure or framework to apply to acquired knowledge in a field (Davis and Parker, 1997). Theory building is typically driven by the desire to explain something that is usually a theoretical (Shoemaker et al., 2004). As Handfield and Melnyk (1998 p: 321) state: ―Without theory, it is impossible to make meaningful sense of empirically-generated data, and it is not possible to distinguish positive from negative results‖, where the theory can be statements or models or frameworks (Bacharach, 1989; Carlston, 1994; Rumelt, 1994).

In this study, the research concept aims to propose a framework and technique that are built based on the collected data. Without linking the findings together, the result will not be sufficient to build this the framework and technique. To analyse the findings and therefore develop the framework and the technique, this chapter adopts the same three fundamental facts as Chapter 6. The reason for this is to link the findings for each fact based on the collected data and present the findings inaccurate sequences.

Therefore, the following sections will begin first by analysing the liability of the schedule impact and attempt to draw a difference between direct and indirect liability in both delay claims and the liability in disruption claims, which will help to define the DAIs that are included in only delay claims.

7.2.1. Liability Analysis

The liability analysis includes the process for identifying the responsibility of any loss or damage. Questions that need to be answered here often include the following (Schumacher, 1995; Wickwire et al., 2004): 1) Why did the impact occur? 2) How did the impact occur? 3) What are the effects?

As Sections 6.3.3 and 6.4.3 stated, the liability in delay claims is based on a direct effect on project time or loss of time on the schedule, while the liability in disruption claims is based on a direct effect on project cost or loss of money without impacting the project time.

Based on the collected data as discussed in Sections 6.3.3 and 6.4.3, the resulting injury or the direct effect of the schedule impacts in disruption claims is a direct loss of money while, in delay claims, is a direct loss of time. Further, the causation of the schedule impacts could occur as a direct or indirect cause depending on the type of schedule impact. For example, a change order's effect on the schedule is a direct cause only, as it is a direct request by one of the contracting parties. However, the loss of productivity that occurs on the schedule is an indirect cause of another impact such as a change order. Therefore, the liability is formed by the type of effect and cause. Table 7-1 shows the two types of liability, direct and indirect, for each cause and effect of the schedule impacts.

Table 7-1: Classification of the liability for the schedule impacts based on the data analysis

<table>
<tr><th rowspan="2">Claim Types</th><th rowspan="2">Schedule Impacts</th><th rowspan="2">Cause</th><th colspan="2">Effect</th><th colspan="2">Liability</th></tr>
<tr><th>Direct Effect</th><th>Indirect Effect</th><th>Direct</th><th>Indirect</th></tr>
<tr><td rowspan="4">Delay Claims
under delays and suspension clause</td><td rowspan="2">Change order
Critical delay (non-performance)
Non-critical delay (non-performance)</td><td rowspan="2">Direct Cause</td><td>Loss of Time</td><td></td><td>✓</td><td></td></tr>
<tr><td></td><td>Other Impacts</td><td></td><td rowspan="3">✓</td></tr>
<tr><td rowspan="2">Productivity lost
Resource Allocation
PFMD (non-performance)</td><td rowspan="2">Indirect Cause</td><td>Loss of Time</td><td></td><td></td></tr>
<tr><td></td><td>Other Impacts</td><td></td></tr>
<tr><td rowspan="4">Disruption Claims</td><td rowspan="2">Change Order
Acceleration</td><td rowspan="2">Direct Cause</td><td>Loss of Money</td><td></td><td>✓</td><td></td></tr>
<tr><td></td><td>Other Impacts</td><td></td><td rowspan="3">✓</td></tr>
<tr><td rowspan="2">Productivity Lost
Resource Allocation</td><td rowspan="2">Indirect Cause</td><td>Loss of Money</td><td></td><td></td></tr>
<tr><td></td><td>Other Impacts</td><td></td></tr>
</table>

In delay claims, the analysis of liability of any loss or damage is based on the direct effect of lost time (see, e.g. Bramble and Callahan, 2010). The loss of time could occur either at the critical or non-critical path(s). The liability for any potential losses and damages on critical or non-critical paths is the occurrence of losing time to complete the project on time, finishing the execution of any activity on time or starting the implementation of any activity on time. Therefore, the liability in delay claims is the liability for any losses or damages which occurred only due to loss of time.

In contrast, the analysis of liability in disruption claims is the analysis of the responsibility for any direct effect of losing money, that does not impact the project time (Cushman and Carpenter, 1990). For example, loss of productivity as a type of schedule impact could occur due to the action of an owner, a contractor, or neither. If there is a loss of time due to productivity loss as a result of an owner's delay, the contractor may add more resource to overcome the shortages of time and complete the task on time. Therefore, any losses or damages due to increasing the resource allocation will be sought through a disruption claim based on losing money only. However, if the contractor decided to work with the same resource and complete the task later than scheduled, the losses and damages as a result of increasing the time of the task will be claimed through a delay claim based on losing time.

Because the causation is one of the fundamental facts that have a significant part in analysing the disruption and delay claims, the following section will discuss causation in delay disruption claims and delay claims.

7.2.2. Causation Analysis

Based on the data presented in Sections 6.3.3 and 6.4.3, once the schedule has been impacted, it should be determined whether the cause should be classified as a direct cause (a direct action or inaction from one or more of the contracting parties, such change orders) or as an indirect cause (a cumulative impact of another impact, such the loss of productivity). Consequence, the effect (the resulting injury or loss) from this impact should be determined, whether as a direct effect (loss of time or loss of money) or as an indirect effect that leads to cause another impact. In this case, if the effect (loss) that is attributed directly to the cause will be a direct effect, the liability can also be determined directly. Otherwise, the causation needs to be proved by further investigations to determine its direct effect and therefore determine its direct liability. Based on that, and for determining the liability of any loss or damage, the cause and the effect should be determined first.

In delay claims, the causation is the process of linking the cause by the loss of time as a first effect. Once the causation of the time loss has been determined, the liability for any loss or damage based on losing time can be established. Although the liability for any potential loss and damage cannot be determined directly in the delay claim due to the DAIs, determining the liability for any potential loss or damage in disruption claims is more complicated. Therefore, Sections 7.2.2.1 and 7.2.2.2 discuss the causation in disruption claims and delay claims, respectively, as follows.

7.2.2.1 Disruption Claims

The direct effect of disruption claims is the loss of money without partially losing time in the activities time or entirely in the project time. However, a disruption, as presented in Section 2.3.4, can be defined as "any change or modification to the method of performance or planned work sequence; it could result in non-effect in term of time or money". However, not every change brings an effect. Based on that, there is a need to explain situations in which the disruption may or may not lead to affect. To demonstrate these situations, the following parties (I and II) will use examples to justify each situation more clearly.

I. A Disruption with Effect

To explain how disruption may occur on the project schedule with a direct effect on the project cost without affecting the project time, Figure 7-1 has been designed in this study as an example to illustrate this case. In this figure, the progress that is required for each activity to be accomplished on time is shown as a percentage in each day. In this example, the first disruption occurred on Day 5 at Act. C, which decreased productivity from 33.33% to 10%. To overcome this loss in productivity, the resources on Day 6 and 7 were increased, which will increase the project cost. In this situation, delay claims analysis cannot be used to verify or prove this effect since the project time was not impacted partially or entirely.

Act.	As-Planned Schedule						
	1	2	3	4	5	6	7
A	50%	50%					
B			50%	50%			
C					33.33%	33.33%	33.33%
D	50%	50%					
E			50%	50%			
F					50%	50%	
Resource Req.	1	1	1	1	1	1	1

Act.	As-Built Schedule						
	1	2	3	4	5	6	7
A	50%	50%					
B			50%	50%			
C					10%	40%	40%
D	50%	50%					
E			50%	50%			
F					50%	50%	
Resource Req.	1	1	1	1	1	2	2

Figure 7-1: Direct cost impact due to the schedule impact

In such a case, the innocent party who suffered the loss must claim the damages through a disruption claim, as discussed in Chapter 6. In this case, the analysis needs further proofs the other party is solely responsible for the case and the effect. Also, it may require more evidence to prove the amount of loss. In summary, the disruption that occurred and its effect is not based on analysing the project schedules used in the case of impacting the project time, as will be discussed in the following section of delay claims. It may need

177other proof, such as daily reports, witnesses, schedules for resource allocation and project productivity, etc.

II. A Disruption without Effect

To explain how disruption may occur on a project schedule without a direct effect on the project cost, and without affecting the project time, Figure 7-2 has been designed. In this figure, the progress that is required for each activity to be accomplished on time is shown as a percentage in each day. In this example, the first disruption occurred on Day 6 at Act. C, which decreased productivity from 33.33% to 20%. This loss in productivity would be overcome on Days 7 and 8 without any additional money. In such a situation, the delay claims analysis cannot be used to verify or prove this effect since the project time was not impacted partially or entirely.

Act.	As-Planned Schedule							
	1	2	3	4	5	6	7	8
A	100%							
B		50%	50%					
C				50%	50%			
D						33.33%	33.33%	33.33%
E		50%	50%					
F				50%	50%			
Resource Req.	1	1	1	1	1	1	1	1

Act.	As-Built Schedule							
	1	2	3	4	5	6	7	8
A	100%							
B		50%	50%					
C				50%	50%			
D						20%	40%	40%
E		50%	50%					
F				50%	50%			
Resource Req.	1	1	1	1	1	1	1	1

Figure 7-2: A time impact would cause nothing in term of project time and cost

A disruption that occurred on Day 6 at Act. D impacted productivity, reducing from 33.33% to 20%. Due to this impact, and comparing it with the as-planned productivity, productivity increased on Day 7 and 8. However, the increase in productivity rates on Days 7 and 9 occurred with the same crew size and the same resources and during the as-planned time for the task. Thus, increasing the production rate to 40% on Days 7 and 8 prevented any loss. Therefore, such a case of disruption on Day 6 happened without effect on time or money.

Based on the findings in Section 7.2.2.1, the DATs, which use the CPM approach and are based on analysing the project schedule, cannot be used for analysing the disruption situations, whether it happens with or without effect. The following section will discuss the causation in delay claims as follow.

7.2.2.2 Delay Claims

Based on the data that are presented in Sections 6.3.3 and 6.4.3, once the impact on the project schedule occurs, the effect of the disruption or/and delay also occurs. Thus, there are three possible effects of this impact that could occur in the project. First, this impact could lead to a disruption which may occur with or without effect, as discussed in Section 7.2.2.1. Second, this impact could lead to a cumulative loss of time that may impact other periods, such as affecting the resource or productivity or pushing the performance into PFMD. Third, this impact could lead to a loss of money resulting from a loss of time at the project level or/and activity level. Each of these possible effects will be highlighted as follows.

I. A Disruption

As discussed in Section 7.2.2.1, a disruption could occur with or without effect. In a case in which the impact has led to disruption and the disruption has occurred with an effect, the loss will be claimed through a disruption claim. For example, the impact could be a delay which has impacted the project productivity, resulting in more resources and additional money to overcome productivity loss. The claim for this case will be based on the loss of productivity but not on the delay. In this case, the effect of the delay transformed into a disruption based on the cause of the resulting injury (productivity loss).

II. A Cumulative Loss of Time

The second possible effect of any impact is a cumulative or indirect loss of time. For example, the impact could be a direct delay, which has an impact on the project schedule and leads to another delay. The possible causes of this situation are the effects that lead to an impact on the resource(s), the productivity or extend the project time into PFMD. In this case, it is possible to claim the loss of the direct delay based on the cumulative time lost. Although the liability will not be determined directly, it is possible for it to be determined through the causation..

To explain the process of the analysis for such cases, which will help in forming the framework and the technique, the following section will discuss the DAIs that may lead to such situations.

1. Resource Overloading and Allocation

To explain how a direct impact may lead to a loss of time indirectly via an overloaded resource, Figure 7-3 has been designed. In this figure, the direct delay occurred on Day 3 of the non-critical path. This did not lead to a delay in the overall project time, which, as a result, cannot be analysed by the existing DATs. Although the project time remained the same, this delay had an indirect effect on the resource allocation on Day 6, which had a number of resources of only one. However, due to this effect, another activity (Act. D, Day 6) could not be implemented. Without additional resources on Day 6 to perform Acts. D and F, the project would not finish on time and would be extended up to Day 8.

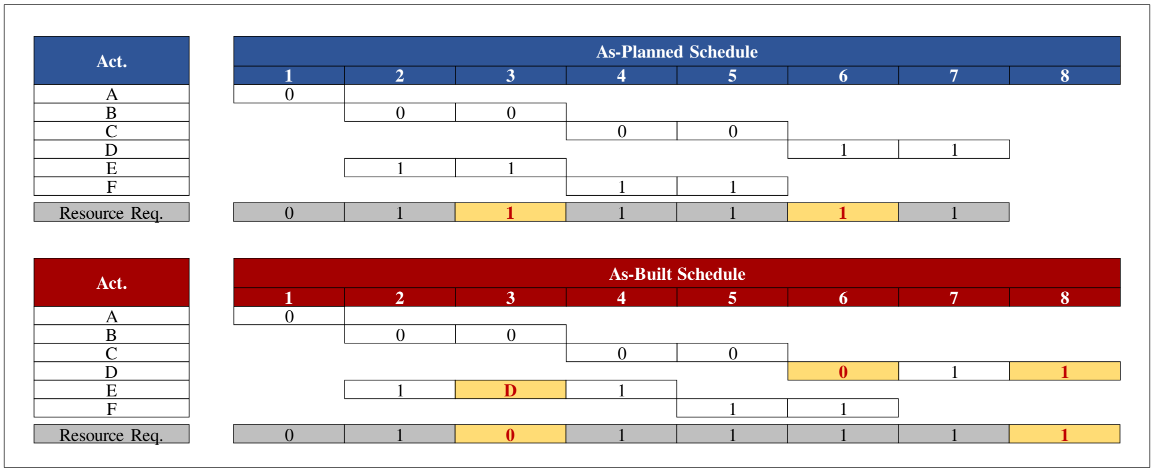


Figure 7-3: A loss of time caused by resource overloading

For considering the issue of resource allocation in the delay claim, the analysis must have the capability to show that the delay on Day 6 at Act. D has occurred only due to the delay on Day 3. As a result of the direct effect of the delay on Day 3, loss of time has extended to Day 6 and caused an indirect effect (another loss of time) due to the resources overloading. Therefore, this type of situation should not be neglected during the analysis processes, which the liability indirectly allocated to the responsible party who caused the delay on Day 3. This is based on the fact that the loss of time on Day 6 would not have occurred if the loss of time on Day 3 had not taken place.

2. Preventable Force Majeure Delay

To explain how a direct impact may lead to a loss of time indirectly by the PFMD, Figure 7-4 has been designed. In this figure, the direct delay occurred on Day 6 on the critical path. This will lead to a delay in the overall project time up to Day 7. This delay also has an indirect effect on pushing the project into PFMD on Day 7, which was not a part of the original project time. Due to this effect, Act. D on Day 7 could not be performed, which extended the project time up to Day 8.

Act.	As-Planned Schedule							
	1	2	3	4	5	6	7	8
A	100%							
B		50%	50%					
C				50%	50%			
D						100%		
E		50%	50%					
F				50%	50%			
Productivity	100%	100%	100%	100%	100%	**100%**		

Act.	As-Built Schedule							
	1	2	3	4	5	6	7	8
A	100%							
B		50%	50%					
C				50%	50%			
D						**D**	PFMD	**100%**
E		50%	50%					
F				50%	50%			
Productivity	100%	100%	100%	100%	100%	**0%**	0	**100%**

Figure 7-4: A loss of time caused by PFMD

In considering the issue of PFMD in the delay claim, the analysis must have the capability to show that PFMD on Day 7 would not have taken place if the delay on Day 6 had not occurred. Although this type of schedule impact occurred due to force majeure, without the first loss of time that happened on Day 6, the second loss of time on Day 7 would not occur. Such a fact should be not be neglected during the claim analysis.

3. Loss of Productivity

To explain how a direct impact may lead to loss of time indirectly by the productivity lost, Figure 7-5 has been designed. In this Figure, the direct delay occurred on Day 6 on the critical path, which led to a delay in the overall project time up to Day 7. Further, this delay had an indirect effect on project productivity on Day 7, which had planned productivity of 50% that could not be achieved due to the productivity loss (30%). Therefore, the project was extended up to Day 8.

Act.	As-Planned Schedule							
	1	2	3	4	5	6	7	8
A	100%							
B		50%	50%					
C				50%				
D					50%	50%		
E		50%	50%					
F				50%				
Productivity	100%	100%	100%	100%	50%	50%		

Act.	As-Built Schedule							
	1	2	3	4	5	6	7	8
A	100%							
B		50%	50%					
C				50%				
D					50%	D	30%	20%
E		50%	50%					
F				50%				
Productivity	100%	100%	100%	100%	100%	0%	30%	20%

Figure 7-5: A loss of time caused by loss of productivity

In considering the issue of productivity loss in the delay claim, the analysis must have the capability to show that loss of productivity on Day 7 at Act. D has occurred only due to the delay on Day 6. As a result of the direct effect of the delay on Day 6 resulting in lost time, the effect has extended to Day 7 and caused an indirect effect (another loss of time) due to the productivity loss. Therefore, this type of situation should not be neglected during the analysis processes, which the liability indirectly allocated to the responsible party who caused the delay on Day 6. This is caused by the loss of time due to the productivity loss on Day 7, which would have not occurred if the loss of time on Day 6 did not exist.

III. Loss of Money

The second possible effect of any impact is the loss of money, which is based on a direct loss of time that occurred directly. This scenario of losing money due to the loss of time is the most popular situation for schedule impacts in construction claims, in which the contracting parties use the DATs to prove the occurrence. In this situation, the damages and losses always result from loss of time, entirely when impacting the PCD, in which the damages result at the project level, or partially when affecting the ES or the D of the activities, in which the losses and damages result at the activity level. Figure 7-6 has been designed in this study as an example to illustrate this case. At the activity level, the potential losses and damages that could result from losing time are as follows: 1) completing Act. B on Day 6; completing Act. C on Day 5; and 2) starting the Act. D on Day 7. At the project level, the potential losses and damages could result from losing time in completing the project on Day 8.

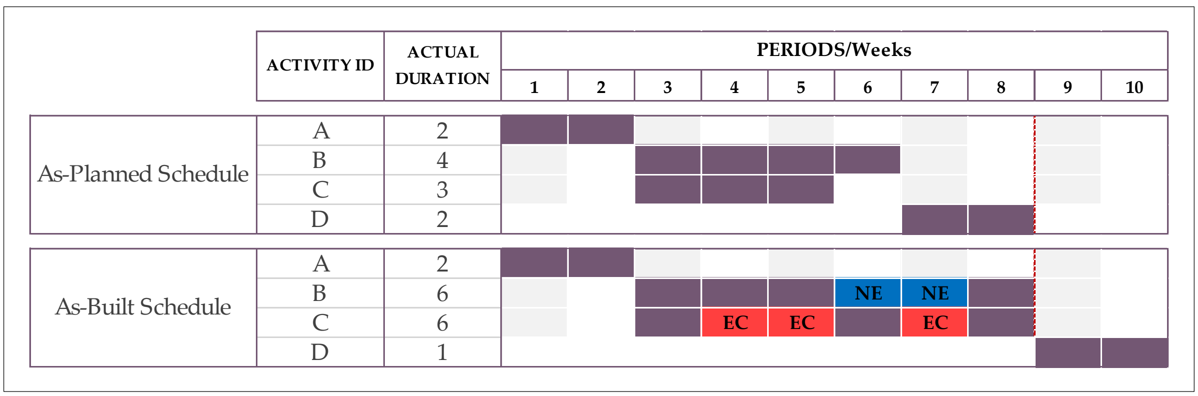


Figure 7-6: A loss of money due to loss of time

Determining the liability for the losses and damages at both levels is the issue of two subjects. First is the matter of deciding at which levels the potential damages will occur, which can be determined by identifying the retrieval day for the time lost. The retrieval day is the first serving day for accommodating the loss of time on the as-planned schedule according to the sequence of activities. Also, determining the retrieval day for recovering the time lost will verify whether the loss of time has extended to any ES or/and PCD. Second is the subject of determining the responsibility for the potential damages that were caused by the time lost for more than one period.

Both the retrieval day and the responsibility for the loss of time will help to determine how the analysis of the delay claims should be conducted and what the issues of analysing the responsibility of the damage are. To explain this, the following section discusses the losses at both levels.

A. Loss of Money at Project-Level

At the project-level, the damages and losses are the additional cost that resulted from extending the Original Project Completion Date (OPCD). Any possible damages or losses at the project-level would be formed due to the delayed period, which is the period after the timeframe that was agreed upon among the contracting parties. Therefore, analysing the responsibility of extending the OPCD will determine the liability for any potential damages at the project-level the responsibility for which may be subject to how the PCD has been extended and what type of losses the party will incur.

Regarding the type of losses due to extending the PCD, the owner will lose the benefit of using the project during the extension time. Further, the contractor will suffer the losses due to extending the overhead cost for completing the delayed works. Regarding how the PCD is extended, Figure 7-7 is provided as an example that was designed for this study to show the retrieval day to determine the responsibility for the potential damages at the activity-level.

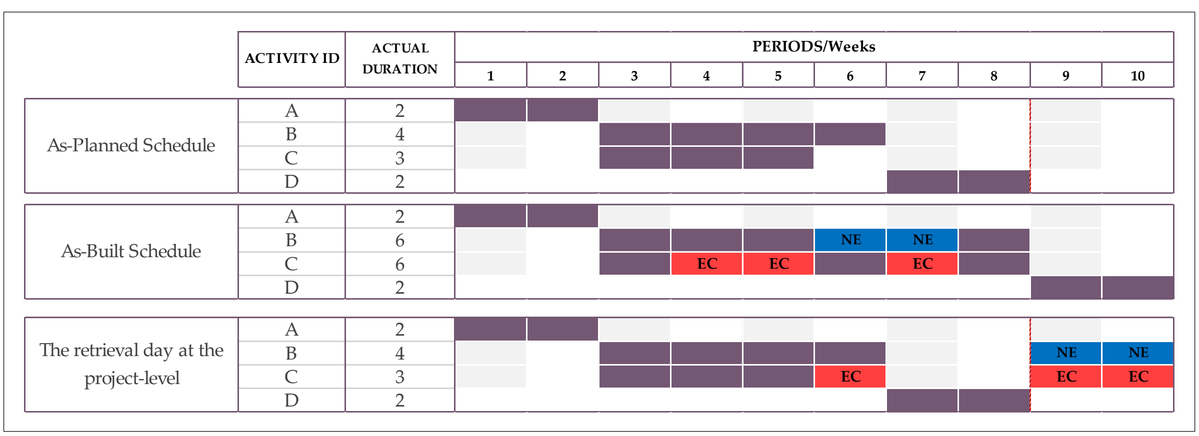


Figure 7-7: The retrieval day for the loss of time at the project-level

The owner will lose the benefit of using the project on Days 9 and 10. Additionally, the contractor will suffer the damages from extending the overhead costs on Days 9 and 10. Thus, determining the retrieval day will help to determine the potential damages. In Day 9, the NE delay that occurred on Day 6 and the EC delay that happened on Day 5 are responsible for any potential damages in this day. In Day 10, the NE and EC delays that occurred on Day 7 are liable for any potential damages in this day. The details analysis for the retrieval day of each loss of time is as follows:

The retrieval day that can accommodate the first delay (EC at Act. C on Day 4) is Day 6. On this day, Act. C has a float, which will prevent the OPCD from being extended and, as such, there will not be any potential damages due to EC-C-4 at the project-level.

The retrieval day that can accommodate the second delay (EC at Act. C on Day 5) is Day 9. This delay will extend the EF of Act. C up to Day 7 and push the ES of Act. D up to Day 8, which will extend the EF of Act. D up to Day 9. Thus, the OPCD is to be extended up to Day 9 due to this delay. In Day 9, there will be potential losses and damages for both parties, such as losing the benefit for the owner and increasing the overhead costs for the contractor. There is one analysis issue due to this delay.

Although the EC delay at Act. C on Day 5will generate a float on Day 7, which will increase the free float of Act. B, the first retrieval day on the as-planned schedule is also Day 9, which can accommodate the third delay (NE at Act. B on Day 6). Thus, this delay has a concurrent effect with EC-C-5 in extending the OPCD up to Day, om which the potential damages for both parties are concurrent due to the simultaneous effect between EC-C-5 and NE-B- 6.

The retrieval day that can accommodate the delays (NE at Act. B on Day 7 and EC at Act. C on Day 7) is Day 10. on Day 7, the concurrent delays between NE-B-7 and EC-C-7 will extend the PCD up to Day 10 and will be responsible for any potential losses or damages in this day.

Form the above analysis, the potential losses or damages at the project-level would occur on Days 9 and 10, which are not a part of the original project completion day. Therefore, to overcome the issue of consuming the generated floats, concurrent delays, and concurrent effects in determining the responsibility for any potential losses or damages at the project-level, the retrieval day that can accommodate each impact of delay should be established from the as-planned schedule.

B. Loss of Money at Activity-Level

At the activity-level, the damages and losses are the additional costs that result from impacting the ES or the D of any activity. When a project schedule experiences a loss of time, the works of some activities will differ from its plan due to this loss of time. In this case, the potential losses and damages at the activity-level come in the form of the loss of time that impacts the ES or the D.

By determining the retrieval day, as shown in the example of Figure 7-8, the ES of Act. D is the only ES that has been impacted by two days (on Days 7 and 8). In Day 7, the loss of time was due to the NE delay that occurred on Day 6 and the EC delay that took place on Day 5. In Day 8, the loss of time was due to the NE and EC delays that occurred on Day 7. Further, Acts B and C are the only activities that have been impacted in their D. Thus, the loss of time that has happened is due to the NE delays (on Days 6 and 7 for Act. B) and EC delays (on Days 4, 5 and 7 for Act. C). The effect on the ES and D will be discussed as follows:

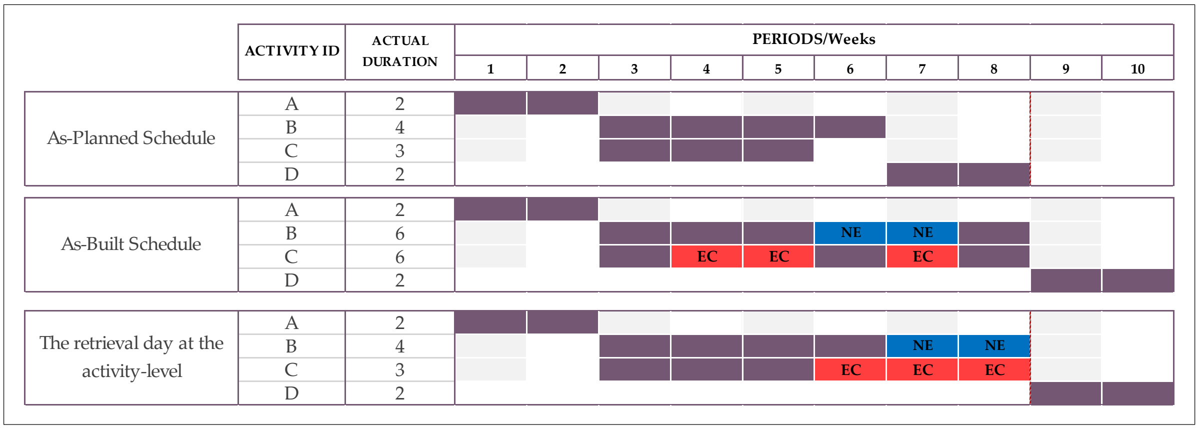


Figure 7-8: The retrieval day for the loss of time at the activity-level

1) Affecting the Early Start:

Any potential damages that may result from impacting the ES will occur due to delaying Act. D on Days 7 and 8. Determining the retrieval day will identify the responsibility for delaying the ES on Days 7 and 8. In Day 7, the loss of time was due to the EC and NE delays that occurred on Days 5 and 6, respectively, while on Day 8, the responsibility is due to NE and EC delays that took place on Day 7. The loss of time that impacts the ES of any activity could result in affecting the cost that is related to the pre-execute phase of that activity. For example, the storage costs could be increased if the start of the activity has been delayed, resulting in losses and damages that are hard to be defined at the project-level. Calculating the Affected Early Start (AES) for Act. X can be determined according to the following formulae:

AES X = Early Start after the impact - Early Start before the impact .... (Equation 7-1)

2) Affecting the Activity Duration:

Any potential losses and damages that may occur due to impacting the D will occur due to delaying Act. B (on Days 6 and 7) and delaying Act. C. (on Days 4, 5 and 7). The loss of time that impacts the Duration (D) of any activity could result in affecting the cost that is related to the execute phase of that activity, which can be identified by determining the real day of the impact. For example, the rental equipment that is specified for completing a particular activity will consume more time that is longer than the as-planned duration, resulting in losses and damages due to additional costs for any extra time. Calculating the Affected Duration (AD) for Act. Y can be determined according to the following formulae:

AD Y = [(Early Finish after the impact - Early Finish before the impact)-
(Early Start Y after the impact - Early Start Y before the impact)] .... (Equation 7-2)

7.3 Proposed Framework for Analysing Delay and Disruption Claims

Since time translates into money, it is essential to assign the responsibility for any potential losses and damages in a manner that is equitable to the owner and the contractor before any economic costs are determined. As concluded from the above discussion, losses and damages in construction projects could occur from a delay and the disruption of a schedule. Although the delay and disruption claims are both based on a financial loss, how this loss occurred via delay or disruption —and which claim process should be used to recover this loss are still questionable.

It is common to label a time lag in the completion of activities from its specified time as "a delay" and the interruptions or changes and any modification to the method of performance or planned work sequence as "a disruption". For further clarification, a delay is a period beyond a scheduled finish date which is required for a contractor to complete work, while disruption is to perform work in a manner that is less efficient than the contractor’s original plan. Further, it has been recognised that the claim of losses or damages on the non-critical paths is as "a disruption claim", while the claim of the losses or damages on the critical paths is as "a delay claim". With the changing of a critical path into a non-critical (and vice versa) alongside the fact that interruptions can be a time lag in the completion of activities, these labels have turned the topic of delay and disruption claims into a foggy and vague theme, which resulted in the emergence of problems or dilemmas in the delay claim analysis that are not easily corrected.

The evaluation of the DATs, as detailed in Sections 4.4 and 4.5, confirmed that the proper analysis of delay claims takes into consideration the effect of a number of DAIs, which is often lacking in practical use. Also, these DAIs, as discussed in Section 3.2, have the potential of affecting the results of delay analysis, creating more difficulties as detailed in Section 6.5. Therefore, the need for greater awareness and incorporation of these issues in delay analysis is crucial to ensuring fairness and amicable resolution of delay claims, as will be discussed in the following sections. To help reduce or avoid the frequent delay claims resolution difficulties amongst claims parties, Figure 7-9 shows two types of direct effects for any schedule impact, which can be used as a framework to distinguish between delay claims and disruption claims. However, the interference between these two claims in several aspects makes the distinction difficult to be defined. Due to that, some problems in delay and disruption claims need to be simplified in clear meanings as follows:

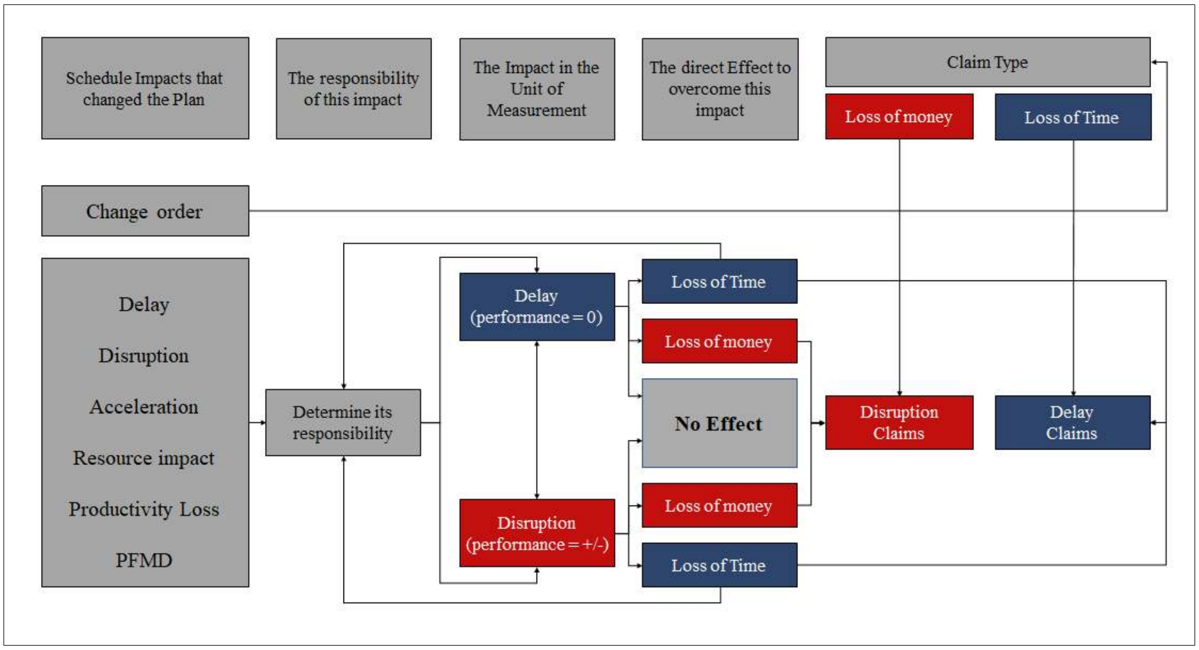


Figure 7-9: Framework for delay claims and disruption claims

1. The change order as a schedule impact is an exception impact which could happen in three scenarios: 1) change without effect in cost or time; 2) change with cost effect but without time effect (cost affected would be settled in advance or through a disruption claim); 3) change with time effect but without cost effect (Keane et al., 2010). Other than the change order, all the impacts can affect the schedule as a delay and disruption.

2. It is common to label the lack of performance in a part of the measurement unit that is used in the schedule as "a disruption" and the non-performance in the entire measurement unit of the schedule as "a delay". For example, loss of productivity, resource overloading, force majeure, access to the site, late material delivery or poor performance can be a cause for a lack of performance or non-performance that is quantified by the measurement unit. The measurement unit of the schedule is the project calendar that is used in the schedule to determine the project progress and performance from the start to the completion date.

For example, if the project performance is measured by the day, then the loss of time for one hour is not classified as a delay. However, the loss of time for one hour is considered a delay if the project performance measured by the hour. Thus, and in this meaning, the delay and disruption can be caused by any event. The classification of the scheduled event would be based on its duration in the measurement unit of the project schedule. In delay and disruption claims, an impact in any part of the schedule that results in extending the project time is a delay, while an impact in any part of the schedule that does not result in extending the project time is a disruption. These meanings will be used to identify the impact of any event on the schedule and measuring its effect.

3. In a delay situation, a result (effect) of impacting any activity by a disruption (a shortage of performance per the unit of measurement) or a delay (a non-performance per the unit of measurement) would extend an activity's time beyond its original time as planned on the schedule. This extension is a loss of time, which is used to overcome the non-performance. Additionally, it possible for the contracting parties to lose money due to this loss of time (the extension). Thus, the analysis should include the process for defining the following: 1) the period of time loss (the extension time); 2) the sole cause of this time loss (disruption/delay); 3) the responsibility for this cause (owner, contractor or beyond both parties' control); 4) the effects of losing this time (the extension effects); 5) the losses or damages resulting from this time loss ; 6) the losses and damages solely the result of this time loss.

4. A disruption situation is entirely different from the delay situation. Due to the impact of any activity by the disruption (a shortage of performance per the unit of measurement) or the delay (a non-performance per the unit of measurement), a loss of money will occur to

overcome this impact. Therefore, a disruption claim is based on the additional cost incurred due to the increased in the performance time to overcome the shortages within the same as-planned time. This type of claim cannot be analysed by using the project schedules alone (as-planned schedule, as-built schedule, and updated schedules). Thus, the disruption claim needs the as-planned data, on-going data, and other data that are usually unavailable for delay claim analysis. This type of claim is often resolved through mediation or ends up in litigation and disputes.

5. In delay claims analysis, the project schedules (as-planned schedule, as-built schedule, and updated schedules) need to be available for use in the claim analysis. Further, Items 1 to 3 that were mentioned in Point 3 need to be defined before considering most of the DAIs. The analysis needs to consider the issues of concurrent delays, the concurrent effects, the offsetting delays, the pacing delay, the floats, the extension of time and the acceleration.
6. From the above clarifications, a delay claim is based on the loss of time as a first effect of the schedule impact, while the disruption claim is based on the loss of money as a primary effect of the schedule impact. This meaning in this way is more accurate than the other meanings, which is compatible with the data in delay and disruption claims, as discussed in Chapters 2 and 6.

For determining the responsibility for any loss of money due to the loss of time at different levels, the DAIs should be considered during the analysis process, as they would affect the responsibility for the loss of time and the liability for any potential losses or damages at the project-level and the activity-level. The following section will discuss DAIs and their impacts in delay claims and the best way for them to be overcome in the analysis.

7.3.1. Concurrent Delays

Figure 7-10 shows an example of time loss that occurred on Day 2 due to D1 and D2. To determine the impacts of D1 and D2 on the schedule, the effects of D1 and D2 should first be determined at the activity and project levels. If there is a loss of time occurring on the ES, D or PCD, then any potential damage can be recovered through a delay claim. Thus, the effects should be analysed, as discussed in Sections 3.2.3, 6.5.1 and 7.2.2.2, as follows.

Act.	As-Planned Schedule						
	1	2	3	4	5	6	7
A	50%	50%					
B			50%	50%			
C					50%	50%	
D	50%	50%					
E			50%	50%			
F					50%	50%	

Act.	Scenario 1: Concurrent Delays						
	1	2	3	4	5	6	7
A	50%	D1	50%				
B				50%	50%		
C						50%	50%
D	50%	D2	50%				
E				50%	50%		
F						50%	50%

Figure 7-10: The potential losses and damages in the concurrent delay situation

By using Equations (7-1) and (7-2), Table 7-2 shows the time loss due to D1 and D2 at the activity and project levels. Due to D1, three activities have been affected Act. A on Day 3, Act. B on Day 3, Act. C on Day 5—while three activities have been affected due to D2: Act. D on Day 3, Act. E on Day 3, Act. F on Day 5.

Table 7-2: The responsibility for the damages and losses Due to D1 and D2 in the concurrent delay situation

Event	Impacted Day	Impacted Activity	Damages at the activity-level		Damages at the project-level
			Impacted on D	Impacted on ES	Impacted on PCD
D1	Day 2	Act. A	Day 3	-	Day 7
		Act. B	-	Day 3	
		Act. C	-	Day 5	
		Act. D	-	-	
		Act. E	-	-	
		Act. F	-	-	
D2	Day 2	Act. A	-	-	Day 7
		Act. B	-	-	
		Act. C	-	-	
		Act. D	Day 3	-	
		Act. E	-	Day 3	
		Act. F	-	Day 5	

At the project level, potential damages will occur due to the loss of time that has occurred on Day 7, which was caused by both D1 and D2. For determining the liability of any potential damages on Day 7, the analysis should consider the impacted day to classify the situation of the occurrence. Because D1 and D2 have taken place on Day 2 and the affected day would be on Day 7, this situation is classified as concurrent delays. As discussed in Chapter 6, the entitlement of any potential damages in the concurrent delay situation is highly subjective to the delay types and the rule of remedies. Table 7-3 shows the result of the entitlement analysis for any potential damages on Day 7.

Table 7-3: The responsibility for the damages and losses in the scenario of concurrent delays

The responsibility of the impacted delays		The Entitlement	
D1	D2	Easy-Rule	Fair-Rule
Owner (EC)	Contractor (NE)	Extension of Time	Apportionment
Contractor (NE)	Neither-party (EN)		Extension of Time
Neither-party (EN)	Owner (EC)		Extension of Time

7.3.2. Concurrent Effects

Figure 7-11 provides an example of time loss that occurred on Days 2 and 4, due to D1 and D2, respectively. To define the effects of D1 and D2 on the schedule, the impacts of D1 and D2 should be determined first at the activity and project levels. If there is a loss of time in the ES, D or PCD, then any potential damage can be recovered through a delay claim. Thus, the effects should be analysed, as discussed in Sections 3.2.4, 6.5.1 and 7.2.2.2, as follows.

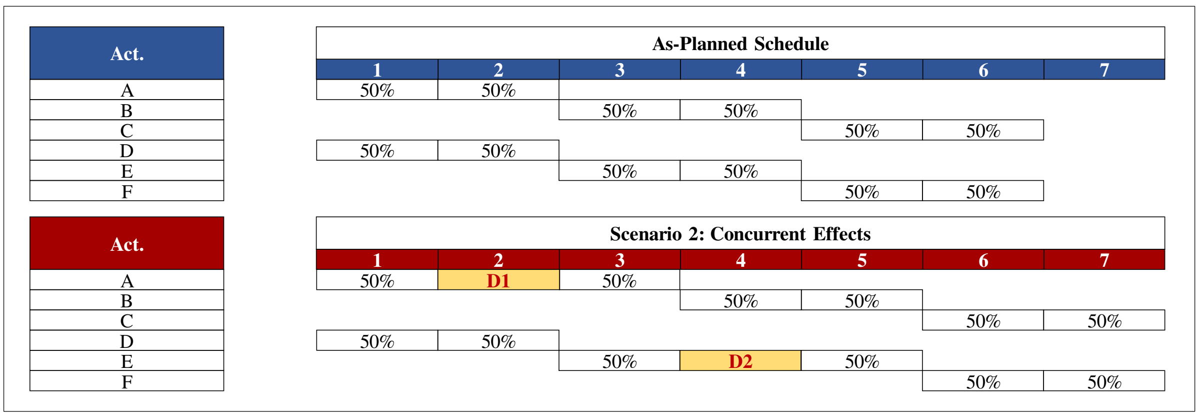


Figure 7-11: The potential losses and damages in the pacing delay situation

By using Equations (7-1) and (7-2), Table 7-4 shows the time loss due to D1 and D2 at the activity and project levels. Due to D1, three activities have been affected— Act. A on Day 3, Act. B on Day 3, Act. C on Day 5. Additionally, two activities have been affected due to D2: Act. E on Day 5 and Act. F on Day 5.

Table 7-4: The damages and losses due to D1 and D2 in the concurrent effects' situation

Event	Impacted Day	Impacted Activity	Damages at the activity-level		Damages at the project-level
			Impacted on D	Impacted on ES	Impacted on PCD
D1	Day 2	Act. A	Day 3	-	Day 7
		Act. B	-	Day 3	
		Act. C	-	Day 5	
		Act. D	-	-	
		Act. E	-	-	
		Act. F	-	-	
D2	Day 4	Act. A	-	-	Day 7
		Act. B	-	-	
		Act. C	-	-	
		Act. D	-	-	
		Act. E	Day 5	-	
		Act. F	-	Day 5	

In the concurrent effects, there are two possible situations in analysing the delay entitlement for the above example. If the owner is liable for D1, and the contractor is liable for D2, this situation would be recognised as a pacing delay. In contrast, if the contractor is liable for D1 and the owner is liable for D2, this situation would be an offsetting delay (Finke, 1992). For each situation of pacing delay and offsetting delay, the extension of time (EoT) plays a vital role in determining the entitlement.

Table 7-5 shows that the entitlement in the pacing and offsetting delays situation will be formed due to the granting of the EoT. For example, if the owner caused D1 and the contractor caused D2, it would be treated as a pacing delay situation only if the EoT had been granted after D1. In this situation, the contractor will be entitled to damage compensation. Without being granted an EoT after D1, this situation would be treated as a concurrent effect, in which the entitlement is based on the concurrent delay situation. Similarly, if the contractor caused D1 and the owner caused D2, it would be treated as a situation of an offsetting delay only if the EoT had been granted after D1. In this situation, the owner will be entitled to damages compensation. Without being granted an EoT after D1, this situation would be treated as a concurrent effect, in which the entitlement is based on the concurrent delay situation.

Table 7-5: The responsibility for the damages and losses in the concurrent effects' scenario

EoT	Delays Situation	The responsibility of delays		The entitlement
	D1 with D2	D1	D2	
With granted EoT before D2	Pacing Delay	Owner (EC)	Contractor (NE)	Contractor entitles to Extension of Time + damages or actual damages Owner entitles to liquidated damages or actual damages
	Offsetting Delays	Contractor (NE)	Owner (EC)	
Without granted EoT before D2	Concurrent Effect	Owner (EC)	Contractor (NE)	The situations would be treated as a situation of concurrent delays
		Owner (EC)	Neither-party (EN)	
		Contractor (NE)	Owner (EC)	
		Contractor (NE)	Neither-party (EN)	

7.3.3. Acceleration

In disruption and delay claims, an acceleration would work to prevent any loss of time and avoid any potential damage that could be resulted at the project or activity levels. Further, it could affect the project floats or the working days and reduce the as-planned duration without affecting a retrieval day for any delay or disruption. Thus, the type of acceleration and its effect on any potential damages play a vital role in the analysis, as discussed in Sections 3.2.8, 6.5.7 and 7.2.2.2. The acceleration will be discussed based on its effects at the project and activity levels and its types (OA and CA), as follows.

I. Acceleration Analysis at Project-Level

Each acceleration will influence two days on the schedule: the affected day and the retrieval day. Figure 7-12 is an example that shows three scenarios of acceleration. In each scenario, the acceleration is executed in a day, which is the affected day. However, its effect occurs on another day, which is the retrieval day. In Scenario 1, the retrieval day is Day 7, and the affected day is Day 8. In Day 8, there is a time loss that occurs due to D2. In this scenario, D2 and acceleration events belong to the same party. However, D2 and the acceleration in Scenario 2 belong to different parties. In Scenario 3, the retrieval and affected days are both Day 5. However, Day 6 is a working day for the original as-planned schedule. Therefore, there are different situations at the project level for the acceleration on the schedule. For each acceleration on the project schedule, the affected day could have five possible situations, with each situation affecting the outcomes of the analysis. Thus, the OA and CA will also be discussed based on the five situations as follow.

Figure 7-12: Acceleration with and the affected day at the project-level

- Acceleration could be applied on a day that is a retrieval day for lost time due to owner delay (EC delay). In this case, the OA or CA will prevent any losses or damages that would result from losing the time due to the EC delay.
- Acceleration could be applied on a day that is a retrieval day for lost time due to contractor delay (NE delay). In this case, the OA or CA will also prevent any losses or damages that would result from losing time due to the NE delay.
- Acceleration could be applied on a day that is a retrieval day for lost time due to neither-party delay (EN delay). In this case, the OA or CA will prevent any losses or damages that would result from losing time due to the EN delay.
- Acceleration could be applied on a day that is a retrieval day for losing time due to concurrent delays (CDs) or concurrent effects (CEs). In this case, the OA or CA will prevent any losses or damages that would result from losing time due to CDs or CEs.
- Acceleration could be applied on a day that was a working day for the original as-planned schedule. In this case, the OA or CA will merely reduce the as-planned time.

At the project level, the ideal situation for applying the acceleration is when the OA or CA will affect the day that is a retrieval day for lost time due to an EC or NE delay, respectively. However, the affected day could have a situation that does not represent the ideal situation. In this case, the party who is planning to obtain a benefit from the acceleration may lose the acceleration money without eliminating the effect of the schedule impact.

Tables 7-6 and 7-7 show the analysis for the OA and CA, respectively. When the acceleration is applied to the project schedule, the day that is affected by the acceleration could have four possible situations. For both the OA and the CA, as shown in Tables 7-6 and 7-7, Case A is the ideal situation. In Cases B, C, D or E for both the OA and CA, the acceleration needs further analysis to overcome the issue of reducing the PCD that was extended by a different party.

Table 7-6: Owner acceleration at the project-level

Case	Acc. Type	The situation in the affected day	The analysis of acceleration	Justification and Comment
A	OA	Loss of Time caused by EC delay	Prevent the losses or damages that resulted from EC	OA will prevent the damages caused by EC in the impacted day because OA affected the Same impacted day. The owner may need to verify the damages that resulted from EC, whether it is higher, less or equal to OA cost at Project Level. For example: *(-Damages +Acceleration cost) =* *(-) save money; (+) lost money*
B		Loss of Time caused by NE delay	Prevent the losses or damages that resulted from NE	OA will speed up the PCD as an updated date after losing time or as an original date for the as-planned schedule. In the first case, the OA will speed up the PCD and eliminate the loss of time that would be due to NE, EN, or CDs/CEs. Based on that, the owner could recover some damages by preventing the damages in the impacted day based on owner calculation and analysis. Also, the owner may need to prove how much the lose/gain that may occurred due to the acceleration and how much the loss/gain that may have if the acceleration had not implemented. The owner may also need to prove how much the lose/gain that the contractor may incur if the acceleration has not been implemented and how much the loss/gain that the contractor will incur after implementing the acceleration. It is a matter of cost, which must be presented and proved through a legal system.
C		Loss of Time caused by EN delay	Prevent the losses or damages that resulted from EN	
D		Loss of Time caused by CD/CE delay	Prevent the losses or damages that resulted from CD/CE	
E		Continuing work for an Activity	Reduce the duration of the impacted activity	

Table 7-7: Contractor acceleration at the project-level

Case	Acc. Type	The situation in the impacted day	The analysis of acceleration	Justification and Comment
A	CA	Loss of Time caused by NE delay	Prevent the losses or damages that resulted from NE	CA will prevent the damages caused by EC in the impacted day because CA has affected the Same impacted day. The contractor may need to verify the damages that resulted from NE, whether it is higher, less or equal to OA cost at Project Level. For example: *(-Damages +Acceleration cost) = (-) save money; (+) lost money*
B		Loss of Time caused by EC delay	Prevent the losses or damages that resulted from EC	CA will speed up the PCD as an updated date after losing time or as an original date for the as-planned schedule. In the first case, the OA will speed up the PCD and eliminate the loss of time that would occur due to EC, EN, or CDs/CEs. Based on that, the owner could recover some damages by preventing the damages in the impacted day, based on owner calculation and analysis. Also, the contractor may need to prove how much the lose/gain that may happen due to the acceleration and how much the loss/gain that may occur if the acceleration had not implemented. The contractor may also need to prove how much the lose/gain that the owner may incur if the acceleration had not implemented and how much the loss/gain that the contractor after implementing the acceleration. It is a matter of cost, which must be presented and proved through a legal system.
C		Loss of Time caused by EN delay	Prevent the losses or damages that resulted from EN	
D		Loss of Time caused by CD/CE delay	Prevent the losses or damages that resulted from CD/CE	
E		Continuing work for an Activity	Reduce the duration of the impacted activity	

II. Acceleration Analysis at Activity-Level

At the activity level, acceleration can prevent any losses or damages that would happen if the acceleration occurred in the same impacted activity, regardless of the situation in the affected day. For example, if an OA occurred in the activity that was impacted by an EC delay, the OA will eliminate any loss of time and prevent any damages that have resulted from an EC delay in this activity. However, if the loss of time has not occurred due to an EC delay in the impacted activity, the OA will eliminate any loss of time in the affected day, regardless of the delay type in the other impacted day. The example in Figure 7-13 illustrates the different effects for any acceleration type during the analysis.

As-Planned Schedule

Act.	1	2	3	4	5	6	7	8
A	50%	50%						
B			50%	50%				
C					50%	50%		
D	33%	33%	33%					
E				50%	50%			
F						100%		

Scenario 1: Accelerating the effected day that has same party delay

Act.	1	2	3	4	5	6	7	8
A	50%	D1	D2	50%				Acceleration
B					50%	50%		
C							100%	
D	33%	33%	33%					
E				50%	50%			
F						100%		

Scenario 2: Accelerating the effected day that has a different party delay

Act.	1	2	3	4	5	6	7	8
A	50%	D1	D2	50%				Acceleration
B					50%	50%		
C							100%	
D	33%	33%	33%					
E				50%	50%			
F						100%		

Scenario 3: Accelerating the effected activity that has a party delay

Act.	1	2	3	4	5	6	7	8
A	50%	50%						
B			50%	50%				
C					50%	50%		
D	33%	D1	D2	66%				
E					50%	50%		
F				Acceleration			100%	

Figure 7-13: Acceleration with and the affected day at the activity-level

As discussed earlier in this section, the damages that will result from extending an activity's duration or pushing the early start of other activity(ies) are the only two possible damages that may occur at the activity-level. If a loss of time has occurred in an activity, the damages will occur due to the duration of the impacted activity and the early start of other activity(ies). Therefore, any acceleration event would not prevent these damages unless it occurs at the same activity. Also, the effects could happen in a successor activity(ies) of the impacted activity and prevent the damages that may result from the early start of the following activity. Tables 7-8 and 7-9 show the analysis for the OA and CA in different cases.

Table 7-8: Owner acceleration at the activity-level

Acc. Event	Impacted Activity	Preventable Damages	Justification and Comments
OA	The impacted activity by OA has affected by EC	Damages resulted from EC	OA that would happen in the same activity that was affected by EC would prevent any possible damages resulted from EC at activity-level, regardless of the impacted day. For each part, the possible damages that will be incurred by any delay are equal in each day at the same activity. Each impacted day (at the same activity) has the same damages cost for each party. Therefore, accelerating any other impacted day will have the same effect of accelerating the impacted day.
	The impacted activity by OA has not affected by EC	Damages resulted in the impacted day	Any possible losses, which the contractor or the owner may incur due to the delay, will take place in the affected day of the delay. Therefore, accelerating the impacted day will completely elimante any possible damages cost for each party separately. There may be some possible loss/gain for the owner due to the acceleration. The owner should consider the cost of acceleration before any action, as follows; Is the damages cost of delay bigger, less or equal to the cost of OA? [- damages cost of delay (owner & contractor) + OA cost] = 0, is an equivalent cost (no damages at activity level) -, save money (acceleration is recommended at activity level) +, lost money (acceleration is not recommended at activity level)

Table 7-9: Contractor acceleration at the activity-level

Acc. Event	Impacted Activity	Preventable Damages	Justification and Comments
CA	The impacted activity by CA has affected by NE	Damages resulted from NE	CA that would happen in the same activity that was affected by NE would prevent any possible damages resulted from NE at activity-level, regardless of the impacted day. For each part, the possible damages that will be incurred by any delay are equal in each day at the same activity. Each impacted day (at the same activity) has the same damages cost for each party. Therefore, accelerating any other impacted day will have the same effect of accelerating the impacted day.
	The impacted activity by CA has not affected by NE	Damages resulted in the impacted day	Any possible losses, which the contractor or the owner may incur due to the delay, will take place in the affected day of the delay. Therefore, accelerating the impacted day will completely elimante any possible damages cost for each party separately. There may be some possible loss/gain for the contractor due to the acceleration. The contractor should consider the cost of acceleration before any action, as follows; Is the damages cost of delay bigger, less or equal to the cost of CA? [- damages cost of delay (owner & contractor) + CA cost] = 0, is an equivalent cost (no damages at activity level) -, save money (acceleration is recommended at activity level) +, lost money (acceleration is not recommended at activity level)

Therefore, when the acceleration happened on the schedule to eliminate the loss of time at the activity-level, there are two situations for any acceleration event. First, the impacted activity may have a loss of time due to the same responsible party who applies the acceleration. In this case, the acceleration will eliminate any loss of time as well as any potential damages. Second, the impacted activity may not have any loss of time that is caused by the same responsible party who applies the acceleration. In this case, the acceleration will only work to reduce the duration of the impacted activity and may prevent potential losses or damages at the project-level. Each of these scenarios, as shown in Figure 7-12, are discussed as follows.

In Scenario 1, an OA or CA has occurred an activity different from the activity that has been impacted by an EC or NE delay, respectively. This acceleration impacts the affected day (Day 8), which has been impacted by D2 (EC or NE delay). Therefore, the OA or CA will prevent any possible damages in Day 8 that would result from D2 at the project level only. At the activity level, the losses and damages due to the loss of time by D2 cannot be eliminated by this acceleration.

In Scenario 2, an OA or CA has also occurred in an activity different from the activity that has been impacted by an EC or NE delay, respectively. This acceleration impacts the affected day (Day 8), which has been impacted by D2 (D2 is a delay caused by the other party). In this case, the OA or CA cannot prevent any potential damages on Day 7 that may have caused by an EC/NE delay. This is because the damages on Days 7 and 8 have different cost slopes. Therefore, the OA or CA will only prevent any possible damages on Day 8 that would result from D2. Due to this, the owner or contractor may need a different analysis process to prove how substantial the damages that may result from an EC or NE delay on the impacted day (Day 7) are and how much the damages could be prevented by an OA/CA on Day 8. However, this case of acceleration cannot prevent or eliminate any potential damages on Day 7 that may be caused by an EC/NE delay.

In Scenario 3, the acceleration has a different situation than that explained in Scenarios 1 and 2. In this case, the OA or CA has occurred in the same activity that was impacted by an EC or NE delay, respectively. Although the OA or CA will impact the affected day that has been impacted by D1 (Day 8), it can only prevent the potential damages that may result from an EC or NE delay on Day 2. This is because an EC or NE delay and an OA or CA have occurred in the same impacted activity. Thus, the damages that may result from an EC/NE delay and

D1 at the activity level are precisely the same damages. Therefore, the only possible damages that can be prevented are the damages that were caused by D1.

7.3.4. Total Float Consumption

A case of consuming a new float that has been generated by any time loss should be analysed differently from the analysis of the original float that was agreed on the as-planned schedule, as discussed in Sections 3.2.6, 6.5.8 and 7.2.2.2. For determining the best analysis in consuming the Total Floats (TFs), the example in Figure 7-14 is designed in this study to show two cases of TF consumption. Case I is the scenario for consuming the original TF. While case II is the scenario for consuming a new TF that was generated by the schedule impact.

Act.	Case I (As-Planned Schedule)						
	1	2	3	4	5	6	7
A	50%	50%					
B			50%	50%			
C					50%	50%	50%
D	50%	50%					
E			50%	50%			
F					50%	50%	

Act.	Case I (As-Built Schedule)						
	1	2	3	4	5	6	7
A	50%	50%					
B			50%	50%			
C					50%	50%	50%
D	50%	50%					
E			D1	50%	50%		
F						50%	50%

Act.	Case II (As-Planned Schedule)						
	1	2	3	4	5	6	7
A	50%	50%					
B			50%	50%			
C					50%	50%	
D	50%	50%					
E			50%	50%			
F					50%	50%	

Act.	Case II (As-Built Schedule)						
	1	2	3	4	5	6	7
A	50%	D1	50%				
B				50%	50%		
C						50%	50%
D	50%	50%					
E			D2	50%	50%		
F						50%	50%

Figure 7-14: The differences between consuming the original TF and the new TF generated by delays

In Case I, the retrieval day for the time lost due to D1 is Day 7. On this retrieval day, the TF is initially in the as-planned schedule, which has been consumed by D1. Due to this consumption, the damages at the project level cannot be formed because the original completion date has not been affected. However, the scenario is entirely different in Case II, as the retrieval day for the time lost due to D1 and D2 is Day 7. Due to the time loss that was caused by D1, the PCD has been extended from Day 6 to Day 7, which has formed a TF on Day 7 on the path D-E-F. The damages at the project level will be for performing only 50% of Act. C in Day 7. However, the loss of time that was due to D2 has consumed this new TF in Day 7 and pushed 50% of Act. F to be performed on Day 7. This consumption of the new TF will cause an additional cost and more damages at the project level.

While the delay claim analysis tries to identify the responsibility for any potential damages at the project and activity levels, Case II can form an issue during the analysis process. Therefore, without agreeing on a new completion date for the project due to D1, the other party who has caused D2 will also be responsible for Day 7, the time loss of which is a situation of a concurrent effect.

7.3.5. Extension of Time

An EoT will have two benefits for the contracting parties. For the contractor, it is to relieve the contractor from liability for any delay damages—usually liquidated damages (LDs). Further, it allows the contractor to reprogram the remaining works for any period before the extended contract completion date. For the owner, it establishes a new contract completion date and prevents any time for completion of the work becoming "at large" and allows for planning of its activities (SCL, 2013). Therefore, without the granting of an EoT, the responsibility of the damages in case of concurrent effects will become the responsibility of the same entitlement in the concurrent delay situation. However, with a granted EoT, the concurrent effects would become a situation of pacing or offsetting delays.

An EoT is also one of the acceleration issues for preventing the damages at the project level. If the EoT has been granted before applying the acceleration, the party who applies the acceleration for any loss of time at the project level will be damaged twice: one for the losses due to the loss of time and for the acceleration costs. This issue, as discussed in Sections 3.2.1, 6.5.3 and 7.2.2.2, can be demonstrated, as in the example shown in Figure 7- 15, as follows.

Act.	As-Planned Schedule						
	1	2	3	4	5	6	7
A	50%	50%					
B			50%	50%			
C					50%	50%	
D	50%	50%					
E			50%	50%			
F					50%	50%	

Act.	Scenario 1: Concurrent Delays						
	1	2	3	4	5	6	7
A	50%	D1	50%			Acceleration	
B				50%	50%		
C						100%	
D	50%	50%					
E			50%	D2	50%		
F						50%	50%

Figure 7-15: Acceleration with the issue of extension of time

Due to D1 caused by the owner that occurred on Day 2, the project completion date has been extended up to Day 7. On Day 4, the contractor caused D2, which has extended the path D-E-F from Day 6 up to Day 7. Thus, D1 and D2 are a situation of a pacing delay because the EoT has been granted due to D1 and before the occurrence time of D2. However, the owner who caused D1 has decided to accelerate the impacted path A-B-C on Day 6 and after the occurrence of D2, although the acceleration on Day 6 will eliminate the loss of time and prevent any potential losses or damages that may result from D1 on Day 7. Further, D1 will become the delay that is responsible for the entire damages on Day 7. However, if the EoT has not been granted after D1, D1 and D2 will become a situation of concurrent effects. In this case, the acceleration will prevent any possible damages that may be caused by D1 on Day 7. Thus, the possible damages on Day 7 are the only damages that have been caused by D2; the party who caused D1 is solely responsible for any potential damages and losses on Day 7.

Therefore, the EoT will work to establish a new PCD for completing the project works on the updating schedule. If an EoT has been granted before the updating schedule, any loss of time that may happen cannot be eliminated unless both parties have agreed on the new PCD after the acceleration. This means that the acceleration should be applied before the EoT. Otherwise, it would be considered as reducing the duration of the updating schedule.

7.3.6. Productivity Loss

To appropriately consider all the afore-highlighted issues related to the delay analysis, the real-time effects of the schedule impact should consider the issue of productivity loss. For resolving this issue, four factors should be addressed during the schedule analysis:

1. Before the activity's execution: If the impact occurs before the beginning of the activity work, the impact will not affect the activity's production rate because the learning curve has not started. However, the impact may affect resource allocation as well as the overall project productivity.
2. During the activity's execution: If the impact occurs at the mid-point of the activities' execution, the learning curve will be affected by the delays and the disruptions. Therefore, adjustments to the activity duration should be considered before the analysis. Furthermore, the resource allocation may be affected by overload. As a result of the impact on the critical path, the analysis technique must have the capability to distinguish between the

delay that occurred before and after the beginning of the activity execution, in which the productivity can be adjusted to reflect any loss.

For highlighting the issue of the productivity in construction projects, as discussed in Sections 2.4, 6.5.5 and 7.2.2.2, the example of an activity of 13 days is shown in Figure 7-16, which was designed to include all possible scenarios of delay. This example will help to distinguish between constant productivity and standard productivity in the delay analysis process. The productivity in each situation of Cases A and B is shown in Table 7-10, and the discussions of the differences between the delay impact in each case are shown as follows.

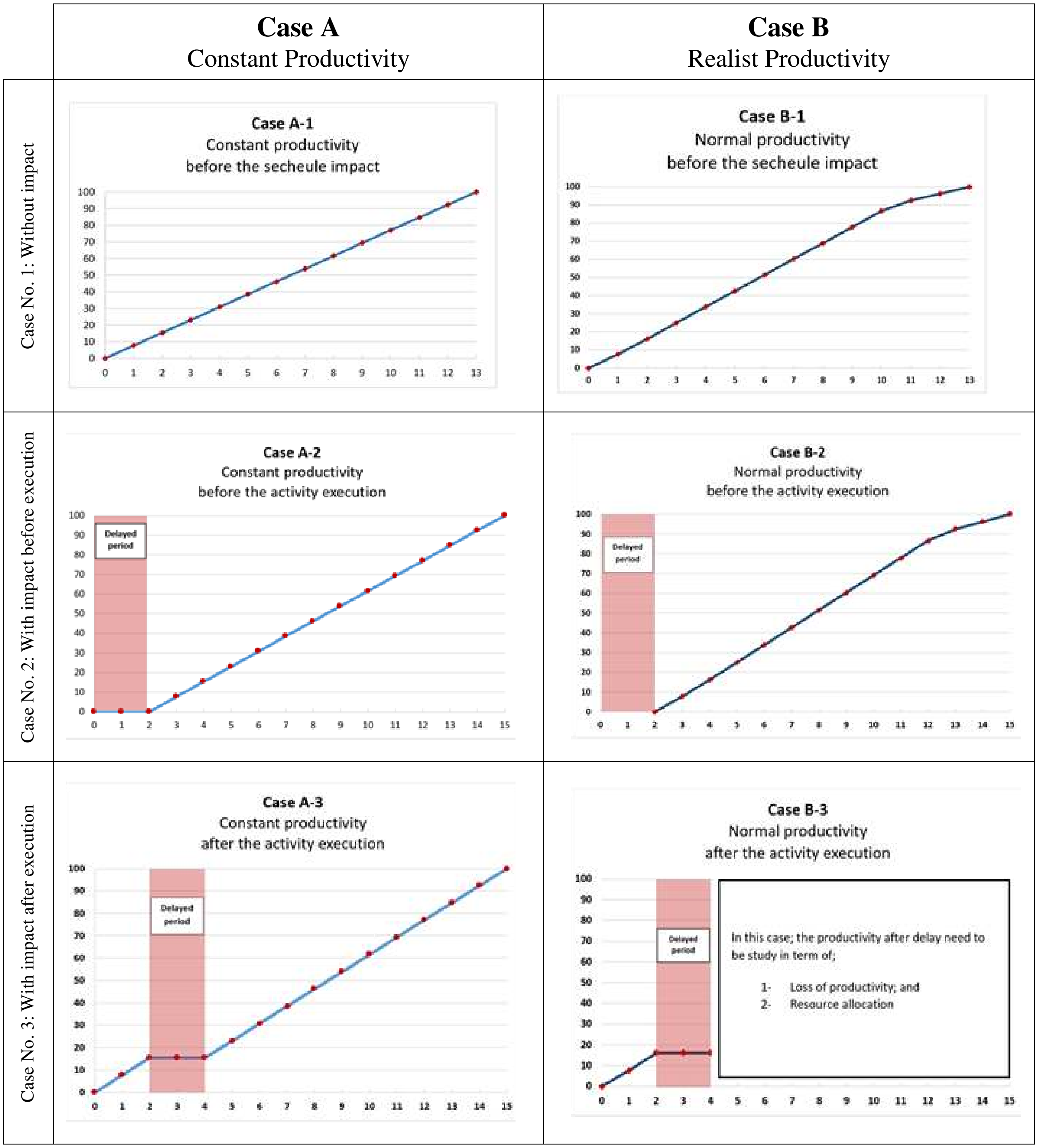


Figure 7-16: A comparison between a constant and realist rate of the productivity

Table 7-10: Production rates as planned for an activity

Activity duration Per Day	Case No. 1				Case No. 2				Case No. 3			
	A Constant Productivity		B Normal Productivity		A Constant Productivity		B Normal Productivity		A Constant Productivity		B Normal Productivity	
	Pro. per day	Cum. Pro.	Pro. per day	Cum. Pro.	Pro. per day	Cum. Pro.	Pro. per day	Cum. Pro.	Pro. per day	Cum. Pro.	Pro. per day	Cum. Pro.
0	0	0	0	0	0	0	0	0	0	0	0	0
1	7.7	7.7	7.7	7.7	delay	0	delay	0	7.7	7.7	7.7	7.7
2	7.7	15.4	8.5	16.2	delay	0	delay	0	7.7	15.4	8.5	16.2
3	7.7	23.1	8.8	25	7.7	7.7	7.7	7.7	delay	15.4	delay	16.2
4	7.7	30.8	8.8	33.8	7.7	15.4	8.5	16.2	delay	15.4	delay	16.2
5	7.7	38.5	8.8	42.6	7.7	23.1	8.8	25	7.7	23.1	In this case, when the impact occurred after the activity execution, the productivity needs to be adjusted	
6	7.7	46.2	8.8	51.4	7.7	30.8	8.8	33.8	7.7	30.8		
7	7.7	53.9	8.8	60.2	7.7	38.5	8.8	42.6	7.7	38.5		
8	7.7	61.6	8.8	69	7.7	46.2	8.8	51.4	7.7	46.2		
9	7.7	69.3	8.8	77.8	7.7	53.9	8.8	60.2	7.7	53.9		
10	7.7	77	8.8	86.6	7.7	61.6	8.8	69	7.7	61.6		
11	7.7	84.7	5.8	92.4	7.7	69.3	8.8	77.8	7.7	69.3		
12	7.7	92.4	3.8	96.2	7.7	77	8.8	86.6	7.7	77		
13	7.7	100	3.8	100	7.7	84.7	5.8	92.4	7.7	84.7		
14					7.7	92.4	3.8	96.2	7.7	92.4		
15					7.7	100	3.8	100	7.7	100		
Productivity	**100**		**100**		**100**		**100**		**100**		**100**	

- **Case A:**

  Case A is a case of constant productivity; the productivity rate remains the same throughout the activity duration. However, constant productivity does not reflect the reality in the construction project implementation. In this case, the productivity will be demonstrated based on three scenarios, as follows:

Case A-1: This case shows that if the delay has occurred before the activity execution, the constant productivity will not be affected.

Case A-2: For constant productivity, a delay before the activity execution does not impact productivity. However, the delay could impact resource allocation. In this case, the extended time for the project extension should be equal to the delay time if the resource allocation has not been impacted.

Case A-3: For constant productivity, a delay following the activity execution will also not affect productivity. However, the delay could impact resource allocation. Since the productivity is constant, the delays during and after activity execution do not lead to any loss of productivity in the project because each day has the same productivity rate. Therefore, the extended time for the project execution should be equal to the delay time if the resource allocation has not been impacted.

- **Case B:**

Case B is a case of standard productivity for implementing the project activities in the construction field. Thus, it involves different productivity rates on each day of the activity duration. Due to the learning curve (an S-curve), the beginning of the production always starts with a lower productivity rate. After that, the production rate increases until it reaches a certain point before it decreases again. Such a distribution of productivity rate reflects the reality of construction execution. In this case, the productivity will be demonstrated based on three scenarios, as follows:

Case B-1: This case shows that if the delay has occurred before the activity execution, the standard productivity will not be affected.

Case B-2: Before the execution of the activity, a delay will not impact the standard productivity. However, the delay could impact resource allocation. In this case, the extended time for the project extension should be equal to the delay time if the resource allocation has not been impacted.

Case B-3: Following the execution of the activity, the standard productivity and resource allocation can both be impacted. The reason for this impact is that each day in the project schedule has a different productivity rate. Therefore, the extended time for the delay will not be equal to the delay effects. In this case, a new productivity plan following the delay impact should be considered. The scenarios for the productivity rate following the impact could be as follows:

1- The productivity continues as planned (optimistic rate for productivity [**a**]).

2- The productivity starts from the beginning due to the effects on the learning curve (pessimistic rate for productivity [**b**]).

3- The productivity and the learning curve are affected by the schedule impact. However, the productivity rate after the impact can be achieved at the same rate as the productivity before the schedule impact (most likely rate for productivity [**m**]).

As mentioned above, there are three possible scenarios for the productivity following the impact on the schedule, which will help to achieve the possible and ideal rates. However, the adjustment for the productivity rate can be computed using a three-point estimation (**E**), which is **[E = (a + b + 4m) / 6]**. This method of analysis for adjusting the productivity rate results because the productivity is usually affected by the delay and disruption; the productivity after any impact needs to be re-planned again to overcome the disturbances. Thus, calculating productivity after the schedule impact is necessary to adjust the rate. In this case, the two days of delay (Days 3 and 4) extended the date of project completion by only two days. The calculation of the adjusted rate of productivity is shown in Table 7-11. Further, the three-point estimation for the project rate, as well as the adjustments is shown in Figure 7-17.

Table 7-11: Computing the productivity rate for case B-3

The analysis of productivity		Activity duration Per Day																**Total**
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
As-Planned	Pro. per day	0	7.7	8.5	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	5.8	3.8	3.8			**13**
	Cum. Pro.	0	7.7	16.2	25	33.8	42.6	51.4	60.2	69	77.8	86.6	92.4	96.2	100			**10**
(a) Optimistic rate for productivity	Pro. per day	0	7.7	8.5	D	D	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	5.8	3.8	3.8	**15**
	Cum. Pro.	0	7.7	16.2	16.2	16.2	25	33.8	42.6	51.4	60.2	69	77.8	86.6	92.4	96.2	100	**10**
(b) Pessimistic rate for productivity	Pro. per day	0	7.7	8.5	D	D	7.7	8.5	8.8	8.8	8.8	8.8	8.8	8.8	8.8	6		**14**
	Cum. Pro.	0	7.7	16.2	16.2	16.2	23.9	32.4	41.2	50	58.8	67.6	76.4	85.2	94	100		**10**
(m) Most likely rate for productivity	Pro. per day	0	7.7	8.5	D	D	8.5	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	4.9		**14**
	Cum. Pro.	0	7.7	16.2	16.2	16.2	24.7	33.5	42.3	51.1	59.9	68.7	77.5	86.3	95.1	100		**10**
(E) adjustment Productivity rate	Pro. per day	0	7.7	8.5	D	D	8.4	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.3	4.9	0.6	**15**
	Cum. Pro.	0	7.7	16.2	16.2	16.2	24.6	33.4	42.2	51.0	59.8	68.6	77.4	86.2	94.5	99.4	100	**10**

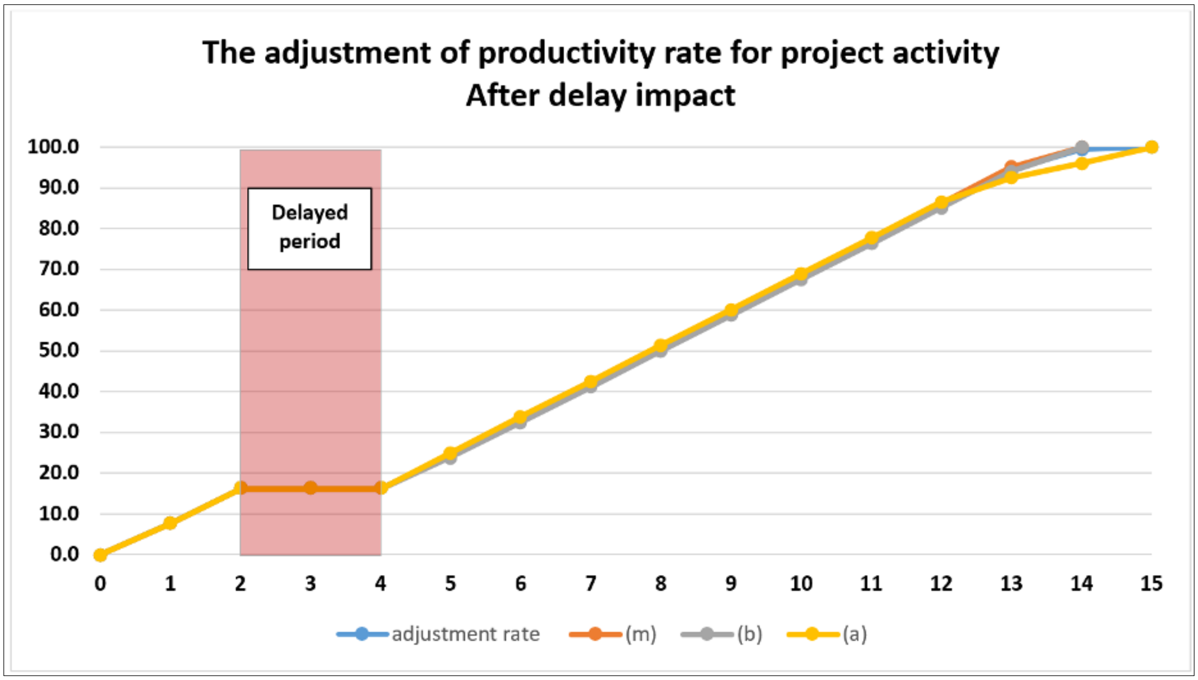


Figure 7-17: The adjustment rate for the average productivity (for case B-3)

As discussed in Case B-3, the productivity following the schedule impact could be adjusted to achieve a more reliable analysis of the delay claims. Moreover, following the adjustment of the productivity rate, the productivity should be analysed to determine the optimal resource allocation. The resource allocation can be expressed via the productivity that was planned to be achieved per day. In each day, the adjustment of productivity should not exceed the as-planned productivity. Therefore, the adjustment rate should be checked once again for resource allocation as shown in Table 7-12.

Table 7-12: The productivity rate with considering resource allocation for case B-3

The analysis of productivity		Activity Duration Per Day																**Total Days**
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
As-planned	Pro. per day	0	7.7	8.5	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	5.8	3.8	3.8			**13**
	Cum. Pro.	0	7.7	16.2	25	33.8	42.6	51.4	60.2	69	77.8	86.6	92.4	96.2	100			**100**
adjustment Productivity rate	Pro. per day	0	7.7	8.5	D	D	8.4	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.3	4.9	0.6	**15**
	Cum. Pro.	0	7.7	16.2	16.2	16.2	24.6	33.4	42.2	51.0	59.8	68.6	77.4	86.2	94.5	99.4	100	**100**
Adjustment for resource allocation	+ or -	0	0	0	-	-	-	0	0	0	0	0	+	+	+	+	+	
		0	0	0	8.8	8.8	0.4	0	0	0	0	0	3	5	4.5	4.9	0.6	

This table shows that the resource allocation has been increased on Day 11 to achieve the productivity rate. On that day, the as-planned productivity with a specific resource is 5.8%. However, productivity has been affected by the impact, resulting in a productivity increase to 8.8%. Thus, an increase in the project resources must offset this increase in productivity. If not, the productivity rate must be decreased to the as-planned rate. Further, the same case can be applied to Days 12 and 13. For the extension days (Days 14 and 15), the productivity rate can be increased to that of the delay days (Days 3 and 4). Table 7-13 expresses this adjustment to the productivity rate, which considered the impacts of resource allocation. The three-point estimation for the project rate along with the adjustments is shown in Figure 7-18.

Table 7-13: Adjustment of productivity rate for resource allocation for case B-3

The analysis of productivity		Activity duration Per Day																	Total Days
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
As-planned	Pro. per day	0	7.7	8.5	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	5.8	3.8	3.8				**13**
	Cum. Pro.	0	7.7	16.2	25	33.8	42.6	51.4	60.2	69	77.8	86.6	92.4	96.2	100				**10**
adjustment Productivity rate	Pro. per day	0	7.7	8.5	D	D	8.4	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.3	4.9	0.6		**15**
	Cum. Pro.	0	7.7	16.2	16.2	16.2	24.6	33.4	42.2	51.0	59.8	68.6	77.4	86.2	94.5	99.4	100		**10**
Adjustment for resource allocation	**+ or -**	0	0	0	-	-	-	0	0	0	0	0	+	+	+	+	+		
		0	0	0	8.8	8.8	0.4	0	0	0	0	0	3	5	4.5	4.9	0.6		
Final rate of Productivity		0	7.7	8.5	0	0	8.4	8.8	8.8	8.8	8.8	8.8	5.8	3.8	3.8	8.8	8.8	0.4	**16**
		0	7.7	16.2	16.2	16.2	24.6	33.4	42.2	51	59.8	68.6	74.4	78.2	82	90.8	99.6	100	**100**

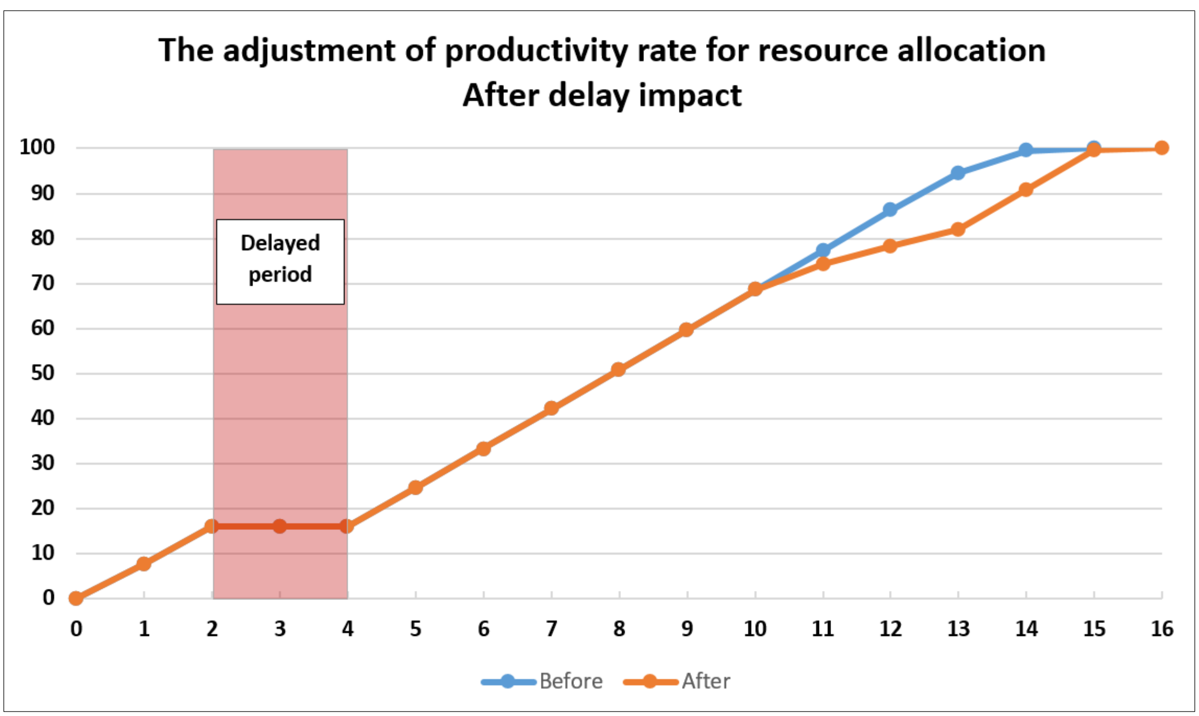


Figure 7-18: The adjustment of productivity rate for resource allocation for case B-3

In Case B-3, the productivity rate is adjusted twice. The first adjustment is due to the impacts of the delays on Days 3 and 4. This adjustment results in a time extension of two days, which is the amount of time that is needed to accomplish 100% of the activity works. In Case B-3, the adjusted productivity following the schedule impact can be achieved by the same activity duration plus the delay event time; however, this is not always the case.

The time extension exceeds the delay time. Thus, the second adjustment is due to the resources allocated for each day to achieve the as-planned productivity. Following the impact event, the resource allocation may not be enough to accomplish the adjusted rate of production. Therefore, the adjusted productivity may require more resources, resulting in additional cost. For overcoming this issue, there is a need for a second adjustment to determine a new productivity rate, which will be equal to or lower than the as-planned productivity rate.

Moreover, the schedule impact time for the productivity rate should not be neglected. For example, the impact on the productivity of 10 days of delay is more significant than that of 2 days of delay in the learning curve. This impact factor should be considered during the analysis. Furthermore, the productivity for the overall project following the adjustment of the activity production rate should be analysed to overcome all the difficulties and shortages in analysing the delay claims.

There are two cases for claiming loss of productivity, whether through a disruption claim or a delay claim. The analysis processes for claiming the loss of productivity through both claims are discussed, as follows:

I. Analysing the loss of productivity through a disruption claim

Based on the proposed framework, claiming the loss of productivity through a disruption claim is suitable only if the contractor has incurred an additional cost by increasing the resources or the crew size. In Case B-3, the activity has experienced two days of delay, which extends the activity duration from Day 13 up to Day 15. If the contractor has increased the resources or the crew size to accomplish 100% by Day 15, the loss of money due to the additional resource or crew size will be recovered through a disruption claim. In this case, the contractor must demonstrate the case of increasing the resources or crew size and show evidence for proving the claim. However, if the contractor claims the additional cost for extending the duration up to Day 16, the recovery of such losses should be demanded through a delay claim.

II. Analysing the loss of productivity through a delay claim

The proposed framework also considers the case of affecting productivity as a result of a delay or disruption and requesting time more than the as-planned time plus delays period. Figure 7-17 for Case B-3 shows that productivity cannot be accomplished 100% on Day 15. In this case, the contractor has the right to claim any losses or damages on Day 16 or any further impact due to the loss of time based on the delays that have occurred on Days 3, 4 and 16.

For further explanation, if the delays on Days 3 and 4 have occurred solely due to an owner-caused delay and the contractor has experienced a loss of productivity due to these delays, the contractor cannot accomplish 100% of the productivity on Day 15 without increasing the resources or the crew size. If the productivity has been designed based on the maximum ratio, it requires an additional day (Day 16) to accomplish 100% completion. In this case, the owner will be responsible for the delay on Day 16 and any further impacts due to time lost on this day. If the contractor does not need any additional time to accomplish 100% of the productivity (100% completion has been reached on Day 15) without any additional resource or increase the crew size, the contractor probably has designed the productivity rate based on the average rate (not the maximum rate of productivity) to minimise any risk. In this case, the contractor has not lost any time in extending the duration and has not lost any money in increasing the resources or crew size. Such a case is usually denied in construction claims for the lack of clarity for the damage.

7.4 The Proposed Technique for Analysing Delay Claims

This method was based on the framework presented in Section 7.2, which was devised for calculating the responsibility for delay damages and is based on tracking the responsibility for any potential losses at the project and activity levels. This requires employing a procedure to determine who is responsible for any damage at both levels as well as considering the most DAIs.

The proposed technique that can be used for the schedule delay analysis involves a systematic approach for analysing any possible damages and losses that can result from the events of the schedule impact with the analyses of the responsibility of the damages. The idea of this proposed method is to bring together benefits for the following: 1) analysing the responsibility for the schedule impacts; 2) determining the liability for extending the overall project time while adequately considering the most DAIs; 3) resolving the responsibility for any possible damages and losses at the project and activity levels.

In including the above benefits in delay analysis, the approach would require a large number of processes along with daily analysis to undertake a thorough evaluation of the responsibility of any time impact in the schedule. The daily analyses are then performed for each day and each impacted event that happened on each day separately. The purpose is to track the following:

1. The activity's duration for defining the responsibility of any possible time impact that is related to the damages at the activity level;
2. The activity's early start for defining the responsibility of any possible time impact that is related to the damages at the activity level;
3. The project completion date for defining the responsibility of any possible time impact that is related to the damages at the project level.

This starts with determining (from the as-planned schedule) the ES of each activity, the EF of each activity and the PCD. For the first day in the schedule, the schedule will be impacted for one event in each time to determine the effect in each activity: updated ES, updated EF and updated PCD. For each event, the impact on the activity's D, ES, EF and PCD can be determined as follows.

- ES updated = ES after the impact – ES before the impact ……………………… (1)
- EF updated = EF after the impact – EF before the impact ……………………… (2)
- D updated = EF updated – ES updated ………………………………………… (3)
- PCD updated = PCD after the impact – PCD before the impact ………………… (4)

In order to ensure clarity on the use of the proposed technique, the fifteen orderly processes that need to be carried out are presented as shown in Figure 7-19 and 7-20, as follows.

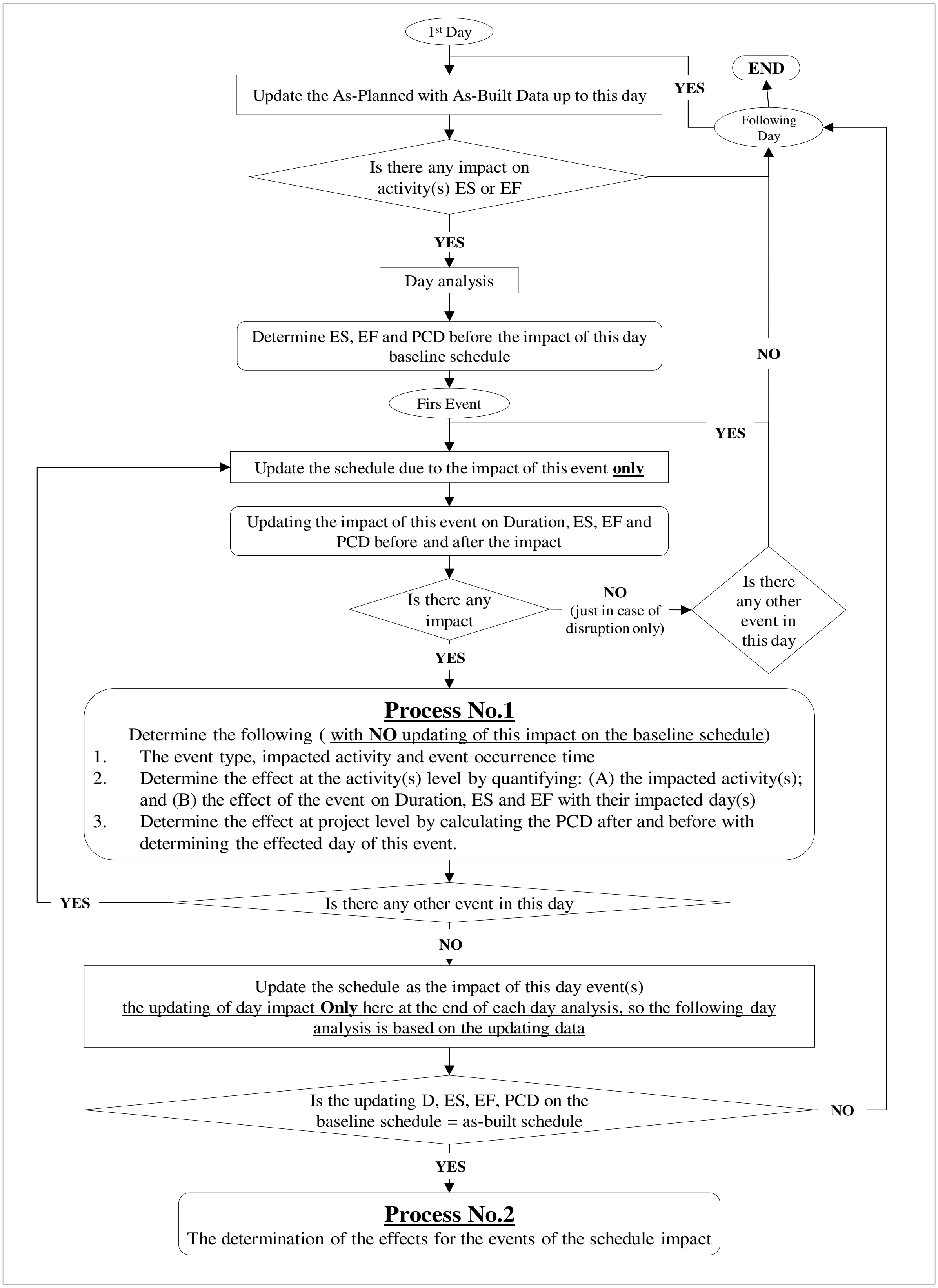


Figure 7-19: The flowchart of the proposed technique, Part 1

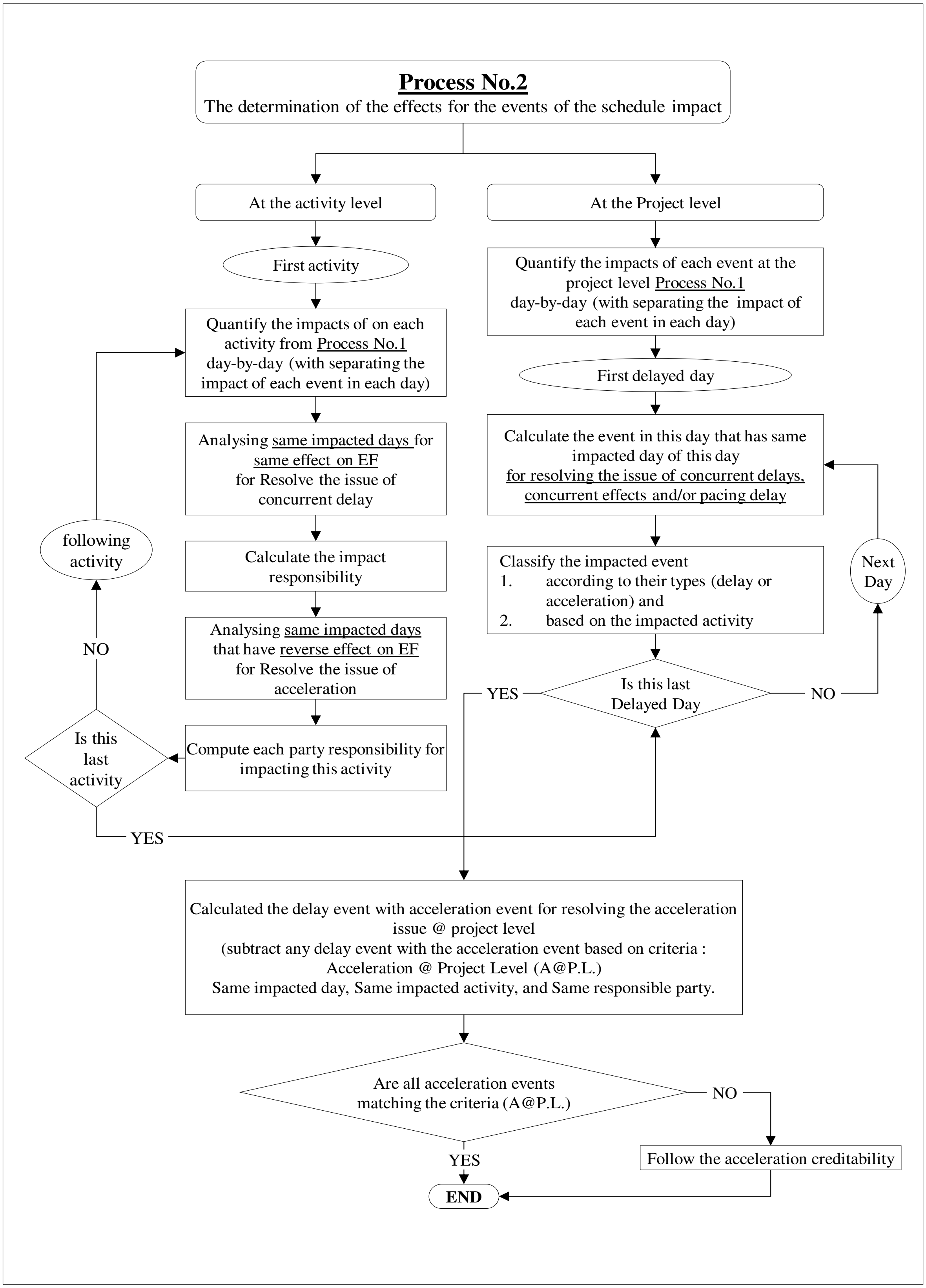


Figure 7-20: The flowchart of the proposed technique, part 2

Step 1: From the as-planned schedule for each activity on the schedule, determine ES before the impact, EF before the impact, PCD before the impact.

Step 2: Impact the as-planned schedule with as-built schedule data up to the first day, which the as-planned schedule become the updated as-planned schedule, to determine any change on the EF after the impact.

Step 3: Verify the impact in this day for each activity according to Equation (5):

$$\text{If (EF updated} = 0\text{) go to Step 4, Otherwise Step 5} \tag{5}$$

Step 4: Impact the updated as-planned schedule with the following day of the as-built schedule for determining EF after the impact and go to Step 3, otherwise go to Step 14.

Step 5: Impact the as-planned schedule with the first event in this day for determining the impacted activity(ies) according to Equation (6):

$$\text{If (EF} \neq 0\text{) go to Step 6, Otherwise Step 12} \tag{6}$$

Step 6: Determine D update, ES update and PCD update.

Step 7: Classify the impacted event according to Equation (7):

$$\text{If (D update} < 0\text{), (ES update} < 0\text{) and (PCD update} < 0\text{) go to Step 8, Otherwise Step 9} \tag{7}$$

Step 8: Allocate the acceleration responsibility for each impacted activity(ies), and then go to Step 10.

Step 9: Allocate the delay responsibility for the impacted activity, and then go to Step 10

Step 10: Determine the effect at the activity-level and project-level, along with determining the Impacted Day (ID).

Step 11: Remove the previous event and insert the following event and then go Step 6, otherwise go to Step 13

Step 12: Analyse the effect of the following event according to Equation (6) and go to step 6.

Step 13: Update the schedule with the effects of the events in this day and return to Step 4.

Step 14: Determine the responsibility for impacting the activities' D, activities' ES, and PCD.

Step 15: Quantify the damages responsibility at activity-level and the damages responsibility project-level.

7.5 Summary

This chapter proposed a technique for analysing delay claims. Based on the data analysis, the impacts of the schedule events could lead to a direct loss of time or money. Thus, the proposed technique was devised for analysing the schedule impacts and calculating the responsibility for any potential damages by tracking any loss of time at the project and activity levels. Further, it considers the DAIs that have been addressed in this study for more accurate results in the delay claims analysis. Therefore, the following chapter intends to show a detailed analysis of the proposed technique by analysing the same hypothetical example that was presented in Chapter 4. The purpose of using the same example is for validation purposes, which will be presented in Chapter 9.

CHAPTER EIGHT: DETAILED ANALYSIS PROCESSES OF THE PROPOSED TECHNIQUE

8.1 Introduction

After presenting the proposed technique in Chapter 7, this chapter attempts to explain the processes of the proposed technique for analysing the schedule impacts in construction projects claims. As discussed in Chapter 4, many DATs have been used to demonstrate the schedule impacts and prove the delay claims in construction projects. However, these techniques suffer from a lack of producing reliable results of the delay analysis. For this reason, the proposed technique will analyse the same hypothetical example that was analysed by the DATs in Chapter 4 because the comparison between the DATs and the proposed technique should be applied to the same set of data and inputs. Also, the results in this chapter with the results in Chapters 4 will be used in the following chapter for validating the proposed technique. Therefore, the analysis in this chapter relies on the proposed technique's accuracy in producing accurate results and its capability in considering the DAIs.

8.2 The Case Study Analysis by The Proposed Technique

To evaluate the proposed technique more thoroughly, the same hypothetical example that was used in Chapter 4 is applied, as shown in Figure 8-1. This figure shows the project's as-planned and as-built schedules, along with the activity, duration and independent relationships. The as-planned schedule is indicating a total project duration of nine days. The project started as scheduled, but the progress was affected by different types of schedule impact events forcing the overall project duration to be extended up to 17 days. Therefore, the following section aims to demonstrate the procedures and the processes for analysing the hypothesis example by the proposed technique. At the end of this section, the results of this analysis can be drawn to show the strengths of the proposed technique in presenting robust analyses results. Thus, the detailed analysis of the proposed technique will be as follows.

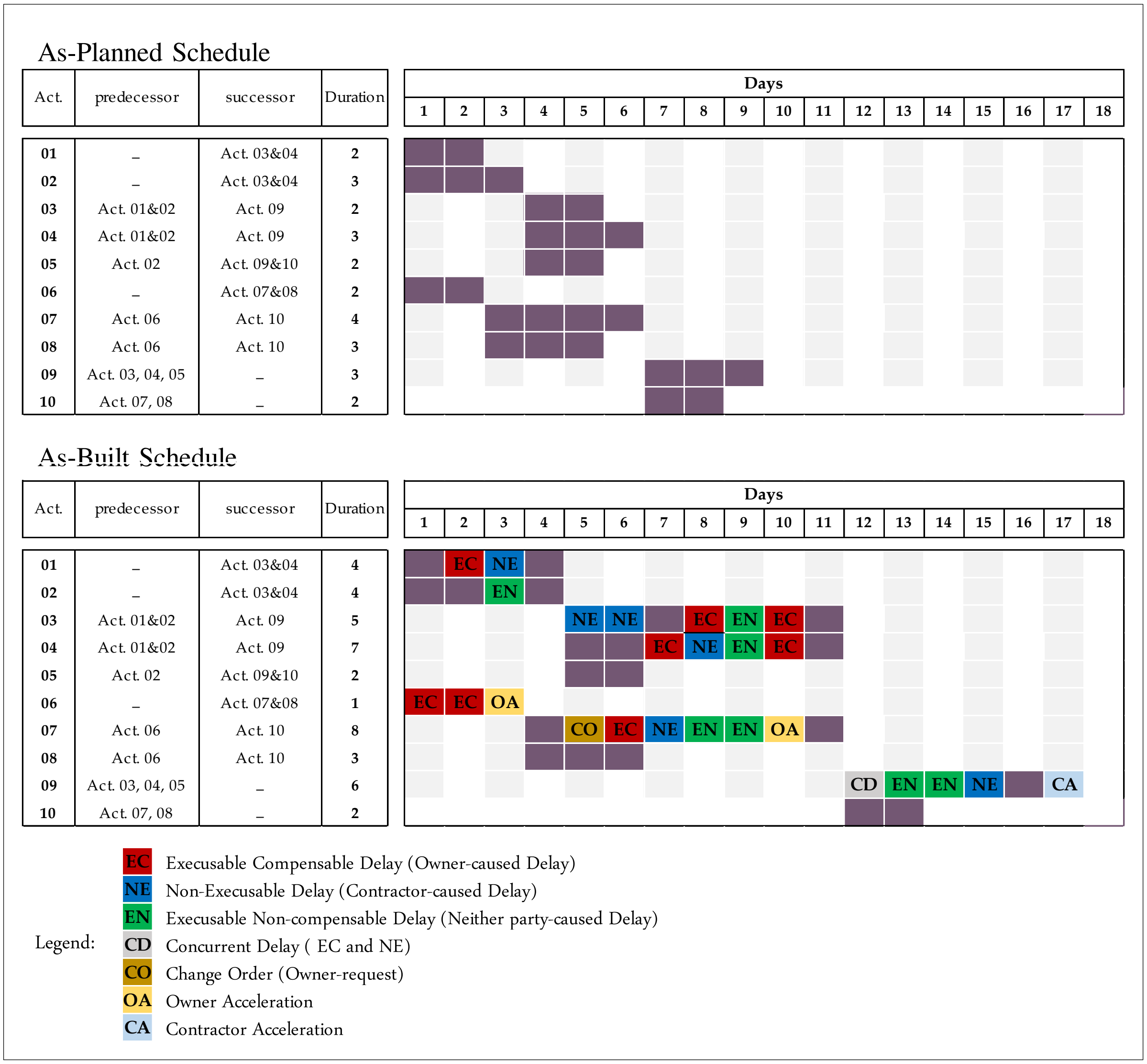


Figure 8-1: Case study schedules, as-planned schedule and as-built schedule

As long as the contracting parties have agreed on the time impact analysis as a first analysis for the responsibility of any time lost on the schedule, the analysis for any potential damage on the project cost can start from analysing the responsibility for any schedule impact. The results of this analysis will define the responsibility for any potential losses at the project-level (from Day 10–17) and any potential losses at the activity-level. The procedures of the proposed technique, which have been presented in Chapter 7, are shown as follows:

1. From the as-planned schedule, as shown in Figure 8-2, the ES, EF and PCD before the impact are analysed as shown in Table 8-1.

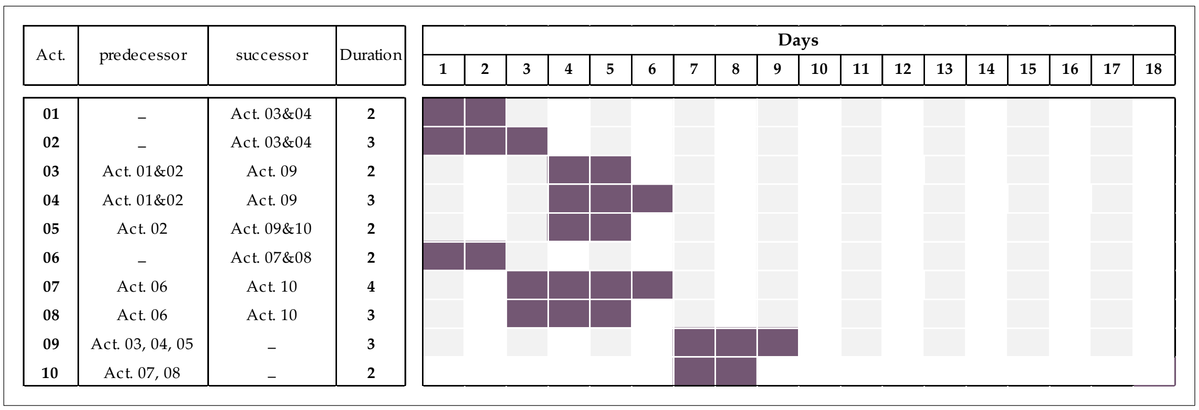


Figure 8-2: As-planned schedule for the project's activities

Table 8-1: As-planned project's activities

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
Before any schedule impact	Day 0	01	0	2					
		02	0	3					
		03	3	5					
		04	3	6					
		05	3	5					
		06	0	2					
		07	2	6					
		08	2	5					
		09	6	9					
		10	6	8					
PCD				9					

The analysis will start by updating the schedule day-by-day into the as-planned schedule. In each day, the schedule will be then impacting by each event separately to define each event on the schedule and measure its effect at the activity-level and the project level. The effect on Duration (D), Early Start (ES), and Project Completion Date (PCD) will define the impact of each event. The analysis of this case study will be shown step-by-step as follows.

- **1st Day analysis:**

In the first day of the schedule, the project has been impacted by EC delay at activity 06, as shown in Figure 8-3. The effects on the ES, EF and PCD are as shown in Table 8-2.

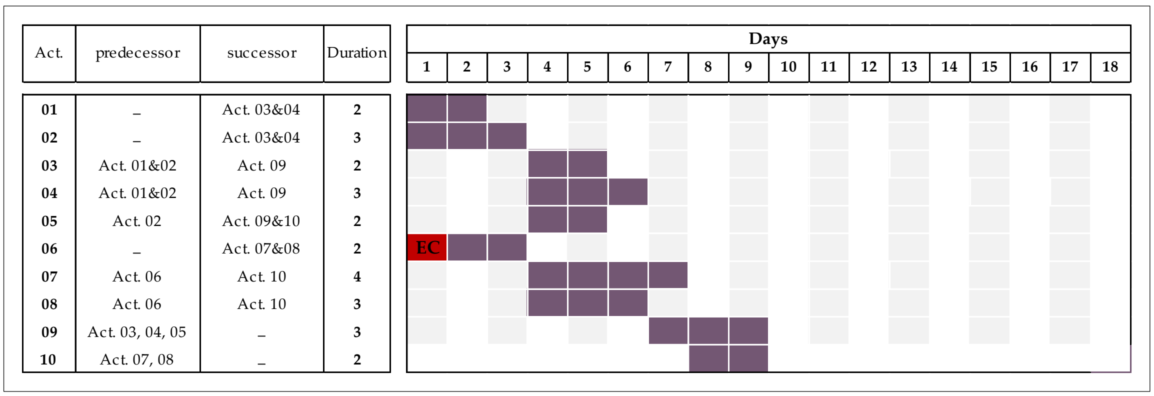


Figure 8-3: 1st Day analysis

Table 8-2: The effect of the 1st- day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.06	1	01	0	2	0	2	0	0	0
		02	0	3	0	3	0	0	0
		03	3	5	3	5	0	0	0
		04	3	6	3	6	0	0	0
		05	3	5	3	5	0	0	0
		06	**0**	**2**	**1**	**3**	**0**	**1**	**1**
		07	**2**	**6**	**3**	**7**	**0**	**1**	**1**
		08	**2**	**5**	**3**	**6**	**0**	**1**	**1**
		09	6	9	6	9	0	0	0
		10	**6**	**8**	**7**	**9**	**0**	**1**	**1**
PCD				**9**		**9**	**0**		

According to Step 7 of the method's procedure, this event is a delay event belongs to the owner responsibility. From Table 8-2, the analysis for effect due to this event at activity-level and project-level are as shown in Table 8-3. The impact due to EC delay at Act.06 on day 1 will be discussed as follows:

Table 8-3: The analysis of the 1st day

The impact			**At Activity-Level**							**At Project-Level**	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EC	06	1	06	0	/	1	1	1	3		
			07	0	/	1	3	1	7		
			08	0	/	1	3	1	6		
			10	0	/	1	7	1	9	0	9

As shown in Table 8-3, EC at Act.06 in Day 1 will not impact the original PCD because the affected day at the project level is day 9, which is part of the original time for the as-planned schedule. However, this event has impacted four activities, which may result in a damage at the activity-level, as shown in Table 8-3, as follow:

1. It has an impact on Act. 06, which may result in two possible damages: a) one day of the possible losses on the cost that is related to the ES in Day 1; and b) one day of possible losses on the cost that is related to the EF in Day 3.

2. It has an impact on Act. 07, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 3; and b) one day of possible losses on the cost that is related to the EF in Day 7.

3. It has an impact on Act. 08, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 3; and b) one day of possible losses on the cost that is related to the EF in Day 6.

4. It has an impact on Act. 10, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 7; and b) one day of possible losses on the cost that is related to the EF in Day 9.

- **2nd Day analysis:**

In the second day of the schedule, the project has been impacted in Day 2 by EC delay (at activity 01) and EC delay (at activity 06), as shown in Figure 8-4. The impacts of the event on the ES, EF and PCD are as shown in Table 8-4.

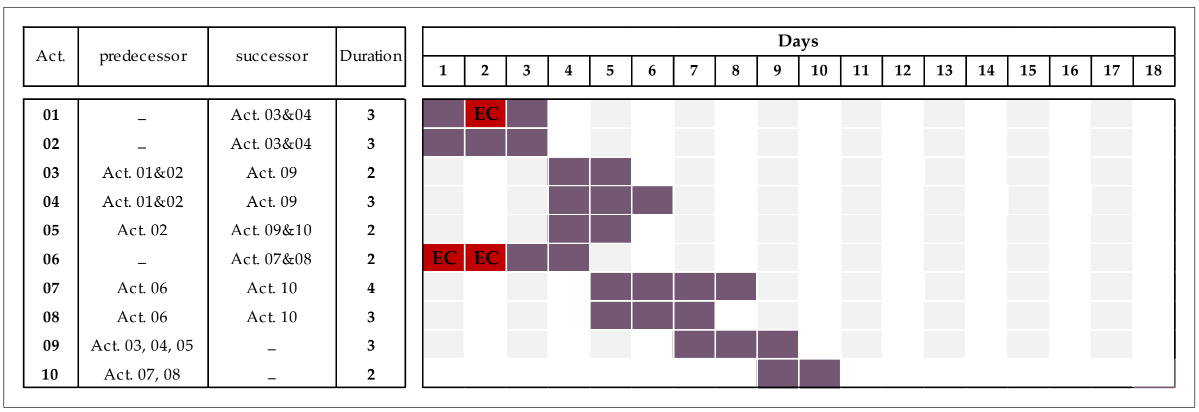


Figure 8-4: 2nd Day analysis

Table 8-4: The effect of the 2nd-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.01 EC at Act.06	2	01	0	2	0	3	1	0	1
		02	0	3	0	3	0	0	0
		03	3	5	3	5	0	0	0
		04	3	6	3	6	0	0	0
		05	3	5	3	5	0	0	0
		06	**1**	**3**	**2**	**4**	**0**	**1**	**1**
		07	**3**	**7**	**4**	**8**	**0**	**1**	**1**
		08	**3**	**6**	**4**	**7**	**0**	**1**	**1**
		09	6	9	6	9	0	0	0
		10	**7**	**9**	**8**	**10**	**0**	**1**	**1**
PCD				**9**		**10**	**1**		

As shown in Table 8-4, EF of five activities in the schedule has been impacted due to the events on day 2, which are: Act.01, Act.06, Act.07, Act.08 and Act.10. For measuring the effects of each event on the project, the updated as-planned schedule has been impacted two times: the first impact will be for EC at Act.01 and the second impact will be for EC Act Act.06.

1. The first event in Day 2 (EC at Act.01)

As shown in Table 8-5, EC at Act.01 does not impact the original PCD because the impacted day at project-level is day 2, which is part of the original time for the as-planned schedule. However, the impact of this event has affected only Act.01, which may result in damage at the activity-level. As shown in Table 8-3, the possible losses and damages are: a) one day of possible losses on the cost that is related to the duration in Day 2; and b) one day of possible losses on the cost that is related to the EF in Day 3.

Table 8-5: The effect of the first event on the 2nd day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.01	2	**01**	**0**	**2**	**0**	**3**	**1**	**0**	**1**
		02	0	3	0	3	0	0	0
		03	3	5	3	5	0	0	0
		04	3	6	3	6	0	0	0
		05	3	5	3	5	0	0	0
		06	0	3	0	3	0	0	0
		07	3	7	3	7	0	0	0
		08	3	6	3	6	0	0	0
		09	6	9	6	9	0	0	0
		10	7	9	7	9	0	0	0
PCD				9		9	0		

Table 8-6: The impact of EC at Act.01 on day 2

The impact			**At Activity-Level**							**At Project-Level**	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EC	01	2	01	1	2	0	/	1	3	0	3

2. The second event in Day 2 (EC at Act.06)

As shown in Table 8-7, EC at Act.06 in Day 2 will impact the PCD as well as some EF of the project activities. Table 8-8 shows the impacts of this event at project-level as well as the impact at the activity-level, as follow:

Table 8-7: The effect of the second event on the 2nd day

Event(s)	**Day**	**Activity**	**Before Impact**		**After Impact**		**Update**		
			ES	**EF**	**ES**	**EF**	**duration**	**ES**	**EF**
EC at Act.06	2	01	0	2	0	2	0	0	0
		02	0	3	0	3	0	0	0
		03	3	5	3	5	0	0	0
		04	3	6	3	6	0	0	0
		05	3	5	3	5	0	0	0
		06	**1**	**3**	**2**	**4**	**0**	**1**	**1**
		07	**3**	**7**	**4**	**8**	**0**	**1**	**1**
		08	**3**	**6**	**4**	**7**	**0**	**1**	**1**
		09	6	9	6	9	0	0	0
		10	**7**	**9**	**8**	**10**	**0**	**1**	**1**
PCD				**9**		**10**	**1**		

Table 8-8: The impact of the 2nd-day analysis

The impact			**At Activity-Level**							**At Project-Level**	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EC	06	2	06	0	/	1	2	1	4		
			07	0	/	1	4	1	8		
			08	0	/	1	4	1	7		
			10	0	/	1	8	1	10	1	10

The affected day by this event at project-level is day 10. This impact could result in damage at project-level due to extending the PCD one extra day beyond the original PCD. Also, this event has an impact at the activity-level, as follow:

1. It has an impact on Act. 06, which may result in two possible damages, as follow: a) one day of possible losses on the cost that is related to the ES in Day 2; and b) one day of possible losses on the cost that is related to the EF in Day 4.
2. It has an impact on Act. 07, which may result in two possible damages, as follow: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 8.
3. It has an impact on Act. 08, which may result in two possible damages, as follow: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 7.
4. It has an impact on Act. 10, which may result in two possible damages, as follow: a) one day of possible losses on the cost that is related to the ES in Day 8; and b) one day of possible losses on the cost that is related to the EF in Day 10.

- **3rd Day analysis:**

In the third day of the schedule, the project has been impacted in Day 3 by NE delay (at Act. 01), EN delay (at Act. 02), and OA (at Act. 06), as shown in Figure 8-4. The updating on the ES, EF and PCD due to these events are shown in Table 8-4.

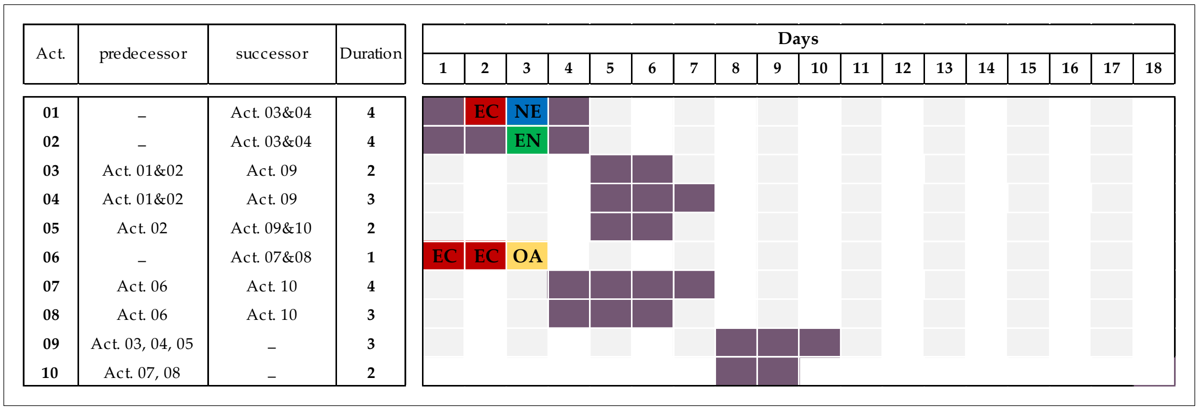


Figure 8-5: 3rd Day analysis

Table 8-9: The effect of the 3rd-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.01 EN at Act.02 OA at Act.06	3	**01**	**0**	**3**	**0**	**4**	**1**	**0**	**1**
		02	**0**	**3**	**0**	**4**	**1**	**0**	**1**
		03	**3**	**5**	**4**	**6**	**0**	**1**	**1**
		04	**3**	**6**	**4**	**7**	**0**	**1**	**1**
		05	**3**	**5**	**4**	**6**	**0**	**1**	**1**
		06	**2**	**4**	**2**	**3**	**-1**	**0**	**-1**
		07	**4**	**8**	**3**	**7**	**0**	**-1**	**-1**
		08	**4**	**7**	**3**	**6**	**0**	**-1**	**-1**
		09	**6**	**9**	**7**	**10**	**0**	**1**	**1**
		10	**8**	**10**	**7**	**9**	**0**	**-1**	**-1**
PCD				10		10	0		

As shown in Figure 8-5, three events have occurred on the schedule in Day 3, which are: NE at Act.01, EN at Act.02 and OA at Act.06. Table 8-9 shows the effects of these events on the project's activities. For measuring their effect on the project-level and activity-level, the updated as-planned schedule up to day 2 will be impacted separately three times: the first impact will be for NE at Act.01, the second impact will be for EN at Act.02, and the third impact will be for OA Act Act.06.

1. The first event in Day 3 (NE at Act.01)

As shown in Table 8-10, NE at Act.01 will impact the Acts 01, 03, 04 and 09. Table 8-11 also shows the effects of this event on the schedule.

Table 8-10: The first impact on the 3rd day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.01	3	01	0	3	0	4	1	0	1
		02	0	3	0	3	0	0	0
		03	3	5	4	6	0	1	1
		04	3	6	4	7	0	1	1
		05	3	5	3	5	0	0	0
		06	2	4	2	4	0	0	0
		07	4	8	4	8	0	0	0
		08	4	7	4	7	0	0	0
		09	6	9	7	10	0	1	1
		10	8	10	8	10	0	0	0
PCD				**10**		**10**	**0**		

Table 8-11: The effect of the first event on the 3rd day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
NE	01	3	01	1	3	0	/	1	4		
			03	0	/	1	4	1	6		
			04	0	/	1	4	1	7		
			09	0	/	1	7	1	10	1	10

As shown in Table 8-11, the impacted day of this event at project-level is day 10. Also, this event will impact the project at the activity-level, as follow:

1. It has an impact on Act. 01, which may result in two possible damages, as follow: a) one day of possible losses on the cost that is related to the duration in Day 3; and b) one day of possible losses on the cost that is related to the EF in Day 4.

2. It has an impact on Act. 03, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 6.

3. It has an impact on Act. 04, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 7.

4. It has an impact on Act. 09, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 7; and b) one day of possible losses on the cost that is related to the EF in Day 10.

2. The second event in Day 3 (EN at Act.02)

As shown in Table 8-12, EN at Act.02 has impacted the activities 02, 03, 04, 05 and 09. Table 8-13 shows the effect of this event at the activity-level and the project-level.

Table 8-12: The second impact on the 3rd day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EN at Act.02	3	01	0	3	0	3	0	0	0
		02	0	3	0	4	1	0	1
		03	3	5	4	6	0	1	1
		04	3	6	4	7	0	1	1
		05	3	5	4	6	0	1	1
		06	2	4	2	4	0	0	0
		07	4	8	4	8	0	0	0
		08	4	7	4	7	0	0	0
		09	6	9	7	10	0	1	1
		10	8	10	8	10	0	0	0
PCD				**10**		**10**	**0**		

Table 8-13: The impact of the second event on the 3rd day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
NE	02	3	02	1	3	0	/	1	4		
			03	0	/	1	4	1	6		
			04	0	/	1	4	1	7		
			05	0	/	1	4	1	6		
			09	0	/	1	7	1	10	1	10

Table 8-13 shows the impacted day of this event at the project-level, which day 10. Also, it shows the effects of this event at the activity-level, as follow:

1. It has an impact on Act. 02, which may result in two possible damages: a) one day of possible losses on the cost that is related to the duration in Day 3; and b) one day of possible losses on the cost that is related to the EF in Day 4.

2. It has an impact on Act. 03, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 6.

3. It has an impact on Act. 04, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 7.

4. It has an impact on Act. 05, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 6.

5. It has an impact on Act. 09, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 7; and b) one day of possible losses on the cost that is related to the EF in Day 10.

3. The third event in Day 3 (OA at Act.06)

Table 8-14 shows the impact of this acceleration event on the project schedule. The OA has impacted four activities on the schedule, which are: Act.06, Act.07, Act.08 and Act.10. Table 8-15 also shows the effect of this acceleration at the project-level and the activity-level.

Table 8-14: The third impact in the 3rd day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
OA at Act.06	3	01	0	3	0	3	0	0	0
		02	0	3	0	3	0	0	0
		03	3	5	3	5	0	0	0
		04	3	6	3	6	0	0	0
		05	3	5	3	5	0	0	0
		06	2	4	2	3	-1	0	-1
		07	4	8	3	7	0	-1	-1
		08	4	7	3	6	0	-1	-1
		09	6	9	6	9	0	0	0
		10	8	10	7	9	0	-1	-1
PCD				**10**		**9**	**-1**		

Table 8-15: The impact of the third event on the 3rd day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
OA	06	3	06	-1	3	0	/	-1	4		
			07	0	/	-1	4	-1	8		
			08	0	/	-1	4	-1	7		
			10	0	/	-1	8	-1	10	-1	10

The OA at Act.06 in Day 3 has impacted the project schedule. At project-level, the impacted day was on day 10, which affects the updated PCD. Also, the effects of this event at the activity-level are shown in Table 8-15, as follow:

1. It has an impact on Act. 02, which may result in two possible damages: a) one day of possible losses on the cost that is related to the duration in Day 3; and b) one day of possible losses on the cost that is related to the EF in Day 4.

2. It has an impact on Act. 03, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 6.

3. It has an impact on Act. 04, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 7.

4. It has an impact on Act. 05, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 6.

- **4th Day analysis:**

In Day 4, the schedule has not been impacted by any event. Therefore, the activities' Duration (D), the Early Start (ES), and the Early Finish (EF) are remaining without any change.

- **5th Day analysis:**

Act.	predecessor	successor	Duration
01	–	Act. 03&04	4
02	–	Act. 03&04	4
03	Act. 01&02	Act. 09	2
04	Act. 01&02	Act. 09	3
05	Act. 02	Act. 09&10	2
06	–	Act. 07&08	1
07	Act. 06	Act. 10	5
08	Act. 06	Act. 10	3
09	Act. 03, 04, 05	–	3
10	Act. 07, 08	–	2

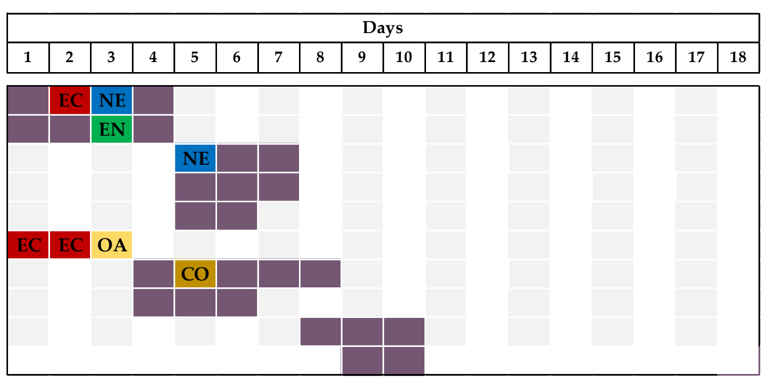


Figure 8-6: 5th Day analysis

As shown in Figure 8-6, there are two events have occurred on the schedule in Day 5, which are: 1) NE at Act.03; and 2) CO at Act.07. The impacts of these events on the schedule are shown in Table 8-16. For measuring the effect of each event, the schedule in Day 5 will be impacted separately by each event, as follow:

Table 8-16: The impact of the 5th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.03 CO at Act.07	5	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	4	6	5	7	0	1	1
		04	4	7	4	7	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	7	3	8	1	0	1
		08	3	6	3	6	0	0	0
		09	7	10	7	10	0	0	0
		10	7	9	8	10	0	1	1
PCD				**10**		**10**	**0**		

1. The first event in Day 3 (NE at Act.03)

As shown in Table 8-17, NE at Act.03 has impacted the activity 03 only in the TF on day 7 at activity 03. Therefore, the impacted day at project-level is day 7. However, this event has impacted the Act. 03. In this case, there would be a possible damage at the activity-level. As shown in Table 8-18, this event has impacted the Act. 03, which may result in two possible damages, which are: a) one day of possible losses on the cost that is related to the ES in Day 4; and b) one day of possible losses on the cost that is related to the EF in Day 7.

Table 8-17: The first impact on the 5th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.03	5	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	4	6	5	7	0	1	1
		04	4	7	4	7	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	7	3	7	0	0	0
		08	3	6	3	6	0	0	0
		09	7	10	7	10	0	0	0
		10	7	9	7	9	0	0	0
PCD				**10**		**10**	**0**		

Table 8-18: The impact of the first event on the 5th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
NE	03	5	03	0	/	1	4	1	7	0	/

2. The second event in Day 3 (CO at Act.07)

Table 8-19 shows the affected of CO at Act.07 on the activities 07 and 10. Table 8-20 shows the impacted day of this event at the project-level as well as the effects at the activity-level.

Table 8-19: The second impact on the 5th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
CO at Act.07	5	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	4	6	4	6	0	0	0
		04	4	7	4	7	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	7	3	8	1	0	1
		08	3	6	3	6	0	0	0
		09	7	10	7	10	0	0	0
		10	7	9	8	10	0	1	1
PCD				**10**		**10**	**0**		

Table 8-20: The impact of the second event on the 5th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
OA	07	5	07	1	5	0	/	1	8		
			10	0	/	1	7	1	10	1	10

As shown in Table 8-20, this event has impacted the schedule at the project-level on day 10. Also, it has impacted the project at the activity-level as follow:

1. It has an impact on Act. 07, which may result in two possible damages: a) one day of possible losses on the cost that is related to the duration in Day 5; and b) one day of possible losses on the cost that is related to the EF in Day 8.
2. It has an impact on Act. 10, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 7; and b) one day of possible losses on the cost that is related to the EF in Day 10.

- **6th Day analysis:**

In Day 6, the schedule has been impacted by two events as shown in Figure 8-7, which are: NE at Act.03 and EC at Act.07. The effects of these events would be as shown in Table 8-21.

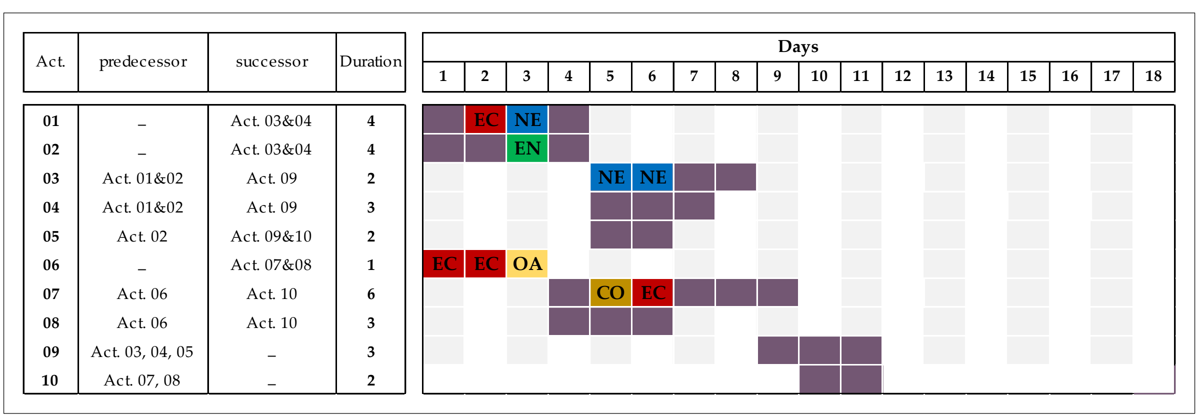


Figure 8-7: 6th Day analysis

Table 8-21: The impact of the 6th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.03 EC at Act.07	6	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	5	7	6	8	0	1	1
		04	4	7	4	7	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	8	3	9	1	0	1
		08	3	6	3	6	0	0	0
		09	7	10	8	11	0	1	1
		10	8	10	9	11	0	1	1
PCD				**10**		**11**	**1**		

1. The first event in Day 3 (NE at Act.03)

As shown in Table 8-22, NE at Act.03 in Day 6 has impacted the activity 03 and 10. The impacts at activity-level and the project-level are as shown in Table 8-23.

Table 8-22: The first impact on the 6th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.03	6	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	5	7	6	8	0	1	1
		04	4	7	4	7	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	8	3	8	0	0	0
		08	3	6	3	6	0	0	0
		09	7	10	8	11	0	1	1
		10	8	10	8	10	0	0	0
PCD				**10**		**11**	**1**		

Table 8-23: The impact of the first event on the 6th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
NE	03	6	03	0	/	1	5	1	8		
			09	0	/	1	7	1	11	1	11

As shown in Table 8-23, the impacted day of this event at project-level is day 11. Also, it impacted the schedule at the activity-level, as follow:

1. It has an impact on Act. 03 which may result in two potential impacts on the cost: a) one day is related to the ES in Day 5; and b) one day is related to the EF in Day 8.
2. It has an impact on Act. 09 which may result in two potential impacts on the cost: a) one day is related to the ES in Day 7; and b) one day is related to the EF in Day 11.

2. The second event in Day 6 (EC at Act.07)

As shown in Table 8-24, EC at Act.07 has affected the activities 07 and 10. Table 8-24 shows the effects of this event at the project-level and the activity-level.

Table 8-24: The second impact on the 6th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.07	6	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	5	7	4	6	0	0	0
		04	4	7	4	7	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	8	3	9	1	0	1
		08	3	6	3	6	0	0	0
		09	7	10	7	10	0	0	0
		10	8	10	9	11	0	1	1
PCD				**10**		**11**	**1**		

Table 8-25: The impact of the second event on the 6th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EC	07	6	07	1	6	0	/	1	9		
			10	0	/	1	8	1	11	1	11

As shown in Table 8-25, the impacted day of this event at project-level is day 11. Also, it impacted the schedule at the activity-level, as follow:

1. It has an impact on Act. 07, which may result in two possible damages: a) one day of possible losses on the cost that is related to the duration in Day 6; and b) one day of possible losses on the cost that is related to the EF in Day 9.
2. It has an impact on Act. 10, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 8; and b) one day of possible losses on the cost that is related to the EF in Day 11.

- **7th Day analysis:**

In Day 7, the schedule has impacted by two events as shown in Figure 8-8, which are: 1) EC at Act.04; and 2) NE at Act.07. The effect of these events is shown in Table 8-26. Due to these events, the schedule will be impacted for two time to measure the effect of each event on the schedule. The first impact will be for EC at Act.04 and the second impact will be for NE at Act. 07.

Act.	predecessor	successor	Duration
01	–	Act. 03&04	4
02	–	Act. 03&04	4
03	Act. 01&02	Act. 09	2
04	Act. 01&02	Act. 09	4
05	Act. 02	Act. 09&10	2
06	–	Act. 07&08	1
07	Act. 06	Act. 10	7
08	Act. 06	Act. 10	3
09	Act. 03, 04, 05	–	3
10	Act. 07, 08	–	2

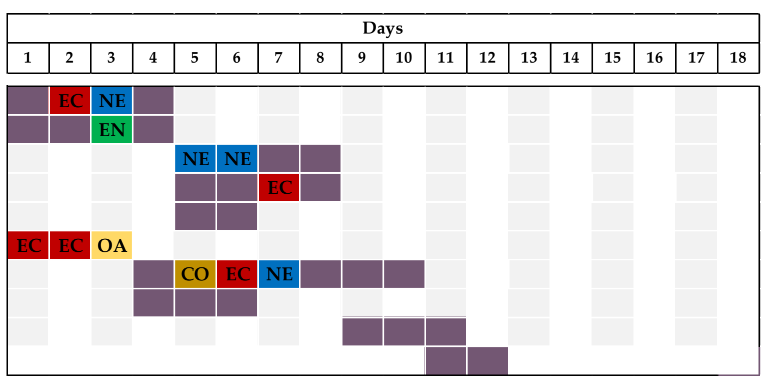


Figure 8-8: 7th Day analysis

Table 8-26: The impact of the 7th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.04 NE at Act.07	7	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	8	6	8	0	0	0
		04	4	7	4	8	1	0	1
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	9	3	10	1	0	1
		08	3	6	3	6	0	0	0
		09	8	11	8	11	0	0	0
		10	9	11	10	12	0	1	1
PCD				**11**		**12**	**1**		

1. The first event in Day 3 (EC at Act.04)

As shown in Table 8-27, EC at Act.04 has impacted the project schedule on day 7. Table 8-27 also shows the impacts at the activity-level and the project-level.

Table 8-27: The impact of the 7th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.04	7	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	8	6	8	0	0	0
		04	4	7	4	8	1	0	1
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	9	3	9	0	0	0
		08	3	6	3	6	0	0	0
		09	8	11	8	11	0	0	0
		10	9	11	9	11	0	0	0
PCD				**11**		**11**	**0**		

Table 8-28: The impact of the first event on a 7th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EC	04	7	04	1	7	0	/	1	8	1	11

As shown in Table 8-28, this event has impacted the schedule at project-level. Also, the impact has occurred on the Act. 04 in two possible effects, which are: a) one day of possible losses on the cost that is related to the D in Day 7; and b) one day of possible losses on the cost that is related to the EF in Day 8.

2. Second impacted event in Day 3 (NE at Act.07)

Table 8-29: The impact of the 7th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.07	7	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	8	6	8	0	0	0
		04	4	7	4	7	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	9	3	10	1	0	1
		08	3	6	3	6	0	0	0
		09	8	11	8	11	0	0	0
		10	9	11	10	12	0	1	1
PCD				**11**		**12**	**1**		

As shown in Table 8-29, NE at Act.07 has affected the activities 07 and 10. Table 8-30 shows the impacts of NE at Act.07 in Day 7 at the activity-level and the project-level, as follow.

Table 8-30: The impact of the second event on a 7th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
NE	07	7	07	1	7	0	/	1	10		
			10	0	/	1	9	1	12	1	12

As shown in Table 8-29, this event has impacted the schedule at project-level on day 12. Also, it has impacted the project at the activity-level as follow:

1. It has an impact on Act. 07, which may result in two possible damages: a) one day of possible losses on the cost that is related to the duration in Day 7; and b) one day of possible losses on the cost that is related to the EF in Day 10.
2. It has an impact on Act. 10, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 9; and b) one day of possible losses on the cost that is related to the EF in Day 12.

- **8th Day analysis:**

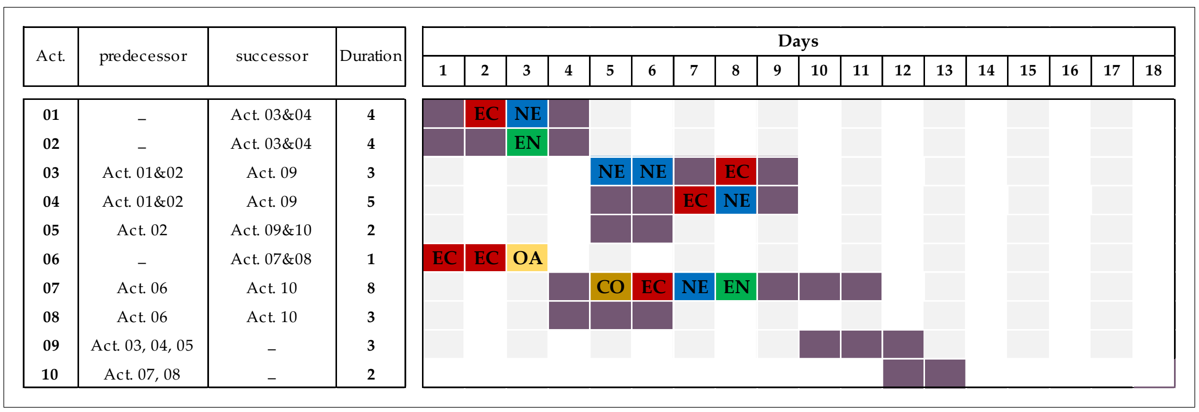


Figure 8-9: 8th Day analysis

Table 8-31: The impact of the 8th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.03 NE at Act.04 EN at Act.07	8	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	8	6	9	1	0	1
		04	4	8	4	9	1	0	1
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	10	3	11	1	0	1
		08	3	6	3	6	0	0	0
		09	8	11	9	12	0	1	1
		10	10	12	11	13	0	1	1
PCD				**12**		**13**	**1**		

As shown in Figure 8-9, three events have occurred on the schedule in Day 8, which are: EC at Act.03, NE at Act.04 and EN at Act.07. Table 8-31 shows the effects of these events. The first impact will be for EC at Act.03, the second impact will be for NE at Act.04, and the third impact will be for EN Act Act.07. Therefore, the updated as-planned schedule will be impacted separately for each event as follow:

1. The first event in Day 8 (EC at Act.03)

Table 8-32 shows the impact of EC at Act.03 on the project schedule, which will impact activities 03 and 09. The effects of the event are shown in Table 8-33.

Table 8-32: The first impact on the 8th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.03	8	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	8	6	9	1	0	1
		04	4	8	4	8	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	10	3	10	0	0	0
		08	3	6	3	6	0	0	0
		09	8	11	9	12	0	1	1
		10	10	12	10	12	0	0	0
PCD				**12**		**12**	**0**		

Table 8-33: The impact of the first event on the 8th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EC	03	8	03	1	8	0	/	1	9		
			09	0	/	1	8	1	12	1	12

As shown in Table 8-33, this event has impacted the schedule at the project-level on day 12. Also, it will impact the project at the activity-level as follow:

1. It has an impact on Act. 03, which may result in two possible damages: a) one day of possible losses on the cost that is related to the duration in Day 8; and b) one day of possible losses on the cost that is related to the EF in Day 9.

2. It has an impact on Act. 09 which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 8; and b) one day of possible losses on the cost that is related to the EF in Day 12.

2. The second event in Day 3 (NE at Act.04)

As shown in Table 8-34, the impact of NE at Act.04 has effect activities 04 and 09. Also, this event has two effects at activity-level and project-level. The impacted day of this event at project-level is shown in Table 8-35, as follow:

Table 8-34: The second impact on the 8th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.04	8	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	8	6	8	0	0	0
		04	4	8	4	9	1	0	1
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	10	3	10	0	0	0
		08	3	6	3	6	0	0	0
		09	8	11	9	12	0	1	1
		10	10	12	10	12	0	0	0
PCD				**12**		**12**	**0**		

Table 8-35: The impact of the second event on the 8th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
NE	04	8	04	1	8	0	/	1	8		
			09	0	/	1	8	1	12	1	12

1. It has an impact on Act. 04, which may result in two possible damages: a) one day of possible losses on the cost that is related to the D in Day 8; and b) one day of possible losses on the cost that is related to the EF in Day 8.

2. It has an impact on Act. 09, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 8; and b) one day of possible losses on the cost that is related to the EF in Day 12.

3. The third event in Day 3 (EN at Act.07)

As shown in Table 8-36, the impact of EN at Act.07 has effect activities 07 and 10. Also, this event has impacted the schedule at the project-level on day 13. Table 8-37 shows the effects of this event at the activity-level and the project-level, as follow:

Table 8-36: The third impact in the 8th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EN at Act.07	8	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	8	6	8	0	0	0
		04	4	8	4	8	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	10	3	11	1	0	1
		08	3	6	3	6	0	0	0
		09	8	11	8	11	0	0	0
		10	10	12	11	13	0	1	1
PCD				**12**		**13**	**1**		

Table 8-37: The impact of the third event on the 8th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EN	07	8	07	1	8	0	/	1	11		
			10	0	/	1	10	1	13	1	13

1. It has an impact on Act. 07, which may result in two possible damages: a) one day of possible losses on the cost that is related to the duration in Day 8; and b) one day of possible losses on the cost that is related to the EF in Day 11.

2. It has an impact on Act. 10, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 10; and b) one day of possible losses on the cost that is related to the EF in Day 13.

- **9th Day analysis:**

As shown in Figure 8-10, three events have occurred on the schedule on day 9, which impact the project schedule as shown in Table 8-38. Therefore, the as-planned schedule will be updated up to day 8 and separately impacted for each event, as follow: the first impact is EN at Act.03, the second impact is EN at Act.04, and the third impact is EN Act Act.07.

Act.	predecessor	successor	Duration	Days																	
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
01	–	Act. 03&04	4		EC	NE															
02	–	Act. 03&04	4			EN															
03	Act. 01&02	Act. 09	4					NE	NE		EC	EN									
04	Act. 01&02	Act. 09	6							EC	NE	EN									
05	Act. 02	Act. 09&10	2																		
06	–	Act. 07&08	1	EC	EC	OA															
07	Act. 06	Act. 10	9					CO	EC	NE	EN	EN									
08	Act. 06	Act. 10	3																		
09	Act. 03, 04, 05	–	3																		
10	Act. 07, 08	–	2																		

Figure 8-10: 9th Day analysis

Table 8-38: The impact of the 9th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EN at Act.03 EN at Act.04 EN at Act.07	9	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	9	6	10	1	0	1
		04	4	9	4	10	1	0	1
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	12	1	0	1
		08	3	6	3	6	0	0	0
		09	9	12	10	13	0	1	1
		10	11	13	12	14	0	1	1
PCD				**13**		**14**	**1**		

1. The first event in Day 9 (EN at Act.03)

As shown in Table 8-39, the impact of EN at Act.03 has effect activities 03 and 09. The effects of the event at the activity-level and project-level are shown in Table 8-40.

Table 8-39: The first impact on the 9th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EN at Act.03	9	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	9	6	10	1	0	1
		04	4	9	4	9	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	11	0	0	0
		08	3	6	3	6	0	0	0
		09	9	12	10	13	0	1	1
		10	11	13	11	13	0	0	0
PCD				**12**		**13**	**0**		

Table 8-40: The impact of the first event on the 9th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EN	03	9	03	1	9	0	/	1	10		
			09	0	/	1	9	1	13	1	13

As shown in Table 8-40, this event has impacted the schedule at project-level on day 13. Also, it will impact the project at the activity-level as follow:

1. It has an impact on Act. 03 which may result in two possible damages: a) one day of possible losses on the cost that is related to duration in Day 9; and b) one day of possible losses on the cost that is related to EF in Day 10.
2. It has an impact on Act. 09 which may result in two possible damages: a) one day of possible losses on the cost that is related to ES in Day 9; and b) one day of possible losses on the cost that is related to EF in Day 13.

2. The second event in Day 9 (EN at Act.04)

Table 8-41 shows the impact of EN at Act.04 on the project schedule. The effect of this event at the activity-level and the project-level are shown in Table 8-42.

Table 8-41: The second impact on the 9th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.04	9	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	9	6	9	0	0	0
		04	4	9	4	10	1	0	1
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	11	0	0	0
		08	3	6	3	6	0	0	0
		09	9	12	10	13	0	1	1
		10	11	13	11	13	0	0	0
PCD				**13**		**13**	**0**		

Table 8-42: The impact of the second event on the 9th-day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
NE	04	9	04	1	9	0	/	1	10	1	13
			09	0	/	1	9	1	13		

As shown in Table 8-42, the impacted day of this event at the project-level is day 13. Also, it will impact the project at the activity-level as follow:

1. It has an impact on Act. 04, which may result of two potential damages: a) one day related to the D in Day 9; and b) one day related to the EF in Day 10.
2. It has an impact on Act. 09 which, may result of two potential damages: a) one day related to the ES in Day 9; and b) one day related to the EF in Day 13.

3. The third event in Day 9 (EN at Act.07)

Table 8-43 shows the impact of this event. The effect of this event at the activity-level and the project-level are shown in Table 8-44.

Table 8-43: The third impact in the 9th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EN at Act.07	9	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	9	6	9	0	0	0
		04	4	9	4	9	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	12	1	0	1
		08	3	6	3	6	0	0	0
		09	9	12	9	12	0	0	0
		10	11	13	12	14	0	1	1
PCD				**13**		**14**	**1**		

Table 8-44: The impact of the third event on a 9th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EN	07	9	07	1	9	0	/	1	12	1	14
			10	0	/	1	11	1	14		

As shown in Table 8-44, this event has impacted the schedule at project-level on day 14. Also, it will impact the project at the activity-level as follow:

1. It has an impact on Act. 07, which may result in two potential damages: a) one day is related to the duration in Day 9; and b) one day is related to the EF in Day 12.
2. It has an impact on Act. 10, which may result of two potential damages: a) one day is related to the ES in Day 11; and b) one day is related to the EF in Day 14.

- **10th Day analysis:**

As shown in Figure 8-11, three events have occurred on the schedule in Day 10, which are: EC at Act.03, EC at Act.04, and OA at Act.07. Table 8-45 shows the effects of these events. The as-planned schedule will be updated up to day 9, and separately impacted by each event: the first impact will be for EC at Act.03, the second impact will be for EC at Act.04, and the third impact will be for OA Act Act.07, as follow:

Act.	predecessor	successor	Duration
01	_	Act. 03&04	4
02	_	Act. 03&04	4
03	Act. 01&02	Act. 09	5
04	Act. 01&02	Act. 09	7
05	Act. 02	Act. 09&10	2
06	_	Act. 07&08	1
07	Act. 06	Act. 10	8
08	Act. 06	Act. 10	3
09	Act. 03, 04, 05	_	3
10	Act. 07, 08	_	2

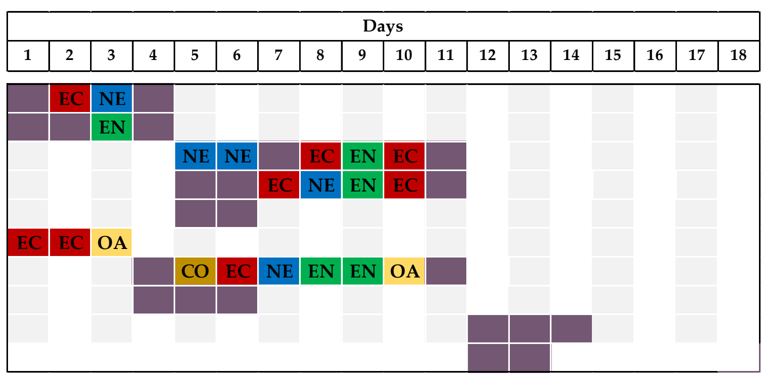


Figure 8-11: 10th Day analysis

Table 8-45: The impact of the 10th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.03 EC at Act.04 OA at Act.07	10	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	10	6	11	1	0	1
		04	4	10	4	11	1	0	1
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	12	3	11	-1	0	-1
		08	3	6	3	6	0	0	0
		09	10	13	11	14	0	1	1
		10	12	14	11	13	0	-1	-1
PCD				**14**		**14**	**0**		

1. The first event in Day 10 (EC at Act.03)

As shown in Table 8-46, the impact of EC at Act.03 has effect activities 03 and 09. The impacts of this event at the activity-level and the project-level are shown in Table 8-47.

Table 8-46: The first impact on the 10th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.03	10	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	10	6	11	1	0	1
		04	4	10	4	10	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	12	3	12	0	0	0
		08	3	6	3	6	0	0	0
		09	10	13	11	14	0	1	1
		10	12	14	12	14	0	0	0
PCD				**14**		**14**	**0**		

Table 8-47: The impact of the first event on a 10th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EC	03	10	03	1	10	0	/	1	11		
			09	0	/	1	10	1	14	1	14

As shown in Table 8-47, this event has impacted the schedule at project-level on day 14. Also, it will impact the project at the activity-level as follow:

1. It has an impact on Act. 03, which may result in two potential damages: a) one day is related to the duration on day 10, and b) one day is related to the EF on day 11.
2. It has an impact on Act. 09, which may result in two potential damages: a) one day is related to the ES on day 10, and b) one day is related to the EF on day 14.

2. The second event in Day 10 (EN at Act.04)

As shown in Table 8-48, the impact of EN at Act.04 has effect activities 04 and 09. The impacts of this event at the activity-level and the project-level are shown in Table 8-49.

Table 8-48: The second impact on the 10th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EC at Act.04	10	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	10	6	10	0	0	0
		04	4	10	4	11	1	0	1
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	12	3	12	0	0	0
		08	3	6	3	6	0	0	0
		09	10	13	11	14	0	1	1
		10	12	14	12	14	0	0	0
PCD				**14**		**14**	**0**		

Table 8-49: The impact of the second event on a 10th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EC	04	10	04	1	10	0	/	1	11		
			09	0	/	1	10	1	14	1	14

As shown in Table 8-49, this event has impacted the schedule at project-level on day 14. Also, it has impacted the project at the activity-level as follow:

1. It has an impact on Act. 04, which may result in two potential damages: a) one day is related to the D in Day 10, and b) one day is related to the EF in Day 11.
2. It has an impact on Act. 09, which may result in two potential damages: a) one day is related to the ES in Day 10, and b) one day is related to the EF in Day 14.

3. The third event in Day 10 (OA at Act.07)

As shown in Table 8-50, the impact of EN at Act.07 has effect activities 07 and 10. The impacts of this event at the activity-level and the project-level are as shown in Table 8-51.

Table 8-50: The third impact in the 10th day

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
OA at Act.07	10	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	10	6	10	0	0	0
		04	4	10	4	10	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	12	3	11	-1	0	-1
		08	3	6	3	6	0	0	0
		09	10	13	10	13	0	0	0
		10	12	14	11	13	0	-1	-1
PCD				**13**		**13**	**0**		

Table 8-51: The impact of the third event on a 10th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
OA	07	10	07	-1	10	0	/	-1	12	-1	14
			10	0	/	-1	12	-1	14		

As shown in Table 8-51, this event has accelerated the schedule at project-level on day 14. Also, it will impact the project at the activity-level as follow:

1. It has an impact on Act. 07, which may result in two possible damages: a) one day of possible losses on the cost that is related to the duration in Day 10; and b) one day of possible losses on the cost that is related to the EF in Day 12.
2. It has an impact on Act. 10, which may result in two possible damages: a) one day of possible losses on the cost that is related to the ES in Day 12; and b) one day of possible losses on the cost that is related to the EF in Day 14.

- **11th Day analysis:**

In Day 11, the schedule has not been impacted by any event. Therefore, the activities' Duration (D), the Early Start (ES), and the Early Finish (EF) are remaining without any change.

- **12th Day analysis:**

As shown in Figure 8-12, the event that has occurred on the schedule in Day 12 at activity 09 is a concurrent delay that caused by owner and contractor.

Act.	predecessor	successor	Duration
01	–	Act. 03&04	4
02	–	Act. 03&04	4
03	Act. 01&02	Act. 09	5
04	Act. 01&02	Act. 09	7
05	Act. 02	Act. 09&10	2
06	–	Act. 07&08	1
07	Act. 06	Act. 10	8
08	Act. 06	Act. 10	3
09	Act. 03, 04, 05	–	3
10	Act. 07, 08	–	2

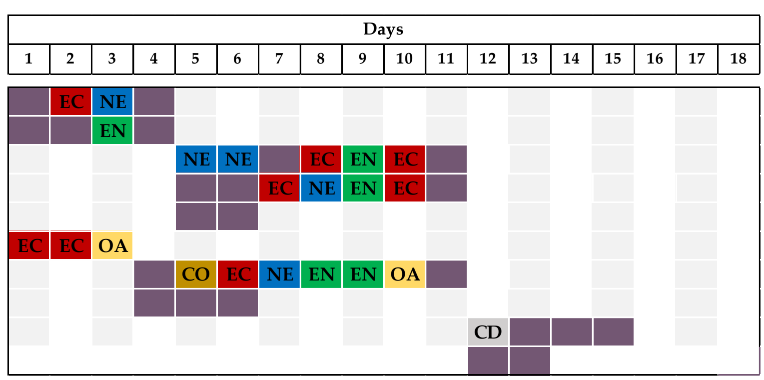


Figure 8-12: 12th Day analysis

This event is a delay event that belongs to the owner and the contractor. The effect of this event at the activity-level and the project-level are as shown in Table 8-52. This event will impact the schedule at the activity-level and the project level, as shown in Table 8-53.

Table 8-52: The impact of the 12th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
CD at Act.09	12	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	11	6	11	0	0	0
		04	4	11	4	11	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	11	0	0	0
		08	3	6	3	6	0	0	0
		09	11	14	12	15	0	1	1
		10	11	13	11	13	0	0	0
PCD				**14**		**15**	**1**		

Table 8-53: The impact of the 12th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
CD	09	12	09	0	/	1	11	1	15	1	15

As shown in Table 8-53, the impacted day of CD at Act.09 in Day 12 day 15 at the project-level, the event has impacted the schedule at the activity-level in two possible effects on the Act. 09, which are: a) one day of possible losses on the cost that is related to the ES in Day 11; and b) one day of possible losses on the cost that is related to the EF in Day 15.

- **13th Day analysis:**

As shown in Figure 8-13, the event that has occurred on the schedule on day 13 at Act. 09 is an EN. This event is a delay event that belongs to neither party. The effect of this event at the activity-level and the project-level are shown in Table 8-54. Also, this event will impact the schedule at the activity-level and the project level, as shown in Table 8-55.

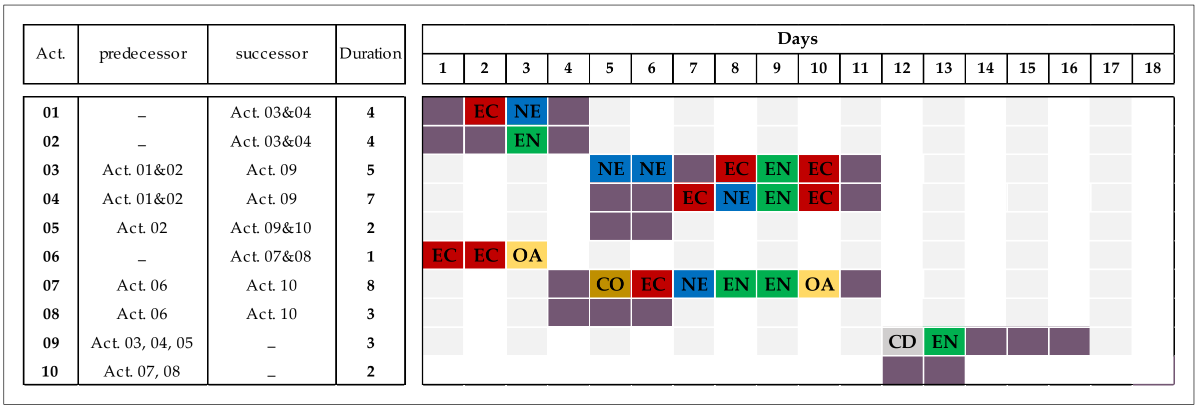


Figure 8-13: 13th Day analysis

Table 8-54: The impact of the 13th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EN at Act.09	13	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	11	6	11	0	0	0
		04	4	11	4	11	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	11	0	0	0
		08	3	6	3	6	0	0	0
		09	12	15	13	16	0	1	1
		10	11	13	11	13	0	0	0
PCD				**15**		**16**	**1**		

Table 8-55: The impact of the 13th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EN	09	13	09	0	/	1	12	1	16	1	16

As shown in Table 8-55, EN at Act.09 on day 13 has impacted day 16 At the project-level. Also, this event has impacted the schedule at the activity-level in two possible effects, which are: a) one day of possible losses on the cost that is related to the ES on day 12; and b) one day of possible losses on the cost that is related to the EF on day 16.

- **14th Day analysis:**

Figure 8-14 shows the event that has occurred on the schedule in Day 14, which is an EN that belongs to neither party. Table 8-56 shows the impacts of this event on the schedule. Also, its effect at the activity-level and the project-level are shown in Table 8-57.

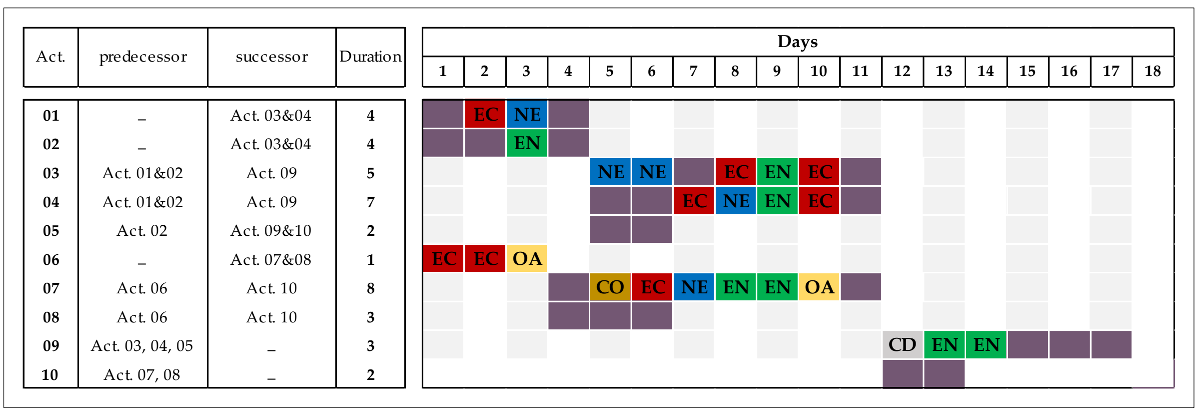


Figure 8-14: 14th Day analysis

Table 8-56: The impact of the 14th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
EN at Act.09	14	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	11	6	11	0	0	0
		04	4	11	4	11	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	11	0	0	0
		08	3	6	3	6	0	0	0
		09	13	16	14	17	0	1	1
		10	11	13	11	13	0	0	0
PCD				**15**		**17**	**1**		

Table 8-57: The impact of the 14th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
EN	09	14	09	0	/	1	13	1	17	1	17

As shown in Table 8-57, the impacted day due to EN (at Act.09 in Day 14) at the project-level is day 17. This event will also impact the schedule at the activity-level in two possible effects, which are: a) one day of possible losses on the cost that is related to the ES on day 13; and b) one day of possible losses on the cost that is related to the EF on day 17.

- **15th Day analysis:**

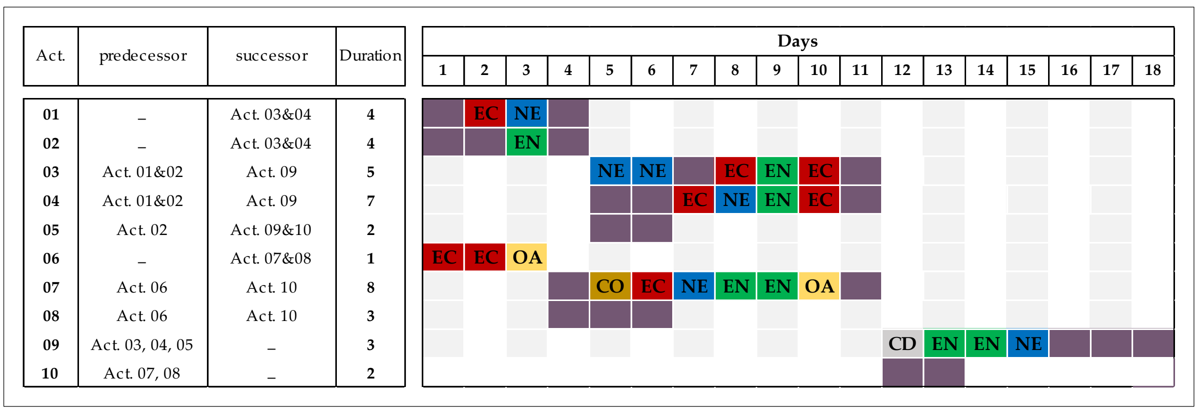


Figure 8-15: 15th Day analysis

Table 8-58: The impact of the 15th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
NE at Act.09	15	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	11	6	11	0	0	0
		04	4	11	4	11	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	11	0	0	0
		08	3	6	3	6	0	0	0
		09	14	17	15	18	0	1	1
		10	11	13	11	13	0	0	0
PCD				**17**		**18**	**1**		

As shown in Figure 8-15, the event that has occurred on the schedule on day 15 at activity 09 is NE that belongs to the contractor.

Table 8-59: The impact of the 15th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
NE	09	15	09	0	/	1	14	1	18	1	18

As shown in Table 8-58, this event has impacted the project schedule. The effect of this event at the activity-level and the project-level are shown in Table 8-59. At the project-level, NE (at Act.09 in Day 15) has impact day 18. Also, this event has impacted the schedule at the activity-level in two possible effects, which are: a) one day of possible losses on the cost that is related to the ES on day 14; and b) one day of possible losses on the cost that is related to the EF on day 18.

- **16th Day analysis:**

In Day 16, the schedule has not been impacted by any event. Therefore, the activities' Duration (D), the Early Start (ES), and Early Finish (EF) are remaining without any change.

- **17th Day analysis:**

As shown in Figure 8-16, the event that has occurred on the schedule in Day 17 (at activity 09) is an acceleration event that was directed by the contractor. The effect of this acceleration event at activity-level and the project-level are shown in Table 8-60. This event has been impacted the schedule at the activity-level and the project level, as shown in Table 8-61.

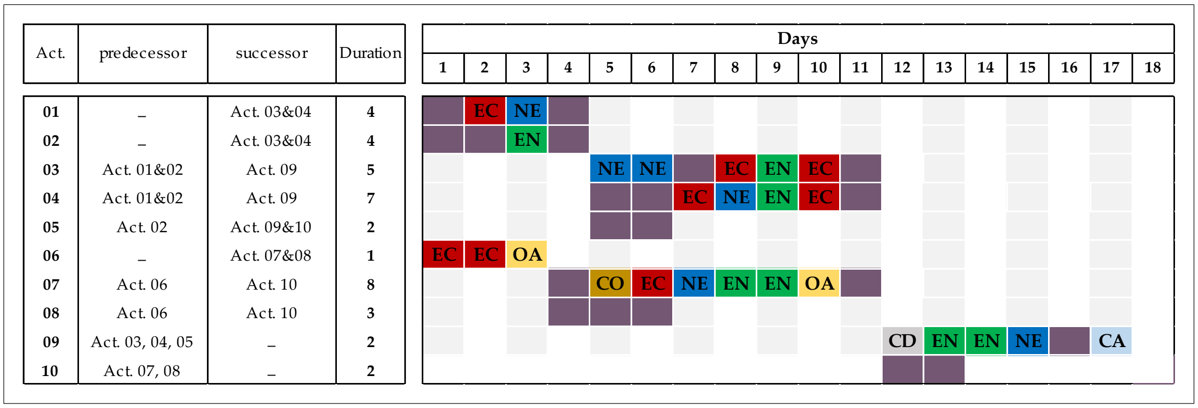


Figure 8-16: 17th Day analysis

Table 8-60: The impact of the 17th-day analysis

Event(s)	Day	Activity	Before Impact		After Impact		Update		
			ES	EF	ES	EF	duration	ES	EF
CA at Act.09	17	01	0	4	0	4	0	0	0
		02	0	4	0	4	0	0	0
		03	6	11	6	11	0	0	0
		04	4	11	4	11	0	0	0
		05	4	6	4	6	0	0	0
		06	2	3	2	3	0	0	0
		07	3	11	3	11	0	0	0
		08	3	6	3	6	0	0	0
		09	15	18	15	17	-1	0	-1
		10	11	13	11	13	0	0	0
PCD				**18**		**17**	**-1**		

Table 8-61: The impact of the 17th day

The impact			At Activity-Level							At Project-Level	
Event	Act.	Day	Act.	D	ID	ES	ID	EF	ID	Delay	ID
CA	09	17	09	-1	17	0	/	-1	18	-1	18

As shown in Table 8-61, CA (at Act.09 in Day 17) has impacted the schedule at the project-level on day 18. Also, this event will impact the schedule at the activity-level in two possible effects, which are: a) one day of possible losses on the cost that is related to the D on day 17; and b) one day of possible losses on the cost that is related to the EF on day 18.

8.3 The Result of The Case Study Analysis

The proposed technique has conducted a day-by-day analysis. The result of this analysis has demonstrated the impacts of each event that have occurred on the schedule as well as the responsibility for any damages at the activity-level. Table 8-62 shows the complete analysis for impacting the project schedule at the activity-level. It shows each event that has occurred on the schedule and its effect on the schedule. For more details of the responsibility analysis, the following analysis will show each effect that has happened on each activity, along with the responsibility for any possible damages.

Table 8-62: Delay analysis at the activity-level

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
01	1st	**EC-01-2**	1	2	0	/	1	3	+1	1			2
	2nd	**NE-01-3**	1	3	0	/	1	4	+1		1		
02	1st	**EN-02-3**	1	3	0	/	1	4	+1			1	1
03	1st	**NE-01-3** **EN-02-3**	0	/	1	4	1	6	+1			1	6
	2nd	**NE-03-5**	0	/	1	5	1	7	+1		1		
	3rd	**NE-03-6**	0	/	1	6	1	8	+1		1		
	4th	**EC-03-8**	1	8	0	/	1	9	+1	1			
	5th	**EN-03-9**	1	9	0	/	1	10	+1			1	
	6th	**EC-03-10**	1	10	0	/	1	11	+1	1			
04	1st	**NE-01-3** **EN-02-3**	0	/	1	4	1	7	+1			1	5
	2nd	**EC-04-7**	1	7	0	/	1	8	+1	1			
	3rd	**NE-04-8**	1	8	0	/	1	9	+1		1		
	4th	**EN-04-9**	1	9	0	/	1	10	+1			1	
	5th	**EC-04-10**	1	10	0	/	1	11	+1	1			
05	1st	**EN-02-3**	0	/	1	4	1	6	+1	0	0	1	1
06	1st	**EC-06-1**	0	/	1	1	1	3	+1	1			1
	2nd	**EC-06-2**	0	/	1	2	1	4	+1	+1			
	3rd	**OA-06-3**	-1	4	0	/	-1	4	-1	-1			
07	1st	**EC-06-1**	0	/	1	3	1	7	+1	1			5
	2nd	**EC-06-2**	0	/	1	4	1	8	+1	0			
	3rd	**OA-06-3**	0	/	-1	4	-1	8	-1				
	4th	**CO-07-5**	1	5	0	/	1	8	+1	1			
	5th	**EC-07-6**	1	6	0	/	1	9	+1	1			

	6th	NE-07-7	1	7	0	/	1	10	+1		1		
	7th	EN-07-8	1	8	0	/	1	11	+1			1	
	8th	EN-07-9	1	9	0	/	1	12	+1			1	
	9th	OA-07-10	-1	10	0	/	-1	12	-1	-1			
08	1st	EC-06-1	0	/	1	3	1	6	+1	+1			1
	2nd	EC-06-2	0	/	1	4	1	7	+1	0			
	3rd	OA-06-3	0	/	-1	4	-1	7	-1				
09	1st	NE-01-3 EN-02-3	0	/	1	7	1	10	+1			1	8
	2nd	NE-03-6	0	/	1	8	1	11	+1		1		
	3rd	EC-03-8 NE-04-8	0	/	1	9	1	12	+1			1	
	4th	EN-03-9 EN-04-9	0	/	1	10	1	13	+1			1	
	5th	EC-03-10 EC-04-10	0	/	1	11	1	14	+1	1			
	6th	CD-09-12	0	/	1	12	1	15	+1			1	
	7th	EN-09-13	0	/	1	13	1	16	+1			1	
	8th	EN-09-14	0	/	1	14	1	17	+1			1	
	9th	NE-09-16	1	16	0	/	1	18	+1		1		
	10th	CA-09-17	-1	17	0	/	1	18	-1		-1		
10	1st	EC-06-1	0	/	1	7	1	9	+1	1			5
	2nd	EC-06-2	0	/	1	8	1	10	+1	1			
	3rd	OA-06-3	0	/	-1	8	-1	10	-1	-1			
	4th	CO-07-5	0	/	1	8	1	10	+1	1			
	5th	EC-07-6	0	/	1	9	1	11	+1	1			
	6th	NE-07-7	0	/	1	10	1	12	+1		1		
	7th	EN-07-8	0	/	1	11	1	13	+1			1	
	8th	EN-07-9	0	/	1	12	1	14	+1			1	
	9th	OA-07-10	0	/	-1	12	-1	14	-1	-1			

8.3.1 The Responsibility at Activity-level

The possible and potential damages at the activity-level can be found by analysing each impact that has occurred on each activity. The potential damages can be measured based on pushing the early start or extending the duration in each activity. The analysis of the possible damages in each project's activity will be as follow:

- **The analysis of Act.01:**

As shown in Table 8-63, owner-caused delay (EC-01-2) and contractor-caused delay (NE-01-3) have impacted Act.01, which may result in possible damages that are related to the activity's duration. Although the possible damages in each day are equal, the damages for each party are not or equal. In this case, each party is responsible for one day of the damages. It means that the owner would be responsible for one day of the contractor damages of in Day 2, and the contractor would also be responsible for one day of the owner damages in Day 3.

This apportionment of losses between the parties is because the damages for the owner in Day 2 and 3 are not very often equal to the damages for the contractor in Day 2 and 3. This apportionment between the parties will give the innocent party the right to claim from the other party. If the damages are not equal, the owner will be responsible for the damages and losses in Day 2 and the contractor for day 3.

Table 8-63: The responsibility for the possible damages at Act.01

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
01	1st	**EC-01-2**	1	2	0	/	1	3	+1	1			2
	2nd	**NE-01-3**	1	3	0	/	1	4	+1		1		

- **The analysis of Act.02:**

As shown in Table 8-64, one delay event only will impact Act.02, which is not belonging to either party. Therefore, each party will bear his damages and losses that may occur at Act.02 on day 3 due to the delay in the activity's duration.

Table 8-64: The responsibility for the possible damages at Act.02

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
02	1st	**EN-02-3**	1	3	0	/	1	4	+1			1	1

- **The analysis of Act.03:**

As shown in Table 8-64, six delay events have affected Act.03, which lead to different impacts. Three of these delays will impact the ES, and the other will impact the D. Therefore, two types of possible damages may happen at this activity. First is the damages that are related to the cost of the early start for Act.03. Second is the damages that are related to the duration for Act.03. In this case, one day of the possible damages that is related to the early start and one day of possible damages that is related to duration are not belonging to either party, since the effects of NE-01-3 and EN-02-3 happened concurrently. However, the contractor will be responsible for any possible damages that the owner may incurred from pushing the early start for 2 days (day 5 and 6). Also, the owner will be responsible for any possible damages that have resulted from delaying the duration in 2 days (day 8 and 10)

Table 8-65: The responsibility for the possible damages at Act.03

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
03	1st	**NE-01-3** **EN-02-3**	0	/	1	4	1	6	+1			1	6
	2nd	**NE-03-5**	0	/	1	5	1	7	+1		1		
	3rd	**NE-03-6**	0	/	1	6	1	8	+1		1		
	4th	**EC-03-8**	1	8	0	/	1	9	+1	1			
	5th	**EN-03-9**	1	9	0	/	1	10	+1			1	
	6th	**EC-03-10**	1	10	0	/	1	11	+1	1			

- **The analysis of Act.04:**

Table 8-66 shows that one delay out of five delays that has impacted the early start of Act.04 is a concurrent effect (between NE-01-3 and EN-02-3), which belongs to neither party. Also, one day of possible damages that is related to the duration is due to NE-04-9, which is not also the responsibility of either party. However, two days of possible damages (in Day 7 and

10) are the responsibility of the owner, and one day of possible damages (in Day 8) is the responsibility of the contractor.

Table 8-66: The responsibility for the possible damages at Act.04

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
04	1st	NE-01-3 EN-02-3	0	/	1	4	1	7	+1			1	5
	2nd	EC-04-7	1	7	0	/	1	8	+1	1			
	3rd	NE-04-8	1	8	0	/	1	9	+1		1		
	4th	EN-04-9	1	9	0	/	1	10	+1			1	
	5th	EC-04-10	1	10	0	/	1	11	+1	1			

- **The analysis of Act.05:**

As shown in Table 8-67, only one delay event has impacted Act.05, which is not belonging to either party. Due to this delay, there will be possible damages in Day 4, which is related to the early start of Act.05. Therefore, each party will bear his damages and losses that may occur in Day 3 at Act.05 due to the delay in the duration.

Table 8-67: The responsibility for the possible damages at Act.05

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
05	1st	EN-02-3	0	/	1	4	1	6	+1	0	0	1	1

- **The analysis of Act.06:**

As shown in Table 8-68, owner has caused two delay events, which may result in two days of a possible damage that is related to the early start of Act.06. However, the owner decided to accelerate Act.06 one day on day 3, which will result in decreasing the activity's duration only. In this case, the contractor may incur an additional cost that is related to delaying the early start of this activity. OA-06-3 will not eliminate the whole impact of EC-06-2 because their effect on Act.06 is not equal. It means if EC-06-2 had increased the duration, the OA-

06-3 will eliminate this increased and any possible damages that may result from this delay. However, the case is that EC-06-2 have pushed the early start and OA-06-3 have decreased the duration, which these impacts are not equal. Due to EC-06-2, EC-06-2 and OA-06-3, there is a possibility of cost damages or saving money for the contractor and the owner due to the entire impacts of these events at Act.06.

Table 8-68: The responsibility for the possible damages at Act.06

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
06	1st	**EC-06-1**	0	/	1	1	1	3	+1	1			**+2 and -1**
	2nd	**EC-06-2**	0	/	1	2	1	4	+1	1*			
	3rd	**OA-06-3**	-1	3	0	/	-1	4	-1	-1*			

- **The analysis of Act.07:**

As shown in Table 8-69, nine events have impacted Act.07. Three of these events have impacted the early start, which is: EC-06-1, EC-06-2 and OA-06-3. Because EC-07-2 and OA-07-3 have the same impact on the early start, OA-07-3 will eliminate any possible damage that is related to the early start of Act.07 due to EC-07-2. However, EC-07-1 will has an impact on the early start, which may result in a possible damage that is related to the early start. Although the owner is responsible for two delays that may have a possible damage on the activity's duration (CO-07-5 and EC-07-6), OA-07-10 will eliminate one day of possible damages because the impacts for EC-07-6 and OA-06-10 are equal on the activity's duration. Therefore, the owner will be responsible for one day that may result in possible damages for the early start, and one day that may result in some possible damages for the duration. Due to the NE-07-7, the contractor will be responsible for one day of possible damages; while both parties are not responsible for any possible damages that may result from EN (in Day 8 and 9).

Table 8-69: The responsibility for the possible damages at Act.07

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
07	1st	**EC-06-1**	0	/	1	3	1	7	+1	1			5
	2nd	**EC-06-2**	0	/	1	4	1	8	+1	0			
	3rd	**OA-06-3**	0	/	-1	4	-1	8	-1				
	4th	**CO-07-5**	1	5	0	/	1	8	+1	1			
	5th	**EC-07-6**	1	6	0	/	1	9	+1	1			
	6th	**NE-07-7**	1	7	0	/	1	10	+1		1		
	7th	**EN-07-8**	1	8	0	/	1	11	+1			1	
	8th	**EN-07-9**	1	9	0	/	1	12	+1			1	
	9th	**OA-07-10**	-1	10	0	/	-1	12	-1	-1			

- **The analysis of Act.08:**

As shown in Table 8-70, Act.08 has been affected on its early start by three events, which are two delays and one acceleration. EC-06-2 and OA-06-3 have different impacts on the same early finish of Act.08. Therefore, OA-06-3 will eliminate any potential damages that may result from EC-06-2. In this case, the owner will be responsible for only one day of any possible damages resulted from delaying the early start of act.06 by the EC-06-1.

Table 8-70: The responsibility for the possible damages at Act.08

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
08	1st	**EC-06-1**	0	/	1	3	1	6	+1	+1			1
	2nd	**EC-06-2**	0	/	1	4	1	7	+1	0			
	3rd	**OA-06-3**	0	/	-1	4	-1	7	-1				

- **The analysis of Act.09:**

Table 8-71 shows three impacts on the early start of the Act.09 that have happened concurrently. The responsibility of the concurrent effect does not belong to either party, which are: the first impact between NE-01-3 and EN-02-3, the third impact between EC-03-8 and NE-04-8, and fourth impact between EN-03-9 and EN-04-9. The concurrent delays between

EC-03-10 and EC-04-10 are the responsibility of the owner. The 10th impacts will eliminate the contractor responsibility for impacting the duration in Act.09 on day 16 that has caused by the contractor acceleration in Day 17. However, the contractor is responsible for any possible damage that will result in delaying the early start of Act.09 from day 7 up to day 8. Therefore, six out of eight impacts on the early start of Act.09 will be the responsibility of neither party. Also, one day of possible damages will be the responsibility of the contractor.

Table 8-71: The responsibility for the possible damages at Act.09

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
09	1st	NE-01-3	0	/	1	7	1	10	+1			1	8
		EN-02-3											
	2nd	NE-03-6	0	/	1	8	1	11	+1		1		
	3rd	EC-03-8	0	/	1	9	1	12	+1			1	
		NE-04-8											
	4th	EN-03-9	0	/	1	10	1	13	+1			1	
		EN-04-9											
	5th	EC-03-10	0	/	1	11	1	14	+1	1			
		EC-04-10											
	6th	CD-09-12	0	/	1	12	1	15	+1			1	
	7th	EN-09-13	0	/	1	13	1	16	+1			1	
	8th	EN-09-14	0	/	1	14	1	17	+1			1	
	9th	NE-09-16	1	16	0	/	1	18	+1		1		
	10th	CA-09-17	-1	17	0	/	1	18	-1		-1		

- **The analysis of Act.10:**

As shown in Table 8-72, all the possible damages in Act.10 is the result of delaying its early start. The owner would be responsible for 1st, 2nd, 3rd, 4th, 5th and 9th impact. However, 2nd impact (EC-06-2) and 5th impact (EC-07-6) will be eliminated by 3rd impact (OA-06-3) and 9th impact (OA-07-10), respectively. Thus, the contractor would be responsible for the 6th impact. For 7th and 8th impacts, neither party would be responsible for their possible damages.

Table 8-72: The responsibility for the possible damages at Act.10

Act.	Impact	Event-Activity-ID	D	ID	ES	ID	EF	ID	Delay	Responsibility			Total
										O	C	NP	
10	1st	**EC-06-1**	0	/	1	7	1	9	+1	1			5
	2nd	**EC-06-2**	0	/	1	8	1	10	+1	1			
	3rd	**OA-06-3**	0	/	-1	8	-1	10	-1	-1			
	4th	**CO-07-5**	0	/	1	8	1	10	+1	1			
	5th	**EC-07-6**	0	/	1	9	1	11	+1	1			
	6th	**NE-07-7**	0	/	1	10	1	12	+1		1		
	7th	**EN-07-8**	0	/	1	11	1	13	+1			1	
	8th	**EN-07-9**	0	/	1	12	1	14	+1			1	
	9th	**OA-07-10**	0	/	-1	12	-1	14	-1	-1			

8.3.2 The Responsibility at Project-Level

Table 8-73: Delay analysis at the Project-level

Analysis Day	**Event**	**Act**	**Day**	**Responsibility at Project Level**		
				Delay	**ID**	**PCD**
Day1	**EC**	06	1	0	9	9
Day2	**EC**	01	2	0	3	9
	EC	06	2	1	10	10
Day3	**NE**	01	3	1	10	10
	EN	02	3	1	10	10
	OA	06	3	-1	10	10
Day4	/	/	/	/	/	10
Day5	**NE**	03	5	0	6	10
	CO	07	5	1	10	10
Day6	**NE**	03	6	1	11	11
	EC	07	6	1	11	11
Day7	**EC**	04	7	1	11	11
	NE	07	7	1	12	12
Day8	**EC**	03	8	1	12	12
	NE	04	8	1	12	12
	EN	07	8	1	13	13
Day9	**EN**	03	9	1	13	13
	EN	04	9	1	13	13
	EN	07	9	1	14	14
Day10	**EC**	03	10	1	14	14
	EC	04	10	1	14	14
	OA	07	10	-1	14	14
Day11	/	/	/	/	/	14
Day12	**CD**	09	12	1	15	15
Day13	**EN**	09	13	1	16	16
Day14	**EN**	09	14	1	17	17
Day15	/	/	/	/	/	17
Day16	**NE**	09	16	1	18	18
Day17	**CA**	09	17	-1	18	17

As shown in Table 8-73, the possible damages at project-level can be found by analysing the effect of each impact day-by-day and tracking the original project completion date, which is day 9. Figure 8-17 shows the as-planned schedule and the schedule activities before any impact. At the project-level, the analysis of the responsibility for any potential losses and damages, is based on the retrieval day, which will lead to track the effect of any event on the schedule. Also, the following analysis will be used to assign any event in the retrieval day for allocating the responsibility at the project-level.

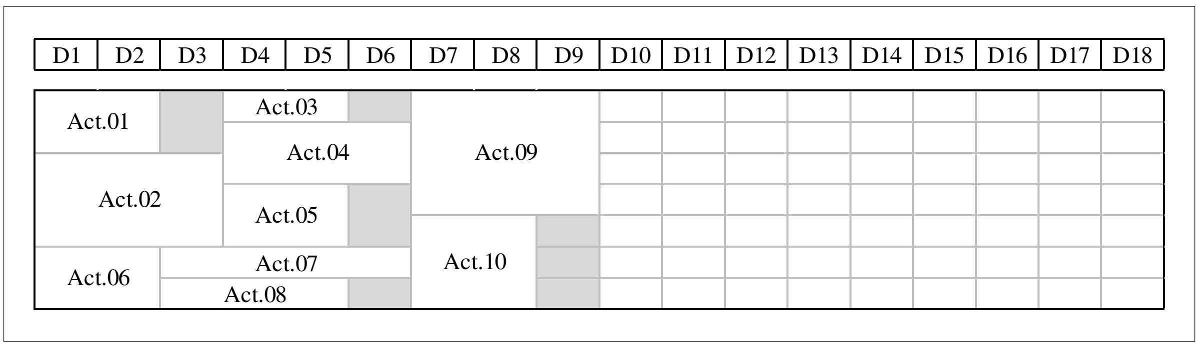


Figure 8-17: The as-planned schedule that used to determine the responsibility at the project-level

The analysis of any possible damage at project-level is conducted based on the retrieval day for any event that has occurred on the schedule. As defined in chapter 7, the retrieval day is the first serving day for accommodating the time loss on the as-planned schedule. The analysis for each event is conducted day by day as follow:

Day 1: EC-06-1 has impacted day 9, which the original PCD will not be affected and remain the same (day 9), as shown in Figure 8-18.

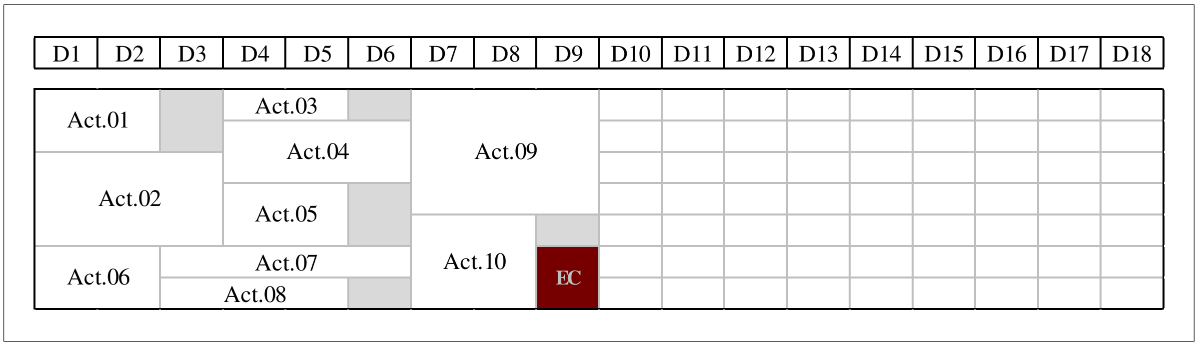


Figure 8-18: The impact at project-level for day 1

Day 2: EC-01-2 has impacted day 3, which will not affect the original PCD and remains the same (day 9). However, EC-06-2 has impacted day 10, which will affect the original PCD and become day 10. Figure 8-19 shows the impacts of the events on day 2.

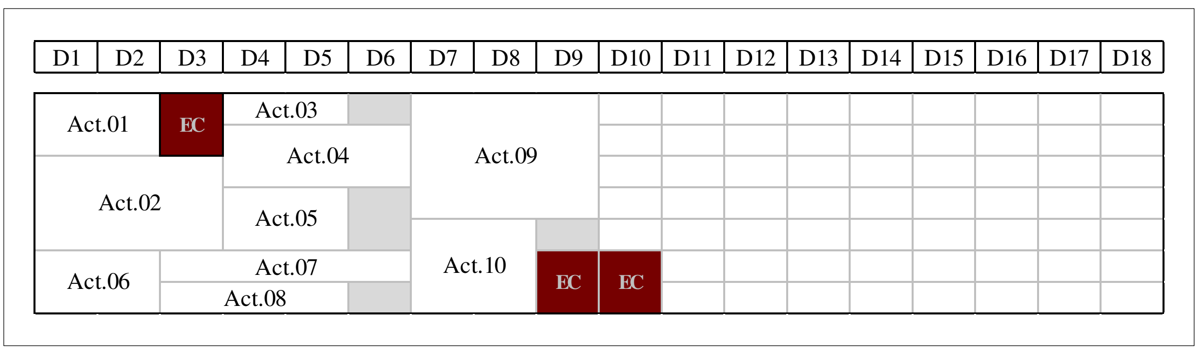


Figure 8-19: The impact at project-level after day 2

Day 3: OA-06-3 will eliminate the effect of EC-06-2 and get the PCD back to day 9. However, NE-01-3 and EN-02-3 have concurrently delayed Act.09 up to day 10. Figure 8-20 shows the impacts of the events on day 3.

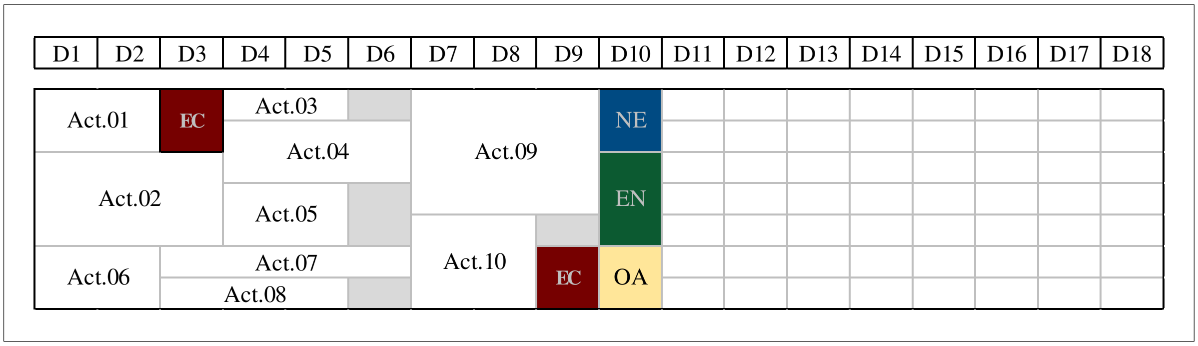


Figure 8-20: The impact at project-level after day 3

Day 4: there is no impact on day 4. Therefore, the Project Completion Date (PCD) has not been affected on this day and remains on D10.

Day 5: NE-03-5 has impacted day 6. However, CO-07-5 will impact day 10 if OA-06-3 has accelerated this day. Figure 8-21 shows the impact of the events on day 3.

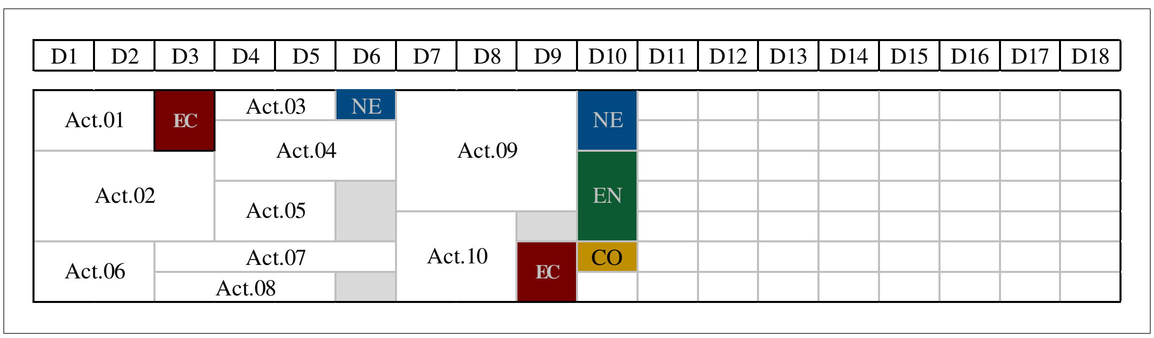


Figure 8-21: The impact at project-level after day 5

Day 6: NE-03-6 and EC-07-6 will impact day 11, as shown in Figure 8-22.

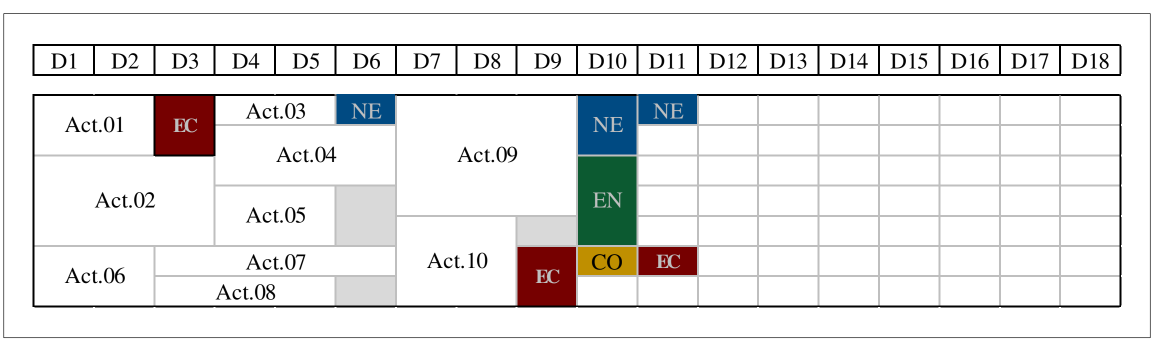


Figure 8-22: The impact at project-level after day 6

Day 7: EC-04-7 will affect day 12 and NE-07-7 will affect day 13, as shown in Figure 8-23.

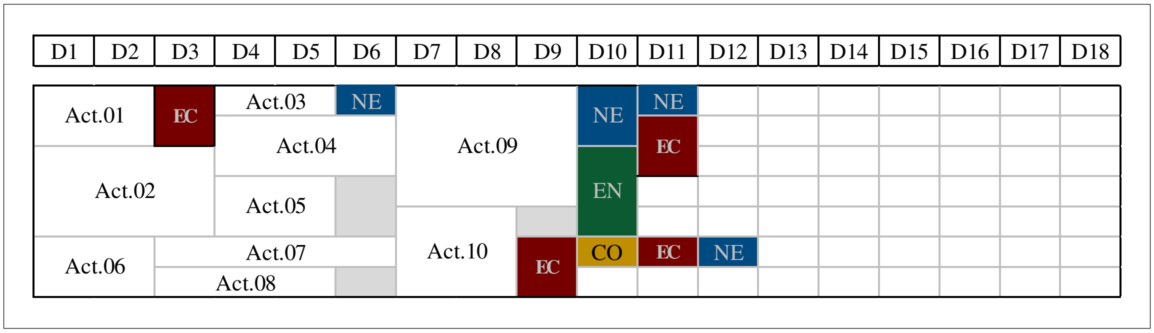


Figure 8-23: The impact at project-level after day 7

Day 8: EC-03-8 and NE-04-8 will affect day 12. However, EN-07-8 will affect day 13, as shown in Figure 8-24.

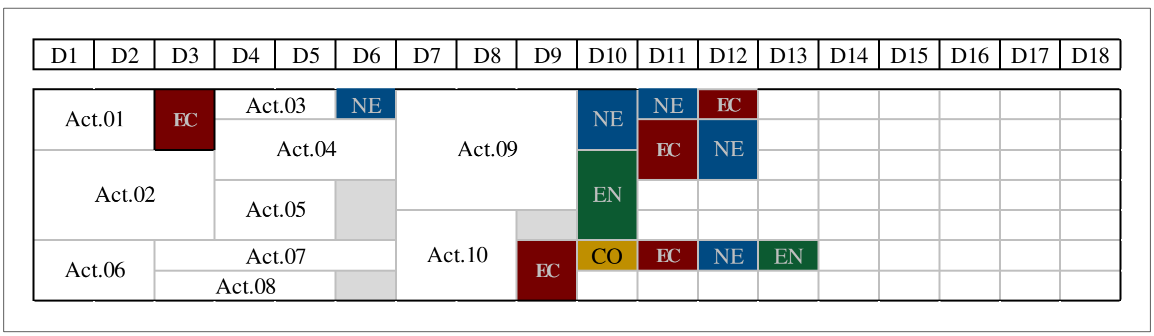


Figure 8-24: The impact at project-level after day 8

Day 9: EN-03-9 and EN-04-9 will affect day 13. However, EN-07-9 will affect day 14, as shown in Figure 8-25.

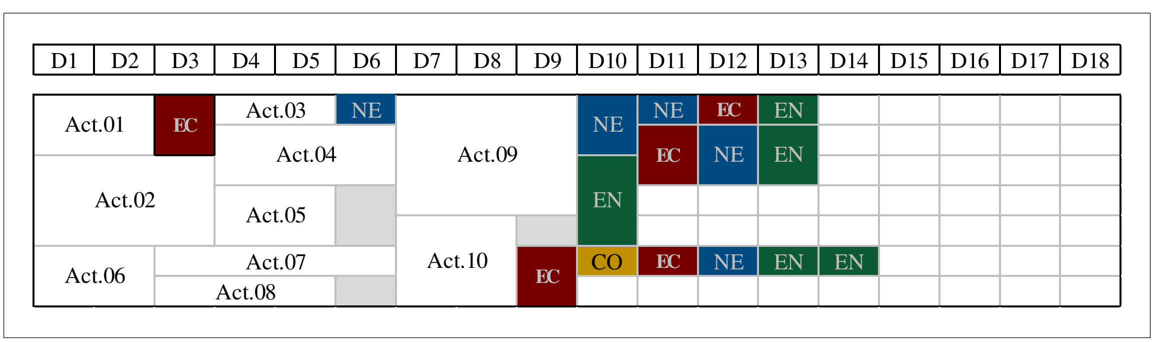


Figure 8-25: The impact at project-level after day 9

Day 10: EC-03-10 and EC-04-10 will affect day 14. However, OA-07-10 will accelerate day 14, as shown in Figure 8-26

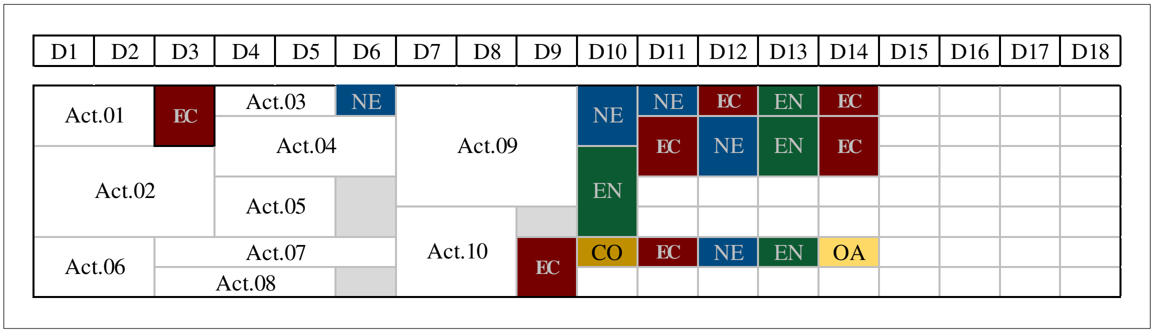


Figure 8-26: The impact at project-level after day 10

Day 11: there is no impact on day 11. Therefore, the Project Completion Date (PCD) has not affected on this day and remains on D14.

Day 12: CD-09-12 will affect day 15, as shown in Figure 8-27.

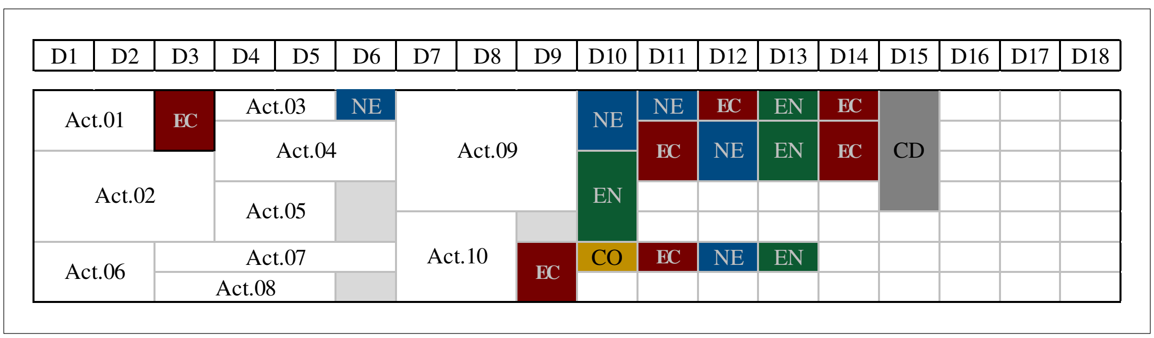


Figure 8-27: The impact at project-level after day 12

Day 13: EN-09-13 will affect day 16. as shown in Figure 8-28.

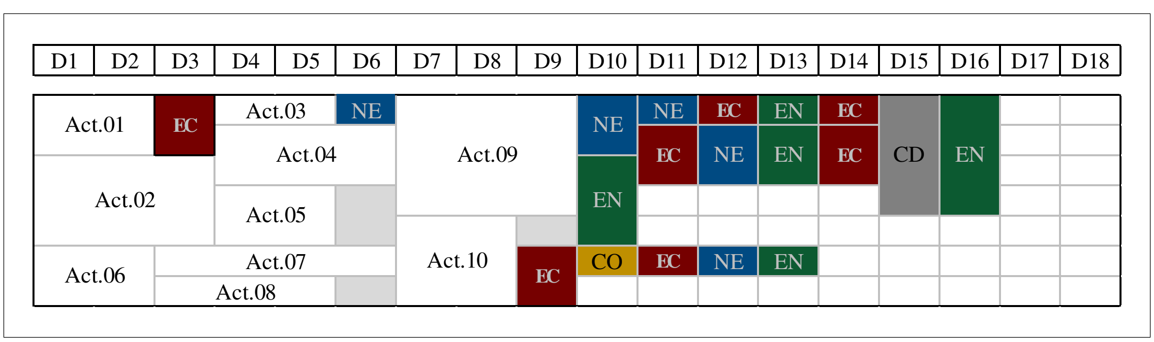


Figure 8-28: The impact at project-level after day 13

Day 14: EN-09-13 will affect day 17, as shown in Figure 8-29.

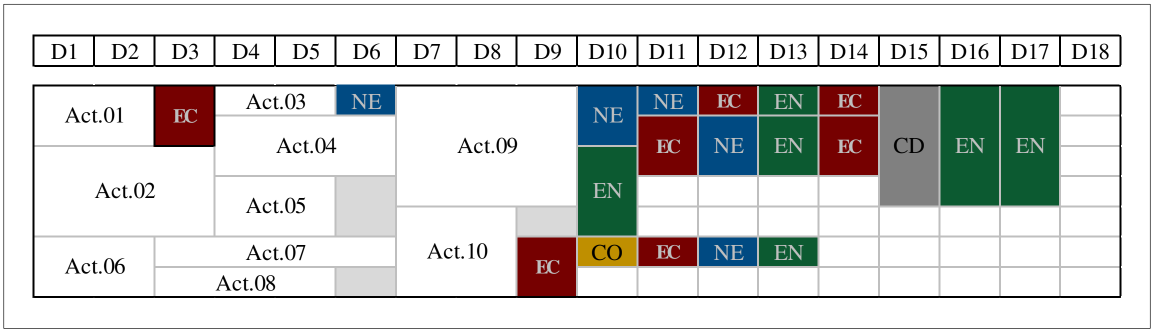


Figure 8-29: The impact at project-level after day 14

Day 15: there is no impact on day 15. Therefore, the Project Completion Date (PCD) has not affected on this day and remains on D17.

Day 16: EN-09-16 will affect day 18. as shown in Figure 8-30.

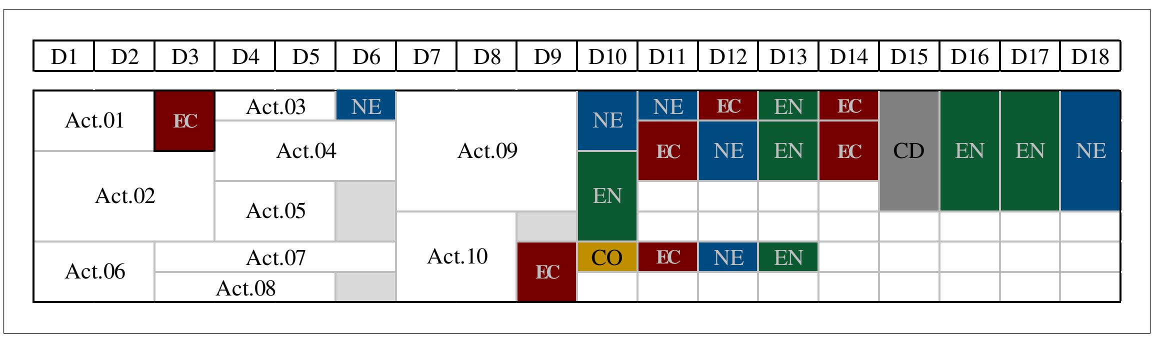


Figure 8-30: The impact at project-level after day 16

Day 17: CA-09-17 will affect day 18. as shown in Figure 8-31

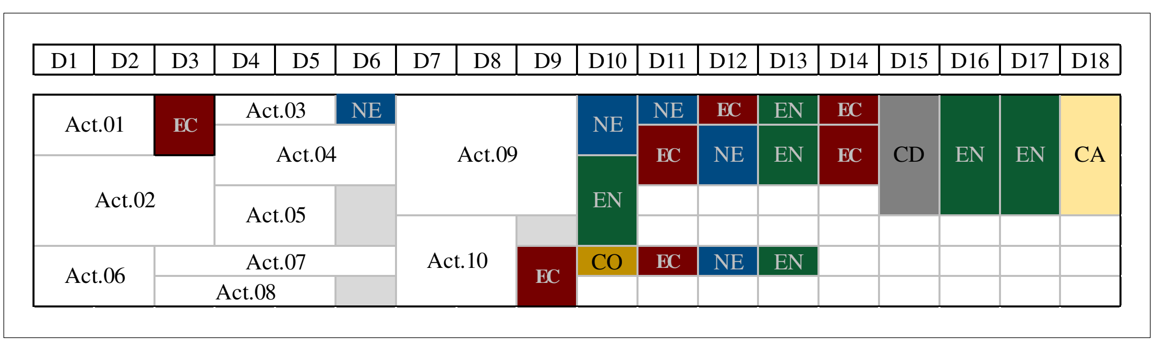


Figure 8-31: The impact at project-level after day 17

The above analysis of the responsibility at project-level shows how the events have impacted the project schedule and contributed in extending the project completion date. The analysis also shows which of the schedule events have formed the delayed period form D10 up to D19. Table 8-74 shows the impacted day for the events in the delayed period of the project's schedule.

Table 8-74: The impacted day of the events in the delayed period of the project's schedule

Responsibility before the accelerations' effects												
Act.	Delays									Accelerations		
	D10	D11	D12	D13	D14	D15	D16	D17	D18	D10	D14	D18
01	NE-3											
02	EN-3											
03		NE-6	EC-8	EN-9	EC-10							
04		EC-7	NE-8	EN-9	EC-10							
05												
06	EC-2									OA-3		
07	CO-5	EC-6	NE-7	EN-8	EN-9						OA-10	
08												
09						CD-12	EN-13	EN-14	NE-16			CA-17
10												

From Table 8-74, the acceleration that has same impacted day of delays will prevent any possible damages at project-level. In Day 10, OA-06-3 will eliminate the potential damages that resulted from EC-06-2. In Day 14, OA-07-10 3 will eliminate the potential damages that resulted from EN-07-9. In Day 18, CA-09-17 3 will eliminate the potential damages that resulted from NE-09-16. At the project-level, these acceleration events will prevent any possible damages from the delays that have the same impacted day in the same path. Therefore, Table 8-75 shows the delay events that are responsible for the possible damages at project-level after resolving the acceleration issues.

Table 8-75: The responsibility for the potential damages after resolving the acceleration issues

Act.	Responsibility after the accelerations' effects											
	Delays									Accelerations		
	D10	D11	D12	D13	D14	D15	D16	D17	D18	D10	D14	D18
01	NE-3											
02	EN-3											
03		NE-6	EC-8	EN-9	EC-10							
04		EC-7	NE-8	EN-9	EC-10							
05												
06												
07	CO-5	EC-6	NE-7	EN-8								
08												
09						CD-12	EN-13	EN-14				
10												

Table 8-75 shows the delay events that are responsible for each day in the delayed period. In Day 17, 16, 13 and 10, it is precise that the potential losses and damages will be due to extending the PCD for three days by EN, which are the responsibility of neither party. Although the EN delay in Day 10 has occurred with NE-3 and CO-5, the losses and damages in this day cannot be compensable for any party due to EN-3. Similarly, both parties have contributed in extending the PCD and the time loss in Day 15. Therefore, neither party will be responsible for any potential losses or damages in Days 10, 13, 15, 16 and 17that have caused by another party. In other word, the party who is carrying the contract risk may take the responsibility in this situation.

In Day 14, the owner is solely responsible for any potential damage that the contractor will incur because the project has been extended up to this day due to EC-03-10 and EC-04-10. Also, the losses and damages in Day 12 and 11 were caused by a concurrent effect and concurrent delay, respectively. EC-03-8 and NE-07-7 are a concurrent effect that has contributed in extending the PCD up to day 12. Also, EN-03-6 and EC-07-6 are a concurrent delay that have contributed in extending the PCD up to day 11.

8.4 Summary

The analysis by the proposed technique has been conducted in this chapter. It begins by analysing the case study day-by-day for each impact each day. The analysis was also performed to analyse the responsibility of any potential losses and damages at both the project-level and activity-level. The analysis by using the proposed technique shows the potential for tracking any effect of any impact occurred on the schedule. Further, by using the retrieval day for analysing the responsibility for any potential losses and damages, the analysis tracks the responsibility for any loss of time that results in any monetary loss or damage at the project and activity levels. At the project-level, the analysis can pursue the PCD day-by-day while considering the most DAIs, such as concurrent delays and concurrent effects. Additionally, any impact on the ES or D of any activity that may result in any loss or damage can be measured by the proposed technique.

CHAPTER NINE: VALIDATION OF THE PROPOSED TECHNIQUE

9.1 Introduction

This chapter examines whether the proposed technique can be generalised to most delay claims. As mentioned in Section 5.3.5, comparison to other DATs and the expert's opinions are two methods that have been adopted to maximise the validity of the proposed technique, which will give a realistic assessment and rigorous results for the validation requirement. The validation has been conducted for measuring the applicability and effectiveness of the proposed technique in the construction delay claims analysis.

9.2 Validation Methods for the Proposed Technique

There are various methods for validating the research results, each of which can be used either subjectively or objectively. The basic concept behind any of the validating methods is the accumulation of evidence regarding the applicability and credibility of the results. It is common to use a combination of these methods (Sargent, 1998;). Brief descriptions of these techniques, as defined in the literature (Gass, 1983; Sargent, 1998; Qureshi et al., 1999; Kennedy et al., 2005), which include: Comparison to Other Models; Degenerate Tests; Extreme Condition Tests; Event Validity; Face Validity; Fixed Values; Historical Data Validation; Sensitivity Analysis; Predictive Validation; Traces; and Turing Tests. According to Gass (1983), the appropriate method to use for validating a technique mainly depends on the real-world aspect being analysed and the type of model/method being used.

As discussed in Section 5.3.5, comparison to other DATs and the expert opinion methods are the only appropriate methods that were adopted to validate the developed method. The objectives of the validation via the adopting method are to: 1) assess the feasibility of the proposed technique in terms of its adequacy and clarity and 2) ensure that the proposed technique is reasonably robust and will be acceptable to users. The following sections describe the detailed procedure of the validation exercise of the proposed technique, which includes the application of the technique to a hypothetical case study, development of validation questionnaire, selection of experts, administration of the questionnaire and analysis of the findings.

9.2.1 Comparison Between Existing DATs and Proposed Technique

The validity by comparison with other techniques means that the output of the proposed technique being validated is compared to the output of other techniques that are already available. In Chapter 4, seven of the DATs were selected and used in analysing a hypothetical, yet realistic, example, of a construction delay claims problem. Also, the same hypothetical example has been used in Chapter 8 by the proposed technique. Thus, the comparison between the proposed technique and the existing DATs is based on the same data of project delay scenario.

In this validation method, as discussed in Section 5.3.5, the analysis results that have been introduced in Chapters 4 and 8 will be used in this method, which are the following: 1) The approach of the proposed technique with the approaches in the existing DATs for analysing the schedule impacts; 2) The accuracy of the proposed technique with the accuracy of the existing DATs in producing a reliable analysis result; 3) The capability of the proposed technique with the capability of the existing DATs in considering the DAIs. These criteria have been adopted in the comparison validation method, and the results are as follows. Thus, the three requirements that have been set as criteria in Section 5.3.5 will be discussed for comparing the proposed technique with the existing DATs, as follows.

For the first criterion, the proposed technique is based on the approach of a daily window analysis, which is highly regarded as a reliable methodology for observing the behaviour of the schedule from update-to-update and measuring variances to determine the overall project delay (SCL, 2013; AACEI, 2007). The approach is undertaken by using the theory of logic-driven CPM to compare the early finish of impacted activities before and after each delay. This approach has been the principle used as a valid criterion for measuring delay impact by several studies in the existing DATs.

The second criterion is the accuracy of the proposed technique in producing a reliable analysis result. Based on the comparison between the analysis results as shown in Table 9-1, Window analysis, Total Float Management and the proposed technique can be used in the construction delay claims to resolve the issue of real-time for the delayed period (eight days) and the issue of Concurrent Delay (CD). Thus, the proposed technique is also suitable in its accuracy for creating more rigorous results in the construction delay analysis.

Table 9-1: The comparison of the analysis results between existing DATs and the proposed technique

No.	DATs	Project Delays				Total Project Delays
		EC	NE	EN	CD	
1	As-Planned (Gross of Measure)	3	2	4	-	9
	As-Planned (Unit of Measure)	7	5	5	-	17
2	As-Built	0	2	5	-	7
3	Impacted As-Planned	2	1	4	-	7
4	Time Impact	1	2	4	-	7
5	But-For (Gross of Measure)	2	2	4	-	8
	But-For (Unit of Measure)	2	2	4	-	
6	Window Analysis	1	1	4	2	8
7	Total Float Management (Easy Rule)	0	1	5	2	8
	Total Float Management (Fair Rule)	1	2	5	-	
8	Proposed Technique	1	-	3	4	8

For the third criterion, Table 9-1 shows that none of the existing DATs has responded to all the DAIs in delay claims, while the proposed technique is able to achieve this. The proposed technique shows the capability for considering the DAIs, which are: direct delay, the effect of change order, acceleration impact and the responsibility of indirect delays, such as the delays due to resource levelling, PFMD and productivity loss. Further, it considers the issue of real-time, concurrent delays, concurrent effects, pacing delays, total floats, the retrieval days and acceleration credit as well as the effect of any possible damages at the activity-level and project-level.

Table 9-2: A comparison between DATs in considering DAIs

DATs	Stage 1						Stage 2								
	Responsibility for the impacted Events						Delay Analysis Issues							Damages and losses at	
	Direct Delay	Change Order	Acceleration Impact	Resource Levelling	PFMD	Productivity Loss	Real-Time	Concurrent Delays	Acceleration Credit	Concurrent Effects	Pacing Delays	Total Floats	Retrieval Days	Project-level	Activity-level
As-Planned	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
As-Built	✓	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
Impacted As-Planned	✓	×	×	×	×	×	✓	×	✓	×	×	×	×	×	×
Time Impact	✓	×	×	×	×	×	✓	×	✓	×	×	×	×	×	×
But-For	✓	×	×	×	×	×	×	✓	×	×	×	×	×	×	×
Window Analysis	✓	×	×	×	×	×	✓	✓	×	×	×	×	×	✓*	×
Total Float Management	✓	✓	✓	×	×	×	✓	✓	✓	×	✓*	✓	×	✓*	×
Proposed Technique	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

* Less accurate

Accordingly, it can be argued that the only delay analysis technique that meets the above three criteria is the proposed technique, which can be used in construction delay claims for producing more accurate and reliable analysis results. Thus, the proposed technique is the only technique that has the capability of analysing the responsibility of any potential loss or damage at the activity-level. This is based on its approach in tracking each impact that occurred in each activity and affected the D or push the ES. Further, the proposed technique is the only technique that has the capability of analysing the retrieval day of each impact such that the losses or damages can be identified to a specific impact and therefore to the responsible party. The proposed technique is also the only technique that has the capability for considering the issue of concurrent effects, pacing delays and acceleration during the analysis process. Moreover, the proposed technique follows the day-by-day approach, which increases the accuracy of the analysis and the results.

9.2.1 Experts' Opinions

As discussed in Section 5.3.5, the validity of the proposed technique by using the experts' opinion is based on some criteria that have been set to determine the capability of the proposed technique for overcoming the DAIs and its efficiency in producing a reliable result of the delay claims. Thus, the experts' opinions will be used as a validation method to ensure the proposed technique's accuracy, completeness, comprehensibility and cost-effectiveness. To fulfil this requirement, a questionnaire survey has been developed to seek the experts' views and comments on the proposed technique. Further, a video has been presented on an online page (YouTube), along with the validation questionnaire on an online page (Google Forms) to show the idea of the framework and the gap of knowledge in delay claims analysis, together with a worked example to clarify its application process. The questionnaire survey also made a provision for experts to express their comments on the technique—on specific aspects of it or in general. A copy of the questionnaire is set out in Appendix (II).

9.2.2.1 Selecting the Experts and Respondents

The same criteria that were set for the participants in the primary questionnaire survey have been considered for the experts who will participate in this validation method. The first criterion is that the participants must have knowledge regarding the topic of project delays, project disruptions, or schedule analyses. The second criterion is that the participants must have a relatively high level of skill, knowledge or experience into construction claims. Thus, the experts were selected from the list of practitioners who responded to the previous questionnaire survey based on the following criteria: relevant expertise, relevant experience and professional qualifications.

The use of the previous survey's respondents list has two main advantages. Firstly, most of the practitioners in this list were individuals in senior positions from construction and consulting firms with relevant expertise and experience in delay claims analyses, preparations and assessments. Secondly, their prior involvement in the earlier survey makes them familiar with this research, which will ensure a reasonable response rate. These advantages will give more reliable results in the validation process of the proposed technique by the experts' opinions.

Before sending out the questionnaire, emails were sent to the experts requesting for their kind assistance in the validation exercise. Following this, a brief description of the model incorporating the working example was sent out via email to 20 selected experts. The email also included the validation questionnaire and a cover letter, which state the purpose of the research, the validation process and what was expected from them.

Out of the 20 questionnaires that were sent out to the selected experts, only 6 were returned. Therefore, and due to the low response rate, the questionnaires were sent back again to another 37 participants who know of delay claims. Out of those 37 questionnaires, 10 responded to the survey

Table 9.3 shows the profile of these experts regarding their organisation, job designation, area of expertise, qualifications and years of experience in delay analysis. As can be seen, the experts are all actively involved in delay analysis within consulting firms specialising in this area of construction discipline. Experts from 1–6 are professional and specialise in delay claims, construction contracts, delay claims analysis and all the subjects related to this research. Most of them have their own business in construction law, construction delay analysis or dispute resolution. Experts 7 – 16 are working in the area of scheduling analysis and project delays. Although their experience is not as much of an in depth knowledge in delay and disruption claims similar to the experts from 1-6, their experience, however, in 1) construction and project management, 2) scheduling and analysis planning and programming and 3) risk management in construction projects, have helped evaluate the method by comparing it with other available DATs. Therefore, and based on the concept of saturation mentioned earlier in Chapter 5, the type and the size of respondents is satisfactory in the reliability for the validation process of the proposed technique.

Table 9-3: Profile of the validation experts

No.	Organisation	Designation	Expertise	Years of experience
1	Construction law and Dispute resolution firm	Director	Construction Delay Analysis	33
2	Construction law and Dispute resolution firm	Attorney at Law	Construction Delay Analysis	+40
3	Construction law and Dispute resolution firm	Senior Advisor	Construction Delay Analysis	38
4	Construction law and Dispute resolution firm	Managing Director	Construction Delay Analysis	+10
5	Construction law and Dispute resolution firm	Associate Director	Construction Delay Analysis	+25
6	Academic organisation	Academic and researcher	Construction Delay Analysis	+15
7	Construction Consultancy	Associate Director	Schedule Analysis	35
8	Dispute resolution firm	Senior Engineering	Schedule Analyst	+10
9	Dispute resolution firm	Advisor	Project Management	30
10	Construction Consultancy	Project Manager	Planning and programming	33
11	Construction Consultancy	Construction scheduling expert	Schedule Analyst	+10
12	Construction and development organisation	Director	Contracts Advisor	28
13	Construction and development organisation	Consultant	Project Management	21
14	Construction and development organisation	Project Manager	Planning and programming	10
15	Construction and development organisation	Project Manager	Planning and programming	+10
16	Construction and development organisation	Reginal manager	Project Management	27

9.2.2.1 Results Discussion for Technique's Evaluation

As mentioned previously, the respondents were asked in a structured, semi-closed questionnaire to comment on the model. In addition to offering ticked-box responses, some of the experts provided their comments about the proposed technique. All the responses received were, in no small extent, positive. A summary of the responses to the various questions in the questionnaire is set out, as shown in the Figures 9-1 to 9-8.

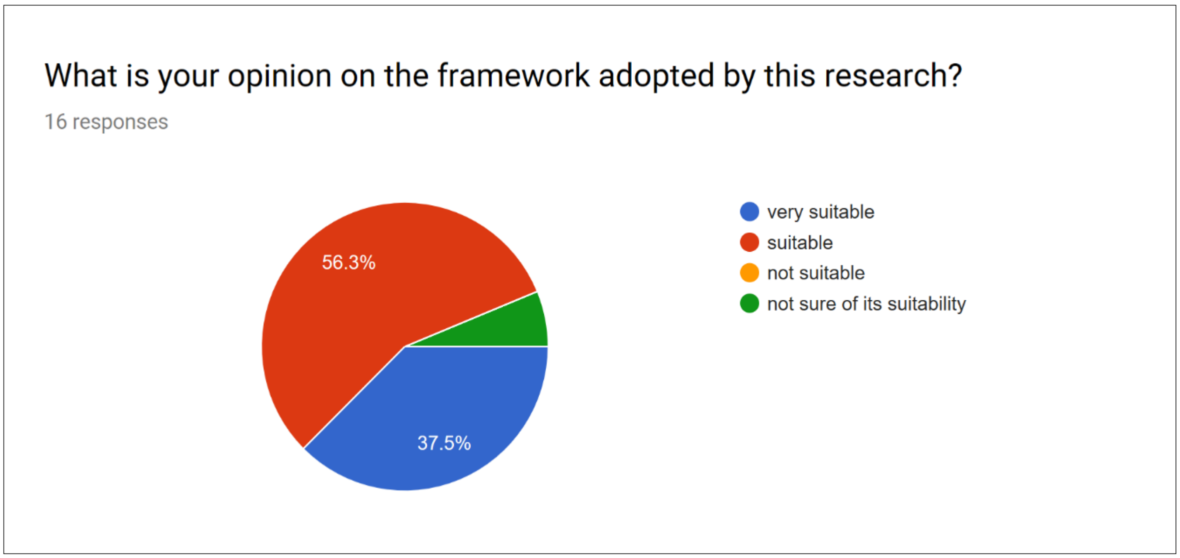


Figure 9-1: Responses to the adopted framework of delay and disruption claims

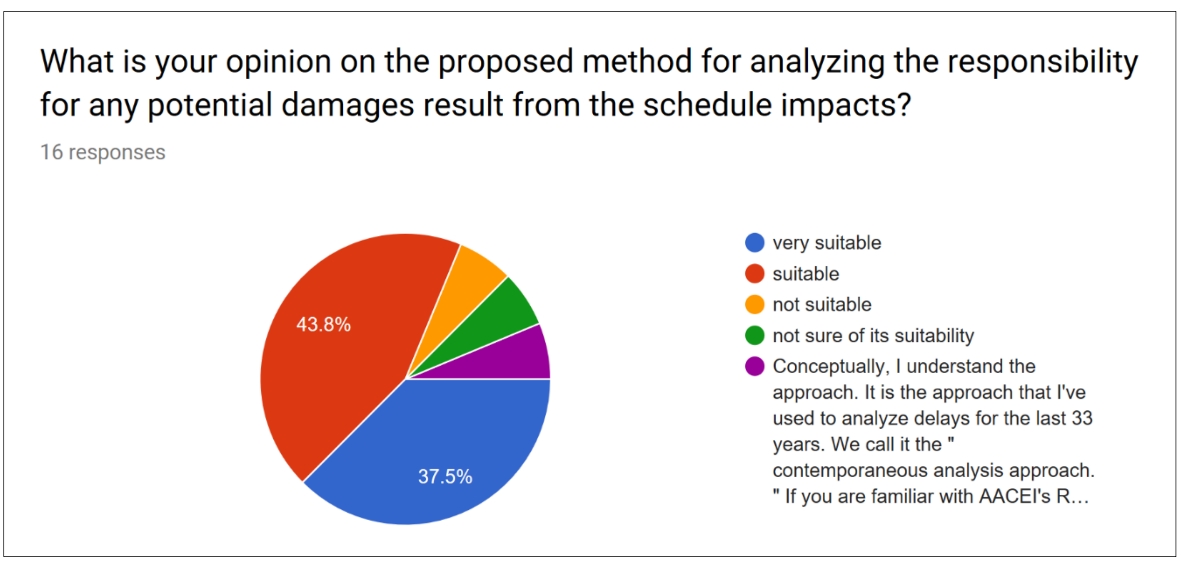


Figure 9-2: Responses to the proposed technique for delay claims analysis

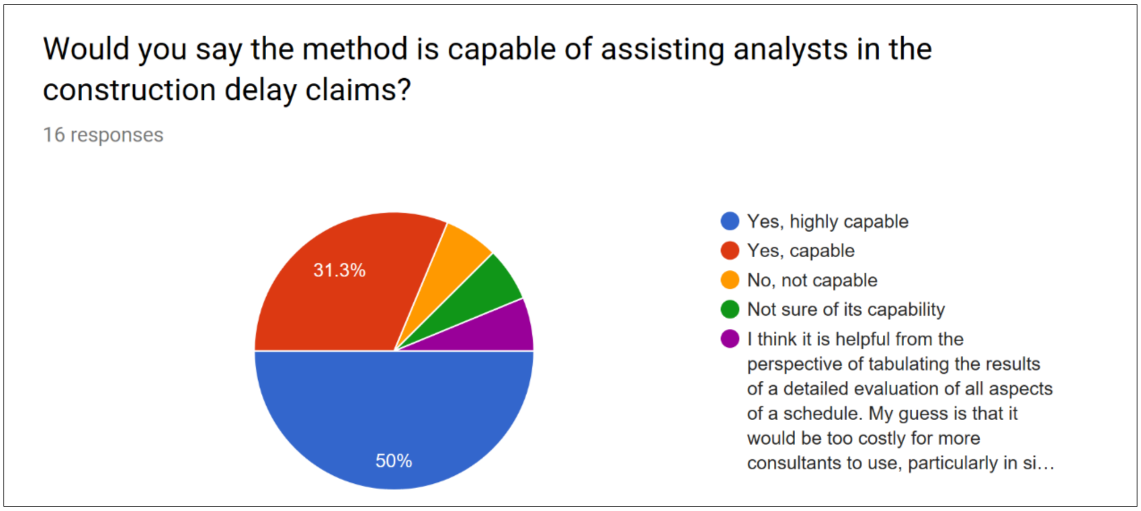


Figure 9-3: Responses to the clarity and understanding of the proposed technique for the practitioners

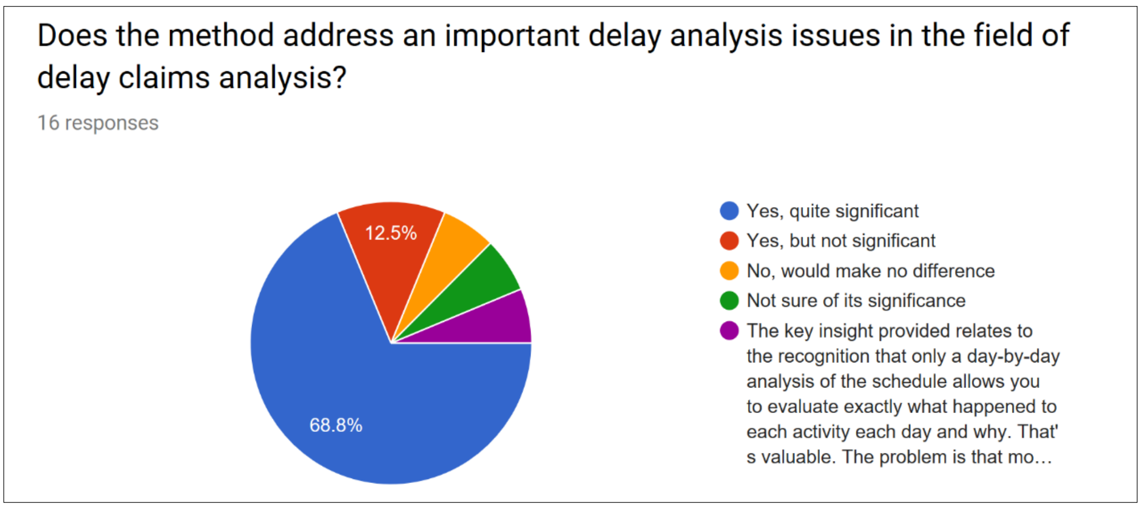


Figure 9-4: Responses to the DAIs that have been addressed in the proposed technique

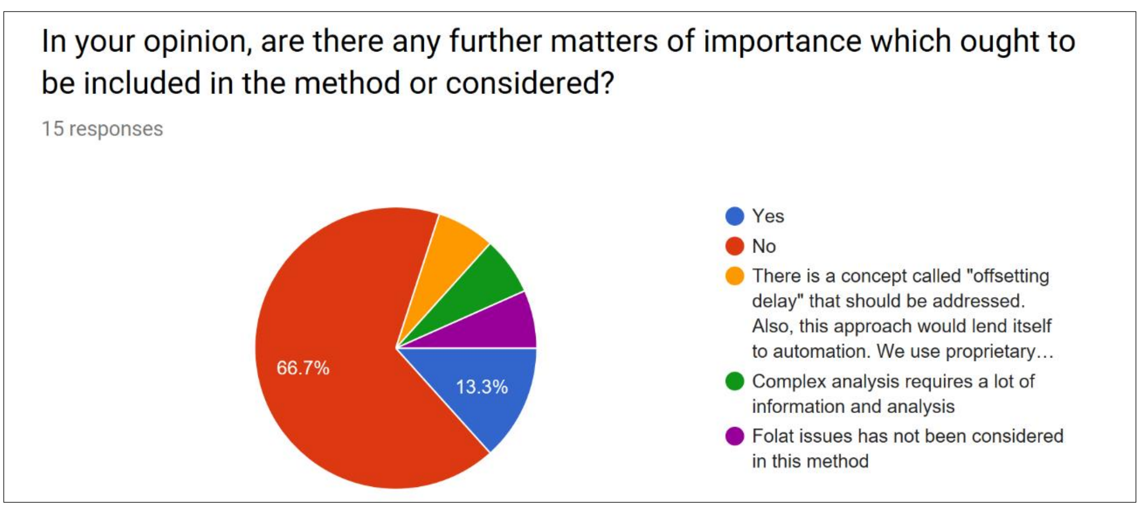


Figure 9-5: Responses to the overall lack in the processes of the proposed technique

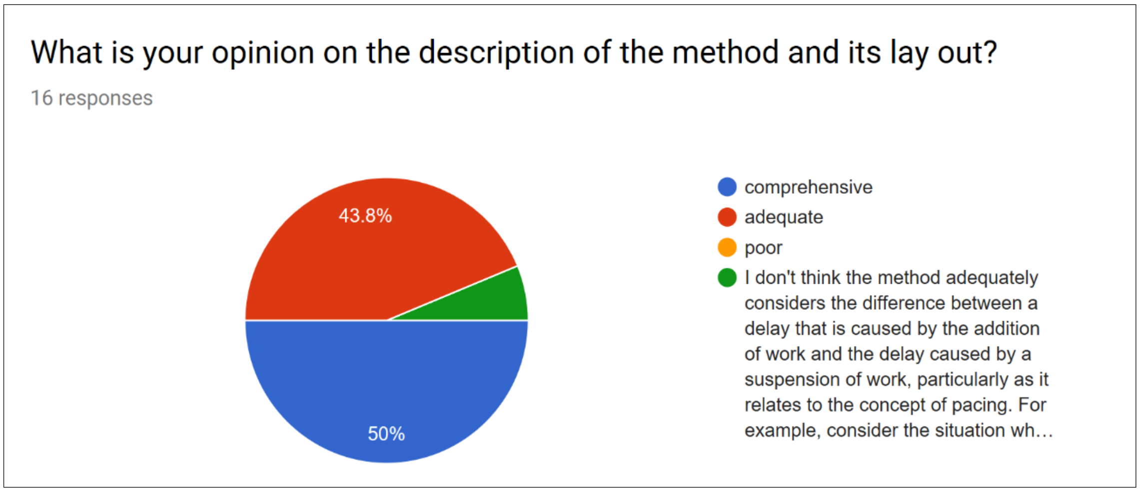


Figure 9-6: Responses to the description and flowcharts of the proposed technique

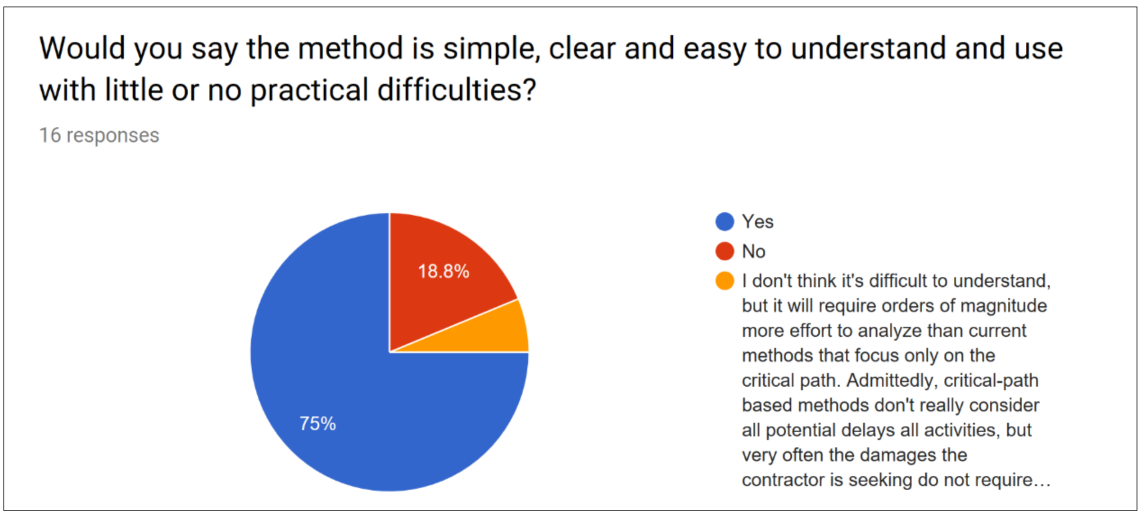


Figure 9-7: Responses to the clarity and understanding of the proposed technique for the practitioners

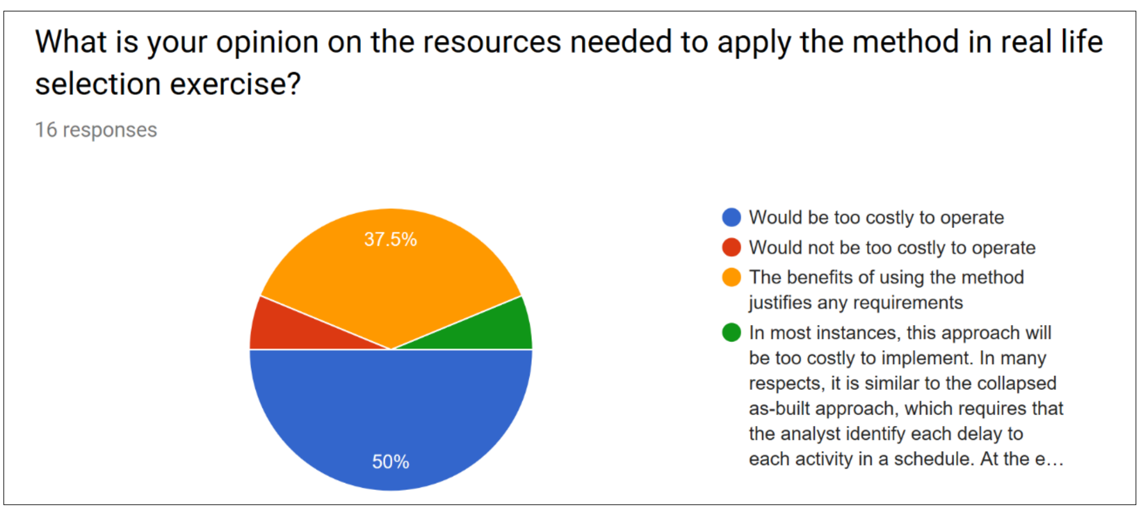


Figure 9-8: Responses to the applicability of the proposed technique in real life of construction claims

These figures provide that the majority of experts agreed on the effectiveness of the proposed technique and its applicability in delay claims analysis. In responding to the four criteria that have been set in the validity survey to verify the capability of the proposed technique, the following results discuss the experts' opinions based on the following criteria:

- Accuracy - does the proposed technique have the potential to be used in construction delay claims?
- Completeness – does the proposed technique include all crucial issues that required to be overcome in the delay analysis?
- Comprehensibility – is the technique simple and understandable to the intended users?
- Cost-effectiveness – does the cost involved in implementing the technique outweigh its potential benefits?

For the first criterion (the accuracy of the proposed technique), Figure 9-1 shows that 93.8% of the experts evaluated the adopted framework as suitable or very suitable. Further, Figure 9-2 shows that 81.3% of the experts agreed on the capability and suitability of the proposed technique regarding the analysis of any potential losses and damages as the result of the schedule impacts.

For the second criterion (the completeness of the proposed technique), Figure 9-3 shows that 81.3% of the experts evaluated the proposed technique as capable or highly capable for assisting the schedule analysts in construction delay claims. Additionally, Figure 9-4 shows that 81.3% of the experts agreed that the proposed technique had addressed essential DAIs in the field of delay claims. Figure 9-5 also shows that 66.7% of the experts expressed their satisfaction regarding the completeness of the processes in the proposed technique.

For the third criterion (the comprehensibility of the proposed technique), Figure 9-6 shows that 93.8% of the experts expressed the description of the proposed technique and its layout as adequate or comprehensive. Further, Figure 9-7 shows that 75% of the experts agreed that the proposed technique is simple, clear and easy to be used on the delay claims analysis.

For the fourth criterion (the cost-effectiveness of the proposed technique), the experts express their concern regarding the implementation cost for the proposed technique in real-life projects. Although Figure 9-8 shows that 50% of the experts considered the proposed technique to be a costly implementation, 37.5% justified the benefit of using the proposed technique even with the high cost of resource requirement.

9.3 Limitations on the Validity of the Proposed Technique

The best method for validating the proposed technique is to implement its processes to a real-life project. Also, testing the general feasibility of any DAT is by performed its processes to many companies that work in the delay claims analysis. However, it has not possible to adopt these validation methods in this research due to the time consumed by the implementation of the proposed technique to a real project analysis.

For validating the proposed technique and its significance in practice, an alternative means was to have the method evaluated by a select group of experts. This was considered the most appropriate method due to the experts' knowledge regarding its adequacy and applicability in the construction claims and its significance in practice. Thus, the experts' opinions were found to be the most applicable and suitable method for validating the proposed technique and meeting the research aim, which was considered advantageous with regards to value, time and accuracy.

9.4 Summary

This chapter reports the validation of the adopted framework and the proposed technique. The validation process involved, first, the application of the model to a hypothetical case study. This example application, together with a description of the framework and method, was then posted to acknowledged delay analysis experts for their opinions on the significance of the framework and the method, its adequacy, completeness, comprehensibility and effectiveness. Out of 57 experts who were sent questionnaires for the validation, only 16 responded.

The majority of the experts were in favour of the method indicates that the framework and the method is a positive contribution to the subject of delay analysis in construction claims. The central reservations expressed regarding the method concerned a potential difficulty of implementing the method due to its cost-effectiveness. Further, there is some lack of agreement among practitioners as to the definition of some DAIs.

CHAPTER TEN: CONCLUSIONS AND RECOMMENDATIONS

10.1 Introduction

This research has aimed to build a framework and method for analysing the construction delay claims to overcome most issues of schedule impacts and reduce the delay claims. This aim has been achieved through the completion of the six stages detailed in the thesis. Five significant stages were designed to achieve the aims and objectives of the research: 1) comprehensive review of the literature; 2) documentary analysis of the court cases in construction delay and disruption claims; 3) questionnaire to investigate the current practice and explore best practice; 4) framework building and validation; 5) method developing and 6) method validation. Ontologically, the research views that the phenomena (i.e. processes of construction delays and claims analysis) are a real fact and that knowledge comes from experience. For obtaining and collecting the research data, the data are considered appropriate regarding this phenomenon, as per the involved experts and court cases in delay and disruption claims. Empiricism is adopted in this research since the study is building a theory based on experience and good practice. This chapter serves to summarise the evolution of the research and emphasise the significant findings. It concludes the research and details of the findings that have been obtained regarding the stated objectives. Further, it presents the limitations of this research and makes recommendations for future research. Finally, the contributions to the field of knowledge are also highlighted in this chapter.

10.2 Meeting the Aim and Objectives

The research was intended to develop a reliable and valid framework and method for analysing project delays in construction claims. The aim has been achieved by meeting four objectives.

Each object is assigned to a separate stage and presented in a specific chapter, as shown in Figure 10-1.

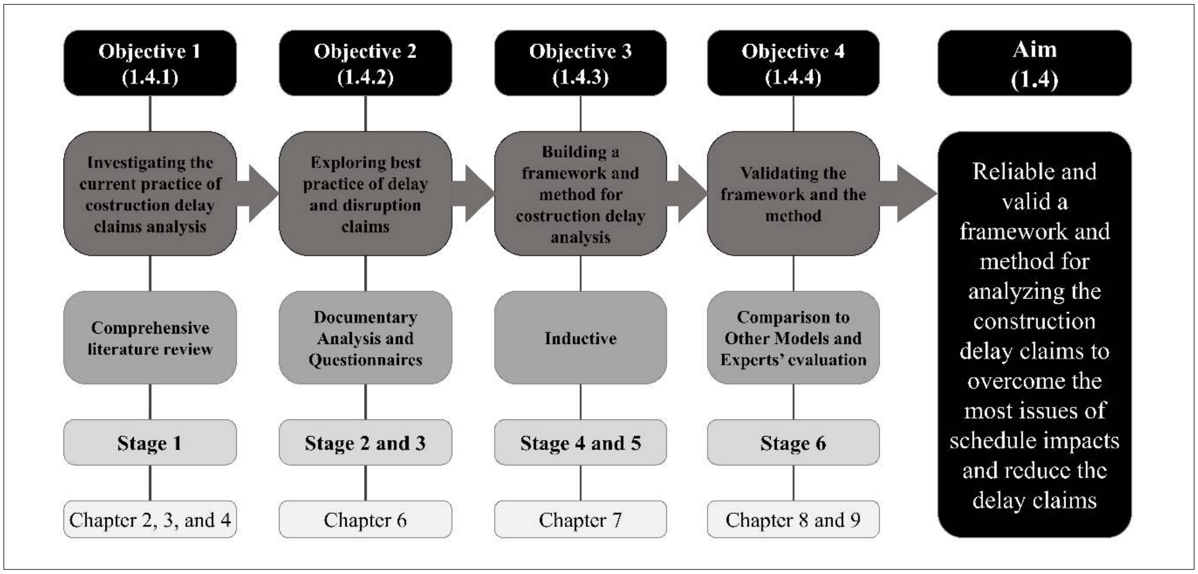


Figure 10-1: Research objectives in their relations to the stages and chapters

10.2.1 Objective One: Investigating the Current Practice

For understanding the concept of delay and disruption claims, there was a need for a comprehensive review of the literature. The purpose is to provide insight to evaluate the theoretical concepts and legal principles in the analysis of the schedule impacts and investigate the current DAIs and the existing DATs. It also helps to define the gap of knowledge and identify the appropriate methodologies to undertaking the research. This stage set out to investigate the current practice of construction delay claims analysis. The following conclusions can thus be drawn from this stage.

Generally, construction projects can be affected by many causes, which lead to delay and/or disruption. The are many factors have been addressed to analyse the schedule due to the project disruptions and delays, and therefore allocate the time overrun and cost overrun to the responsible parties. Thus, many DATs have been introduced to achieve this objective.

However, none of them existing DAT has widely accepted in delay claims analysis due to the current DATs.

10.2.2 Objective Two: Exploring the Best Practice

This stage set out to explore the best practice of delay and disruption analysis in construction claims. Data was collected from many court cases with the opinions from the practitioners in delay claims analysis. The court cases have analysed based on the claims types, which leads to identifying a new DAIs. For more effective results in the research, it was decided to survey the issues of delay analysis with the expertise in delay claims analysis. The answer was provided by the 34 practitioners using a close-ended questionnaire survey. The following conclusions can thus be drawn from this stage.

The evidence from this study suggested that some of the current DATs not consider in the existing DATs. Also, some of delay and disruption claims have not identified in any DAT. One of the most significant findings to emerge from this stage is that the disruption and delay both may have the same impact on the schedule, but their effect in term of losing time and money is entirely different. Also, the analysis of delay and disruption currently is lacked in addressing significant factors that should be considered before any time and/or cost compensation can be decided, which will minimise the construction claims disputes.

10.2.3 Objective Three: Building A Framework and Technique

The framework and the technique were constructed and developed based on the results obtained from the documentary analysis and questionnaire analysis. The building processes commenced with the presentation of the conclusion for every issue in delay claims analysis. The approach to developing the method is based on the induction method, using a systematic approach. The framework is presented on three levels: delay claims, disruption claims, and change order claims. It suggested individual steps to form an accumulative framework. The framework claims that no matter how the impact on the schedule has happened, without losing time or losing money as a direct effect, the claiming party will not benefit from this framework. This approach formed the proposed technique based on losing time.

Based on the results obtained from the adopted methods, the loss of time may result in losing money, which happens on three different levels. The environment of delays analysis in construction claims is influenced by different issues that analyse to allocate the responsible party for losing money challenging to be defined. Thus, the method has considered the current DAIs that affect the analysis result as well as addressed some DAIs that are not existing before in any DAT.

10.2.4 Objective Four: Framework and Method Validation

Since the framework was primarily built based on a small number of cases, it was necessary to find out whether it can be generalisable (applicable and practical) to the delay claims. Some factors were considered early on in this project. These included using a randomly selected sample in the survey. Choosing a sample of experts and practitioners in construction delay claims is the best possible process for the validating the framework and method to assess the capacity to utilise the method in construction delay claims. A further step was taken to test the generalisability of the framework by comparing the results of the proposed technique with the results of the existing DATs. The results have indicated that the framework and the method and its components are applicable and valid.

10.3 Limitations of the Research

Proper research usually focuses on a particular area, evaluating a pre-determined context and seeking accomplishment through understanding the subject matter. The proposed framework and the proposed technique have some constraints:

- Although the framework was built based on the best practice of delay and disruption claims, the method is limited to the delay claims. Therefore, the disruption claim is only considered to understand the context. It means that the method can be used to track any potential loss of money due to the loss of time, but not the loss of money that is not based on time loss.
- It is essential to use productivity baseline programmes, as such programmes provided for reliable task duration for the project activities. Without taking such programming requirements into account in the analysis, the baseline programme would not adequately reflect the plan of work as dictated by the actual loss of productivity during the schedule impacts, thereby leading to results that are not accurate nor trustworthy.
- The proposed technique cannot measure the disruption claims without considering resource programming during the analysis process.

10.4 Value of the Findings

The empirical findings in this research provide a new understanding of delay and disruption claims. It provides a cumulative perspective on the issues that are related to delay and disruption analysis. The findings of the research are interpreted in the framework and the proposed technique as the basis of the outcome of the research project. The practical benefits of the framework and the proposed technique are as follows:

- Provide processes for the construction industry, enabling them to minimise the construction claims disputes.
- The proposed technique relies on the appropriate input data which consists of the as-planned schedule, as-built schedule and update schedules, as recommended in the current practice, by using the theory of logic-driven CPM to measure any effect on the schedule. It is designed to create more awareness among researchers and industry practitioners when dealing with real-life construction projects.
- The best accuracy that analysts can hope to achieve is an objective reflection of the facts as represented in the project documents and data. Second, it considers the level of accuracy as a function of the quality of the data used herein, the accuracy of the assumptions, and the subjective judgments made by the forensic schedule analysts. Therefore, to enhance the validity of the proposed technique, the study followed the recommended protocol's requirements in delay and disruption analysis to ensure its acceptability and practicality amongst practitioners and researchers.
- The DAIs that affect the outcome of the analysis have been considered in the developed method.

10.5 Contribution to Knowledge

The findings from this research make several contributions to the current literature. These contributions include the following:

- The research has contributed to enhancing the delay and disruption claims analysis by identifying some DAIs that have not been addressed in any DAT.
- The research has also contributed to providing a deep understanding of the current DATs that can be used in delay and disruption claims analysis. It also identifies the most DAIs

that have a sufficient impact on the analysis results. This can provide a solid ground for future studies to understand the current practice of delay and disruption claims analysis.

- The framework and the technique have been built based on the data collection from documentary analysis of the court cases for delay and disruption claims and the experts in delay and disruption analysis. This typically can ensure the applicability of the collected data for the best practice of delay and disruption claims analysis.
- The proposed technique can be used for measuring any potential losses and damages that may occur due to the schedule impact at the project-level and the activity-level.

10.6 Recommendation for Further Researches

During the progress of the research, many areas were identified as useful subjects of study. The recommendations made in this section were related to the research issues being investigated and the methodology being adopted. This research has prompted many questions that highlight the need for further investigation. It is recommended that future research is to undertake in the following areas:

- Although taking account of resource loading ensures reliable analyses and results, thereby contributing to successful claims resolution, there is very little research done on how this consideration can best be incorporated in DATs. Developing a model to measure the effect of resource conflict due to the activities that share the same resources may eliminate any conflict. This limitation thus calls for the need for further research studies in this area.
- The entire process of how the contracting parties manage and control the information of project delays and disruptions significantly influences the ability to resolve the construction claims amicably but has, so far, received very little attention. This area thus requires further investigation.

- Update the framework and the proposed technique when appropriate to reflect any change in the research.
- The proposed technique calls for programming its processes to facilitate its applicability in practice and overcome any massive expenses during its implementation in real-life projects.

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APPENDICES

Appendix (I): Case Study Analysis

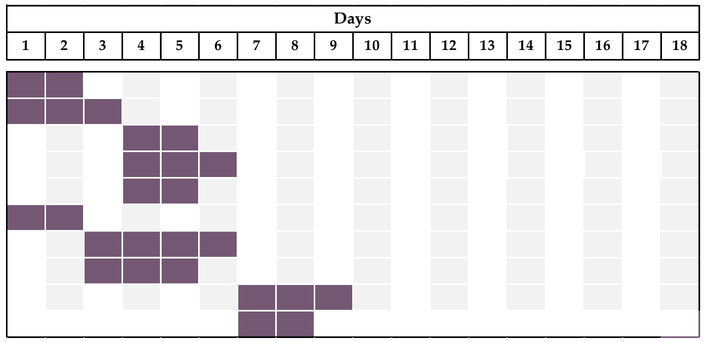
Appendix (II): Questionnaire Survey

Appendix (III): A validation of New Delay Analysis Technique

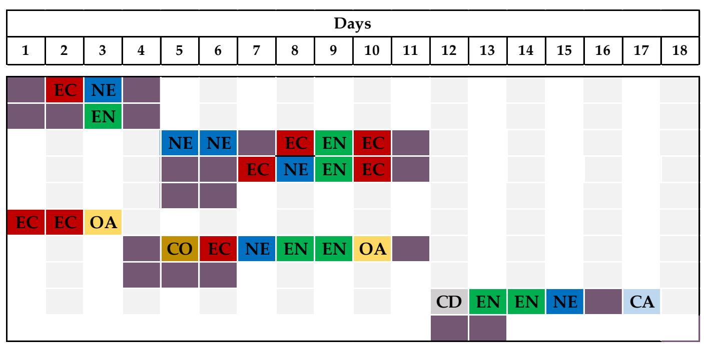
Appendix (I)

Case Study Analysis

Act.	ID	predecessor	successor	Duration
01	A	_	Act. 03&04	2
02	D	_	Act. 03&04	3
03	B	Act. 01&02	Act. 09	2
04	C	Act. 01&02	Act. 09	3
05	E	Act. 02	Act. 09&10	2
06	G	_	Act. 07&08	2
07	H	Act. 06	Act. 10	4
08	O	Act. 06	Act. 10	3
09	M	Act. 03, 04, 05	_	3
10	N	Act. 07, 08	_	2



Act.	ID	predecessor	successor	Duration
01	A	_	Act. 03&04	4
02	D	_	Act. 03&04	4
03	B	Act. 01&02	Act. 09	7
04	C	Act. 01&02	Act. 09	7
05	E	Act. 02	Act. 09&10	2
06	G	_	Act. 07&08	3
07	H	Act. 06	Act. 10	8
08	O	Act. 06	Act. 10	3
09	M	Act. 03, 04, 05	_	6
10	N	Act. 07, 08	_	2



- EC Execusable Compensable Delay (Owner-caused Delay)
- NE Non-Execusable Delay (Contractor-caused Delay)
- EN Execusable Non-compensable Delay (Neither party-caused Delay)
- CD Concurrent Delay (EC and NE)
- CO Change Order (Owner-request)
- OA Owner Acceleration
- CA Contractor Acceleration

1. As-Planned Technique

A. (Gross of Measure)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	A		B	B		M	M	M									
			C	C	C												
D	D	D	E	E													
G	G	H	H	H	H	N	N										
		O	O	O													

I. Owner (EC)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	A	B	EC	EC	B		EC	M	M	M						
			C	C	EC	EC	C										
D	D	D	E	E													
EC	EC	OA	H	CO	EC	OA	H	N	N								
			O	O	O												

II. Contractor (NE)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	NE	A	NE	NE	B	B	NE	M	NE	CA							
			C	C	NE	C											
D	D	D	E	E													
G	G	H	CO	NE	H	H	H	N	N								
		O	O	O													

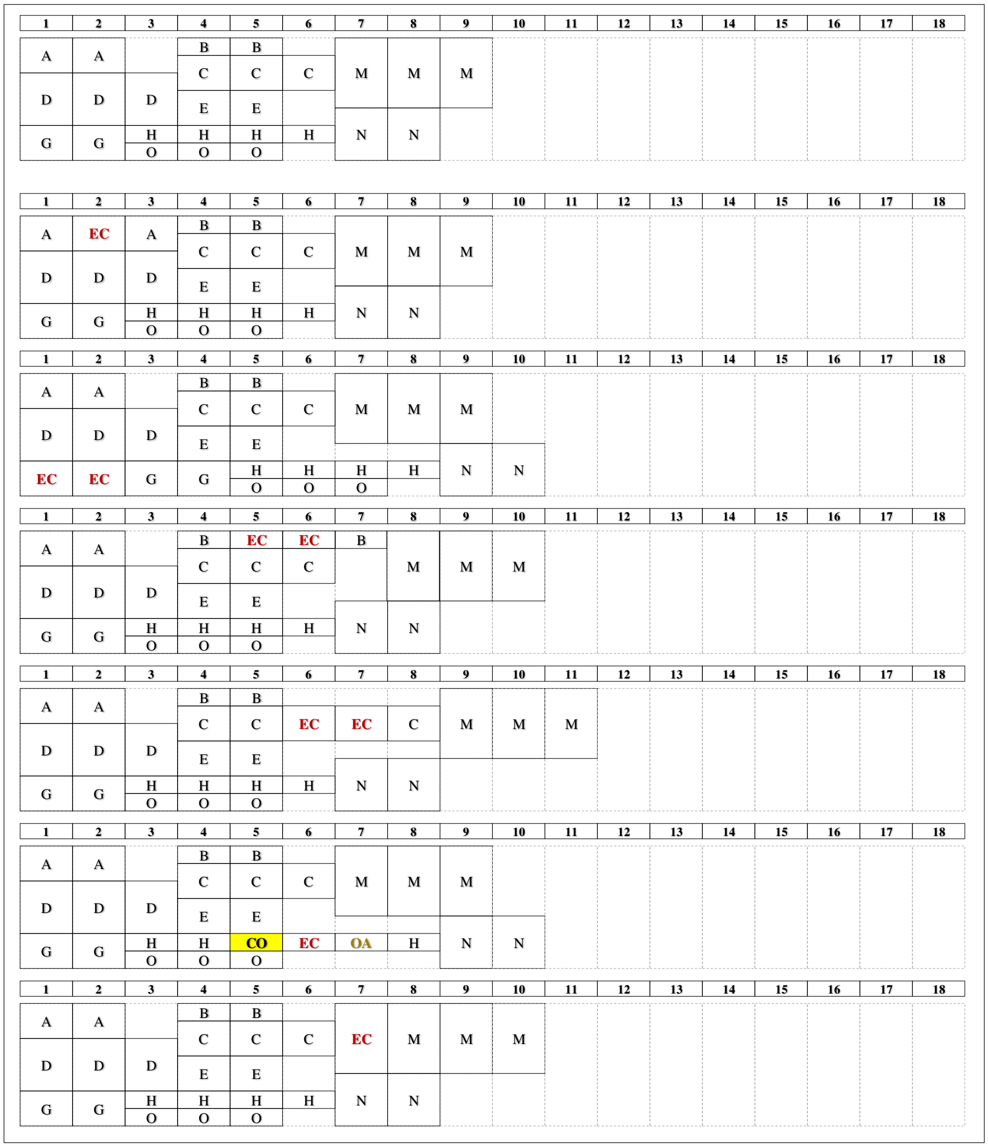
III. Third Party (EN)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	A			B	EN	B		EN	EN	M	M	M					
				C	C	EN	C										
D	D	EN	D	E	E												
G	G	H	CO	EN	EN	H	H	H	N	N							
		O	O	O													

Responsibility	Completion Date		Project Delay
	Before	After Impacted	
Owner (EC&OA)	9	12	3
Contractor (NE&CA)	9	11	2
Neither Party (EN&SA)	9	12	3

1. As-Planned Technique

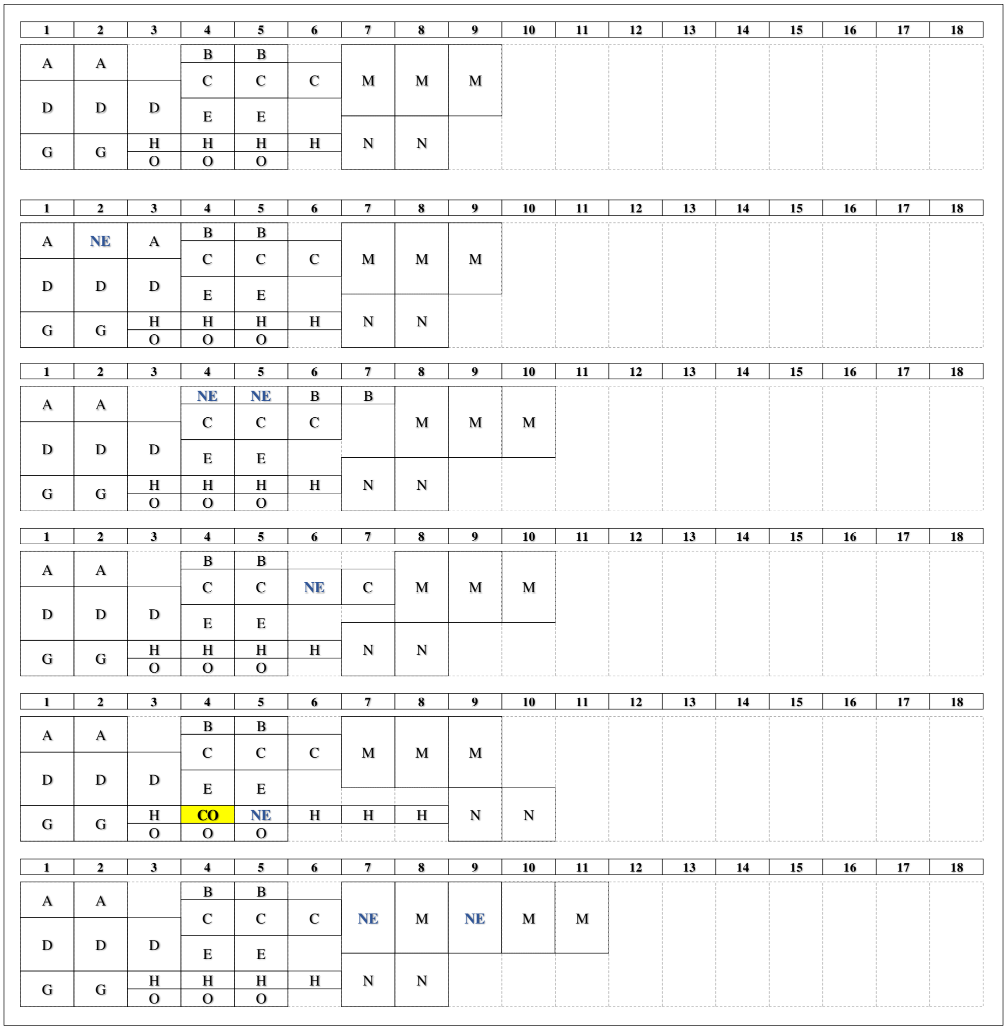
B. (Unit of Measure), I. Owner (EC)



Activity	Impacted Type	Completion Date		Project Delay
		Before Impacted	After Impacted	
A	EC	9	9	0
G	EC	9	10	1
B	EC	9	10	1
C	EC	9	11	2
H	EC	9	10	1
M	EC	9	10	1
G	OA	9	9	0
H	OA	9	9	0
Total Delays				**6**

1. As-Planned Technique

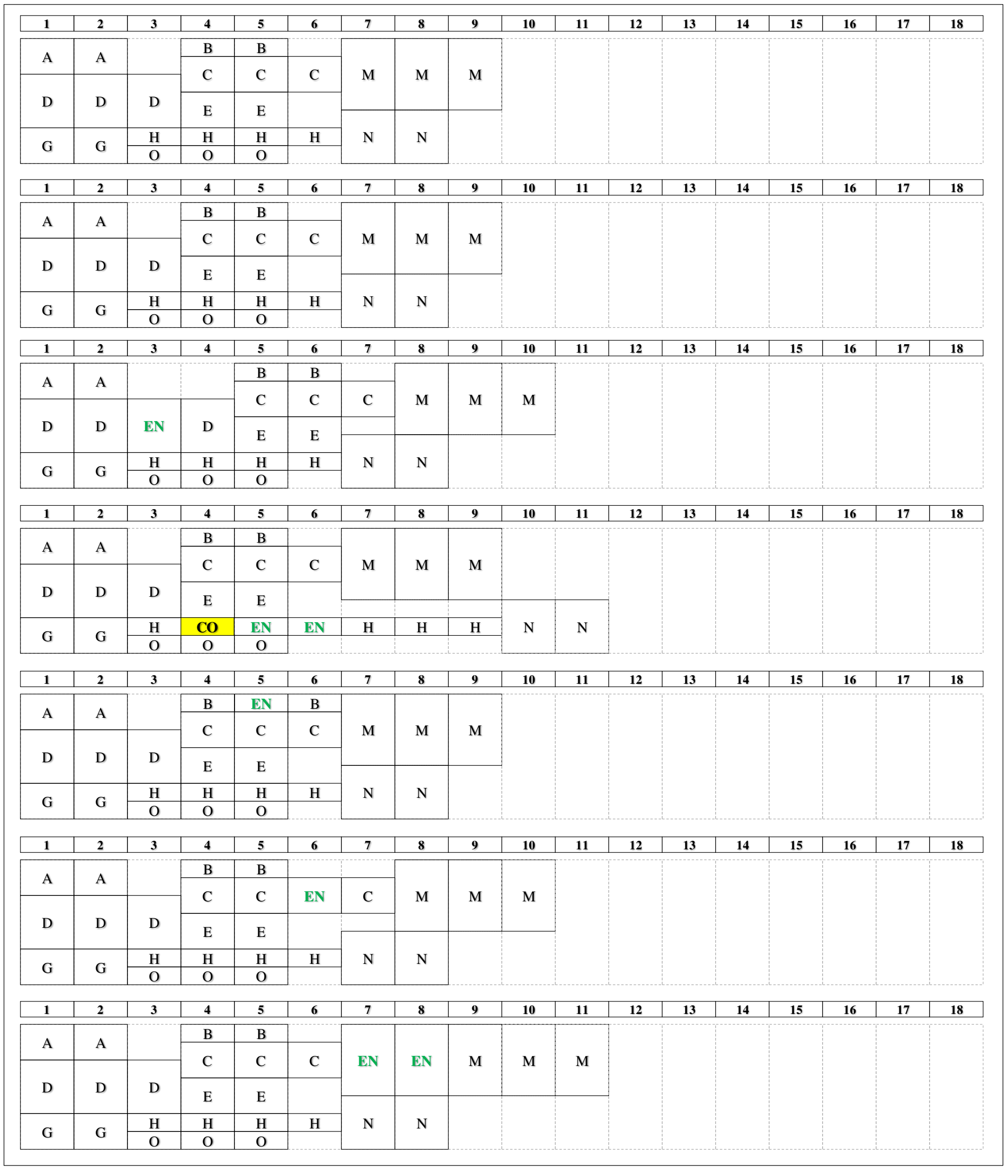
B. (Unit of Measure), II. Contractor (NE)



Activity	Impacted Type	Completion Date		Project Delay
		Before Impacted	After Impacted	
A	NE	9	9	0
B	NE	9	10	1
C	NE	9	10	1
H	NE	9	10	1
M	NE	9	11	2
M	CA	9	9	0
Total Delays				**5**

1. As-Planned Technique

B. (Unit of Measure), III. Neither Party (EN)



Activity	Impacted Type	Completion Date		Project Delay
		Before Impacted	After Impacted	
B	EN	9	9	0
C	EN	9	10	1
D	EN	9	10	1
H	EN	9	11	2
M	EN	9	11	2
Total Delays				**6**

2. As-Built Technique

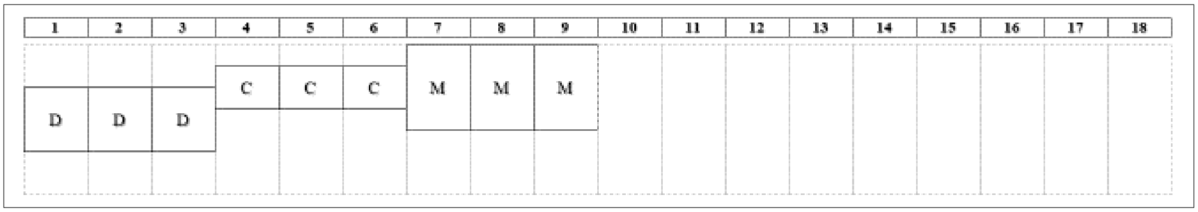
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	A		B	B		M	M	M									
			C	C	C												
D	D	D	E	E		N	N										
G	G	H	H	H	H												
		O	O	O													

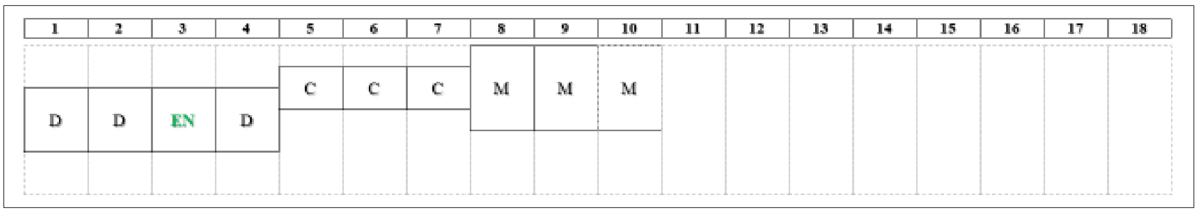
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	EC	EN	EC	B	EC & NE	EN	EN	M	NE	CA	
				C	C	EC	NE	EN	EC	C							
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	EN	EN	OA	H	N	N					
			O	O	O												

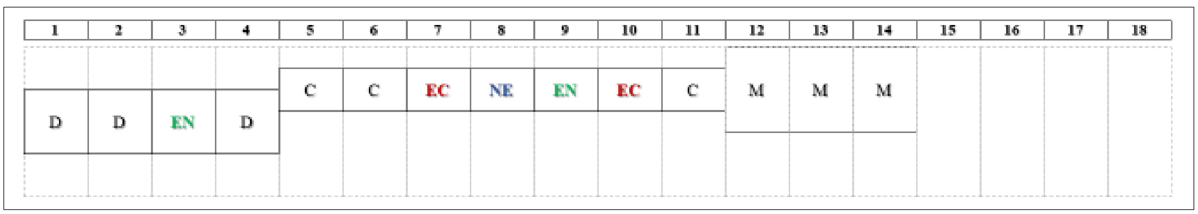
Act.	As-Planned			As-Built			Events		TF	Project Delay
	ES	EF	TF	ES	EF	TF	Day	Type		
01	0	2	1	0	4	0	1 1	EC NE	0 0	0 0
02	0	3	0	0	4	0	1	EN	-1	1
03	3	5	1	4	11	0	2 2 1	EC NE EN	-1 -1 0	1 1 0
04	3	6	0	4	11	0	2 1 1	EC NE EN	-2 -1 -1	2 1 1
05	3	5	1	4	6	5	-	-	-	-
06	0	2	1	0	3	0	2 -1	EC OA	-1 2	1 -2
07	2	6	1	3	11	0	1 1 1 2 -1	CO EC NE EN OA	0 0 0 -1 2	0 0 0 1 -2
08	2	5	2	3	6	5	-	-	-	-
09	6	9	0	11	17	0	1 2 1 -1	CD EN NE CA	-1 -2 -1 1	1 2 1 -1
10	6	8	1	11	13	4	-	-	-	-

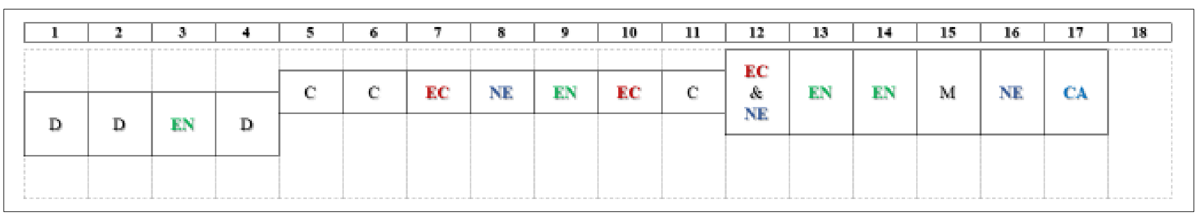
Activity	Delay Type	Project Delays
Total Owner Responsibility		0
Total Contractor Responsibility		2
Total Neither Party Responsibility		5

3. Impacted As-Planned Technique





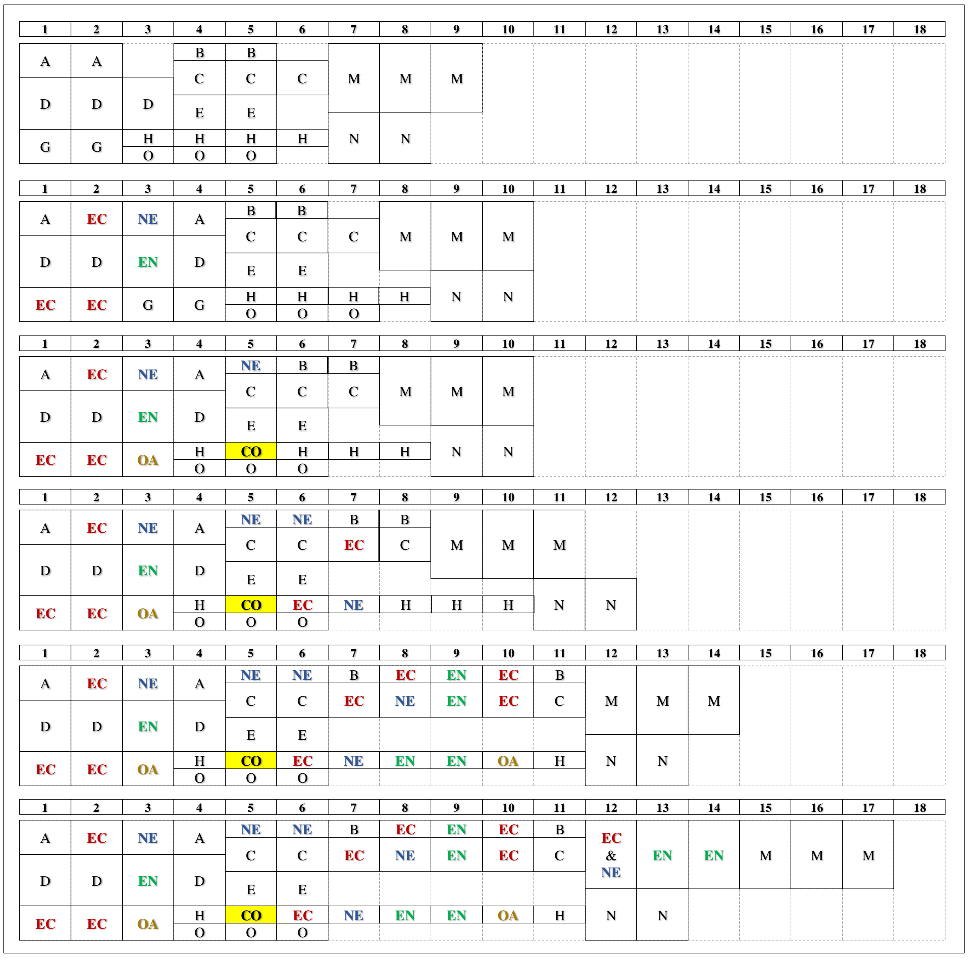




Impacted Schedule	Activity	Events		Project Completion		Project Delay
		Type	Day	Before	After	
1	02	EN	1	9	10	1
2	04	EC	1	10	11	1
3		NE	1	11	12	1
4		EN	1	12	13	1
5		EC	1	13	14	1
6	09	CD	1	14	15	1
7		EN	2	15	17	2
8		NE	1	17	18	1
9		CA	1	18	17	-1

Activity	Delay Type	Project Delays
Total Owner Responsibility		2
Total Contractor Responsibility		1
Total Neither Party Responsibility		4

4. Time Impact Technique

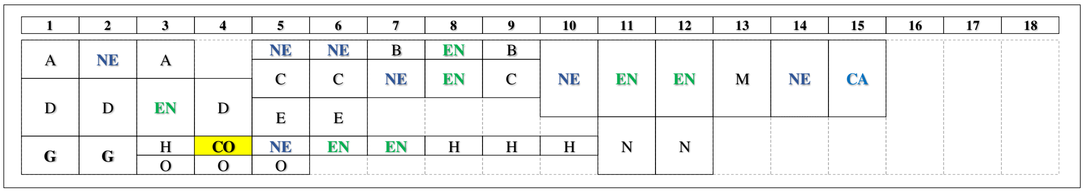


No.	Activity	Delay Type	Delay Day	Project Completion Date Before	Project Completion Date After	Project Delay
1	06	EC	2	9	10	1
		OA	1	10	9	-1
2	01	EC	1	9	9	0
		NE	1	9	10	1
3	02	EN	1	10	10	0
4	07	CO	1	10	10	0
		EC	1	10	11	1
		NE	1	11	12	1
		EN	2	12	14	2
		OA	1	14	13	-1
5	03	NE	2	13	13	0
		EN	1	13	13	0
		EC	2	13	14	1
6	04	EC	2	14	14	0
		NE	1	14	14	0
		EN	1	14	14	0
7	09	CD	1	14	15	1
		EN	2	15	17	2
		NE	1	17	18	1
		CA	1	18	17	-1

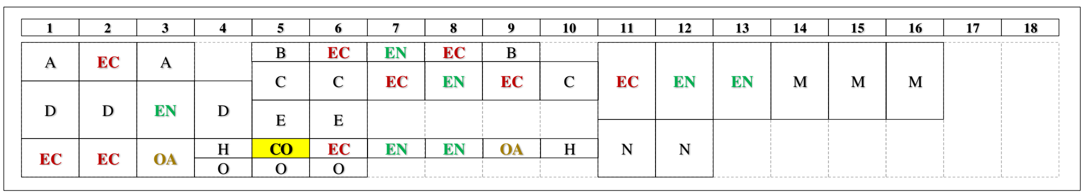
5. But-For Technique

A. Gross of Measure

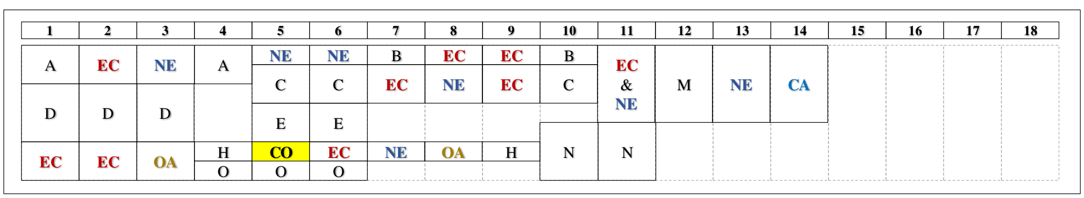
I. Owner (EC)



II. Contractor (NE)



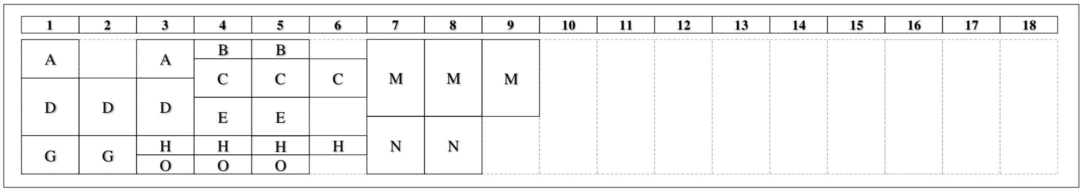
III. Neither Party (EN)



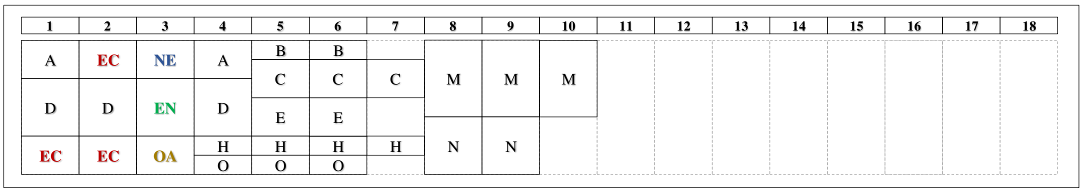
Activity	Project Completion Date		Delay
	Before Collapsed	After Collapsed	
Owner	17	15	2
Contractor	17	16	1
Neither Party	17	14	3
Total Project Delays			**6**

6. Window Analysis Technique

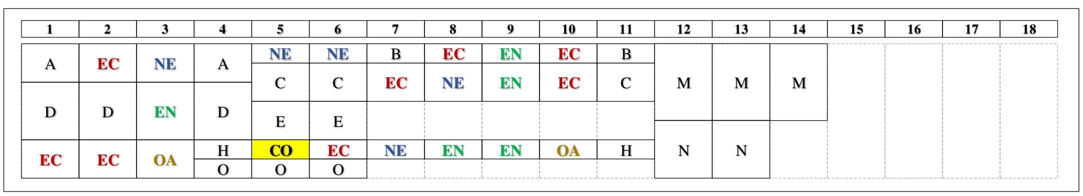
Window No.0



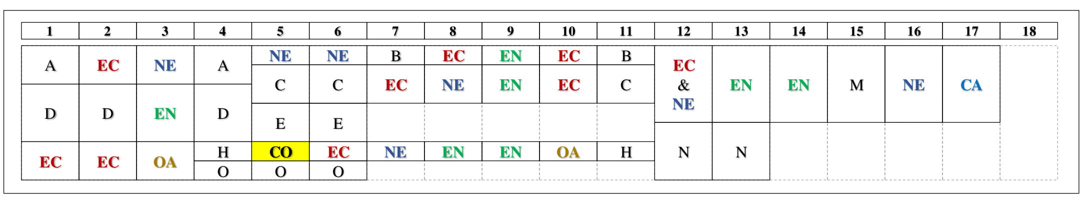
Window No.1-3



Window No.4-11

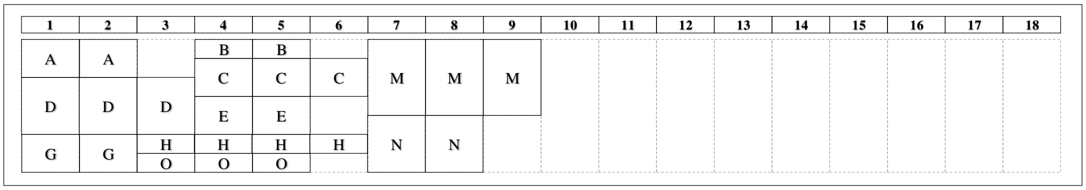


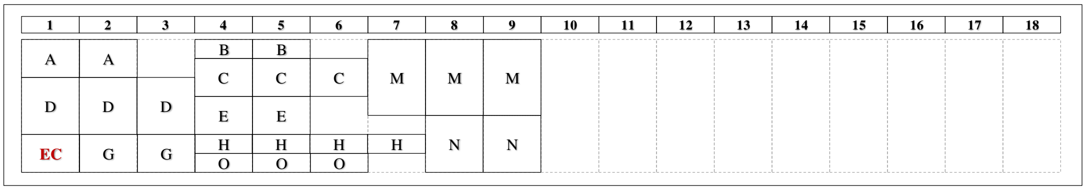
Window No.12-17

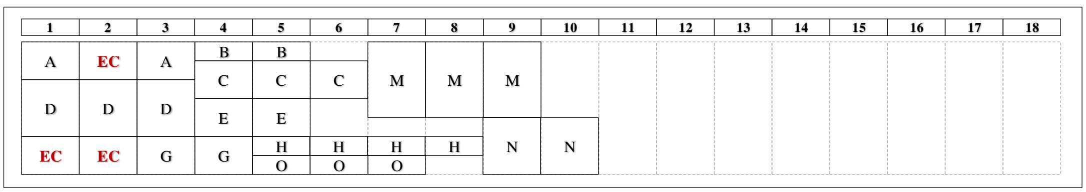


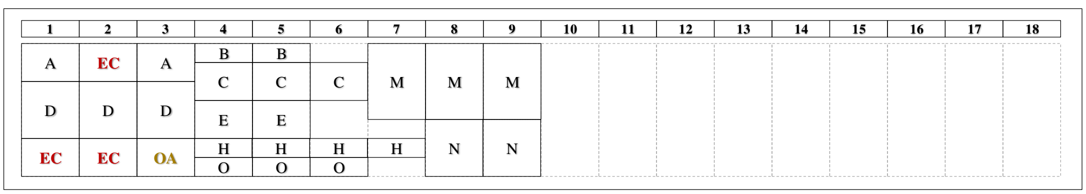
Window Day No.	Schedule Update	Completion Date	Delay			
			EC	NE	EN	Concurrent
0 (start)	0	8	-	-	-	-
1	8	9	-	-	-	-
2	9	10	1	-	-	-
3	10	10	-	-	-	-
4	10	10	-	-	-	-
5	10	10	-	-	-	-
6	10	11	-	-	-	1
7	11	12	-	1	-	-
8	12	13	-	-	1	-
9	13	14	-	-	1	-
10	14	14	-	-	-	-
11	14	14	-	-	-	-
12	14	15	-	-	-	1
13	15	16	-	-	1	-
14-17	16	17	-	-	1	-
Total Project Delays			**1**	**1**	**4**	**2**

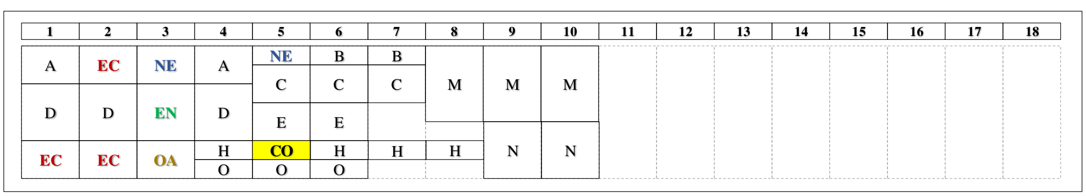
6. Total Float Management Technique

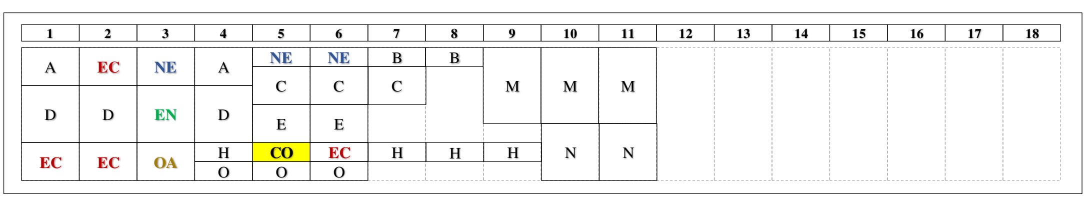


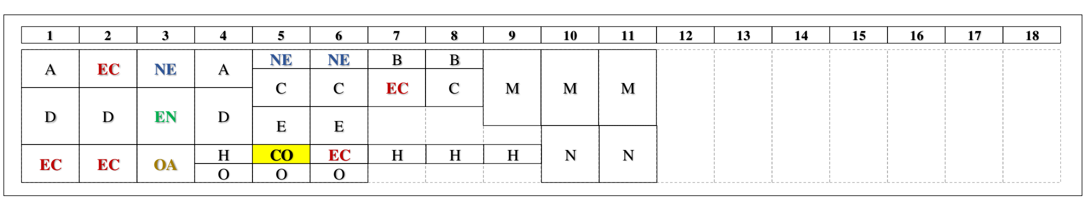












1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	B										
				C	C	EC	C	M	M	M							
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	H	H	H	N	N						
			O	O	O												

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	EC	B									
				C	C	EC	NE	C	M	M	M						
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	H	H	H	N	N						
			O	O	O												

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	EC	B									
				C	C	EC	NE	C	M	M	M						
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	EN	H	H	H	N	N					
			O	O	O												

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	EC	EN	B								
				C	C	EC	NE	EN	C	M	M	M					
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	EN	EN	H	H	H	N	N				
			O	O	O												

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	EC	EN	EC	B							
				C	C	EC	NE	EN	EC	C	M	M	M				
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	EN	EN	H	H	H	N	N				
			O	O	O												

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	EC	EN	EC	B							
				C	C	EC	NE	EN	EC	C	EC & NE	M	M	M			
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	EN	EN	OA	H	N	N					
			O	O	O												

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	EC	EN	EC	B							
				C	C	EC	NE	EN	EC	C	EC & NE	EN	EN	M	M	M	
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	EN	EN	OA	H	N	N					
			O	O	O												

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	EC	NE	A	NE	NE	B	EC	EN	EC	B	EC & NE	EN	EN	M	NE	M	M
				C	C	EC	NE	EN	EC	C							
D	D	EN	D	E	E												
EC	EC	OA	H	CO	EC	NE	EN	EN	OA	H	N	N					
			O	O	O												

Day	Activity	Delay							Total Float	
		Easy Rule				Fair Rule			Owner	Contractor
		EC	NE	EN	CD	EC	NE	EN		
1	06	-	-	-	-	-	-	-	-	-
2	01	-	-	-	-	-	-	-	-	-
	06	-1	-	-	-	-1	-	-	-	-
3	01	-	-	-	-	-	-	-	-	-1
	02	-	-	-1	-	-	-	-1	-	-
	06	+1	-	-	-	+1	-	-	-	-
5	03	-	-	-	-	-	-	-	-	-
	07	-	-	-	-	-	-	-	-1	-
6	03	-	-	-	-1	-	-0.5	-	-	-
	07	-	-	-		-0.5	-	-	-	-
7	04	-	-	-	-	-	-	-	-1	-
	07	-	-1	-	-	-	-1	-	-	-
8	03	-	-	-	-	-	-	-	-1	-
	04	-	-	-	-	-	-	-	-	-1
	07	-	-	-1	-	-	-	-1	-	-
9	07	-	-	-1	-	-	-	-1	-	-
10	03	-1	-	-	-	-1	-	-	-1	-
	04		-	-	-		-	-	-1	-
	07	+1	-	-	-	+1	-	-	-	-
12	09	-	-	-	-1	-0.5	-0.5	-	-	-
13	09	-	-	-1	-	-	-	-1	-	-
14	09	-	-	-1	-	-	-	-1	-	-
16	09	-	-1	-	-	-	-1	-	-	-
17	09	-	+1	-	-	-	+1	-	-	-
Total Delays		**0**	**-1**	**-5**	**-2**	**-1**	**-2**	**-5**	**-5**	**-2**

Appendix (II)

Cover Letter for The Questionnaire Survey

Dear [Name],
a construction expert in the areas of claims,

Subject: Questionnaire for Practitioners regarding Construction Delay Claims

I am a PhD student who is undertaking a research into the development of construction delay analysis. As part of this research, I have designed a questionnaire to investigate an issue in in construction delay analysis.
The questionnaire is available online and can be seen by clicking on the link below:

https://www.surveymonkey.co.uk/r/Construction_Delay_Analysis_Issues

Among the experts in construction delay claim, I am counting on you so much to help me in this survey, through your knowledge and experience in construction delay claims. I know how very busy you might be, but without the contribution of experts like yourself the quest to ensuring improvements in delay claim resolutions cannot be achieved. Also, we hope that the outcomes of this research would serve as a very useful resource to practitioners.

Please feel free to share any comments or feedback you might have on the final page of the questionnaire. If you require additional information or have questions, do not hesitate to contact me.

Best regards,
Your sincerely,

Saud Ayid Alshammari
PhD Candidate

Participants information

Participant information (Optional)

Please enter the following Information in the form below. Summaries and statistical analyses of responses will be presented to the University. Your contact details will be kept strictly confidential

Name:

Organization:

Position:

Address:

City/Town:

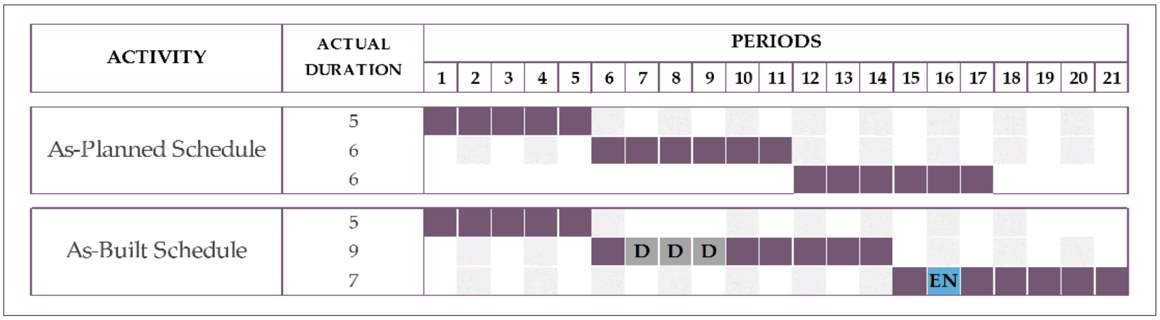
P.O. Box:

Email:

Contact No.:

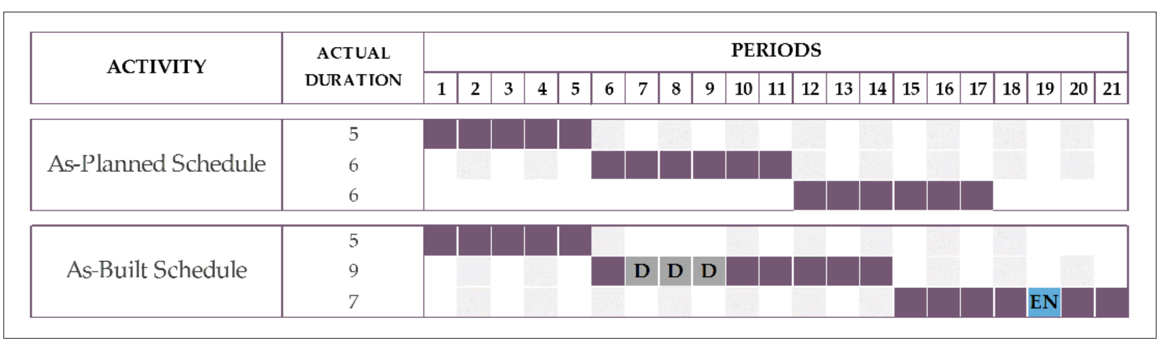
SECTION ONE: Force majeure delay in construction claims

As a visual aid for considering the rights of the contracting parties, Figures 1 & 2 show two scenarios for force majeure delay in a construction project. In both scenarios, the original date for project completion is day 17; however, the project extended up to day 21 due to delay events on days 7, 8, 9 and 16. In scenario A, the force majeure happened during the original agreed contract period on day 16, while in scenario B, the force majeure happened during the extension period on day 19.



Figures 1: Scenario A, force majeure happened during the original contract period

1. To what extent do you agree with the view that: "with or without the delay events on days 7, 8, and 9, the force majeure event that happened on day 16 could not possibly have been avoided by the exercise of ordinary care because day 16 is within the original contract period"?
   - ○ Agree
   - ○ Neither
   - ○ Disagree
   - ○ Other (please specify)



Figures 2: Scenario B, force majeure happened after the original contract period

2. To what extent do you agree with the view that: "the delay events on days 7, 8, and 9 have contributed to extending the project performance into a period after the original date of project completion, on which the force majeure event occurred on day 19"?
   - Agree
   - Neither
   - Disagree
   - Other (please specify)
3. To what extent do you agree with the view that: "the force majeure event on day 19 is preventable and could reasonably have been avoided if the project was completed (as-planned) during the original contract period (on day 17)"?
   - Agree
   - Neither
   - Disagree
   - Other (please specify)

4. To what extent do you agree with the view that: "the force majeure event that happened after the originally agreed contract period (on day 19) is the result of other delays that pushed the project performance beyond the original contractual completion date (day 17) into a period where EN delays (on day 19) are experienced"?
   - Agree
   - Neither
   - Disagree
   - Other (please specify)

SECTION TWO: Concurrent Delays

Concurrent delay is sometimes defined as 'Two or more delay events occurring within the same period, each independently affecting the completion date. In Figure 7, concurrent delay happened due to EC and NE on day 16, which have contributed in extending the original contract period up to day 20.

The above situation is clear for concurrent delay situation which extended the project schedule up to day 20. However, to assign the right party who is responsible in extending the original completion date (one day) up to day 21, the project schedule should be fairly and accurately analyze to reflect exactly what happened to be extended up to day 21 among EC delay [on day 17] and NE delay [on day 19].

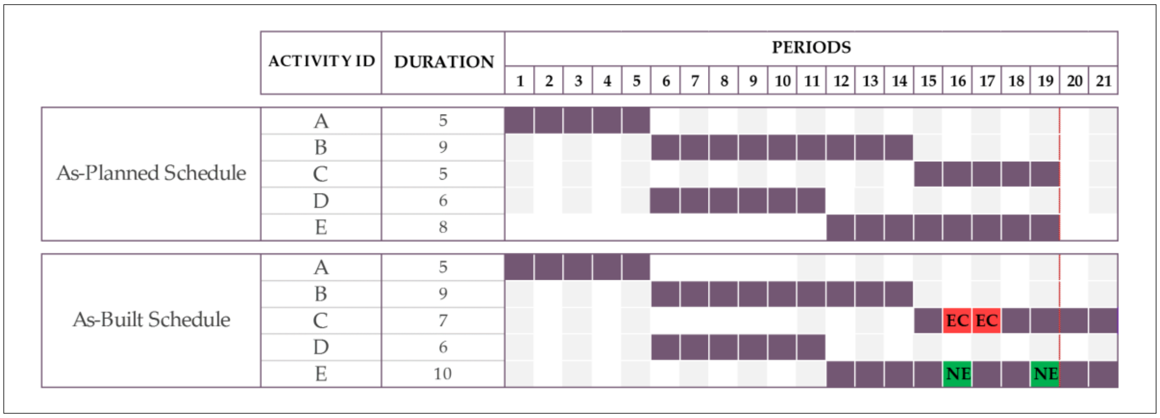


Figure 3: The issues of concurrent delays and concurrent effects in delay claims

5. To what extent do you agree with the view that: "EC delay (on day 17) and NE delay (on day 19) happened at different times, but their effects (at least in part) are felt concurrently"?
   - ○ Agree
   - ○ Neither
   - ○ Disagree
   - ○ Other (please specify)

6. To what extent do you agree with the view that EC delay (on day 17) will form on day of total float on day 21, which will create an issue of pacing delay (because the NE delay on day 19 will get benefit of that?
   - ○ Agree
   - ○ Neither
   - ○ Disagree
   - ○ Other (please specify)

7. To what extent do you agree with the view that EC delay (on day 17) and NE delay (on day 19) are both responsible for day 21?
   - ○ Agree
   - ○ Neither
   - ○ Disagree
   - ○ Other (please specify)

8. Which of the following decisions represents a fair and reasonable approach for apportioning the one-day project delay (day 21) among the contracting parties?
    - ○ Employer is solely responsible for the project delay
    - ○ Contractor is solely responsible for the project delay
    - ○ Neither party
    - ○ Both parties
    - ○ Other (please specify)

SECTION THREE: Pacing Delay

Pacing delays are a type of delay in construction claims that are rather controversial. Pacing delays are, in some instances, legitimate business management decisions. The issue has been addressed by the courts, and a contractor has a legal right to a pacing delay. However, the practical effect of a pacing delay is to decrease the amount of time between the actual end date of the project and the but-for end date.

In Figure 8, an EC delay happened on day 16 and formed one extra day of total float in paths (A-D-E). In path (A-D-E), the contractor noticed that there are two days of total floats (one from the original project total float and one from the EC delay on day 16) and decided to decrease the amount of the work (NE delay on day 18 and 19).

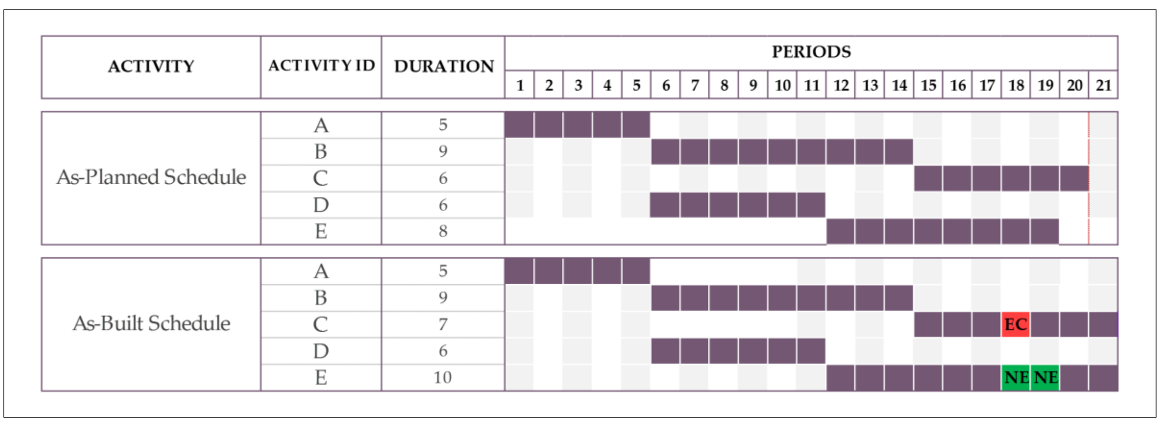


Figure 4: Pacing delay

9. To what extent do you agree with the view that "without EC delay (on day 18), the contractor would be responsible for extending the project's performance up to day 21 due to NE in Day 19; therefore, this fact should be expected in sound analysis for the delay claims"?

- Agree
- Neither
- Disagree
- Other (please specify)

10. To what extent do you agree with the view that the contractor (who had delayed the path [A, D, and E] on days 18 and 19) has to share day 21 with Employer who formed the extra day of total float (on day 21) by EC delay (on day 18)?
    - Agree
    - Neither
    - Disagree
    - Other (please specify)

11. Which of the following decisions represent a fair and reasonable analysis (as Figure 4 shows) to apportioning the one-day project delay (day 21) among the contracting parties?
    - Employer is solely responsible for the project delay
    - Contractor is solely responsible for the project delay
    - Neither party
    - Both parties
    - Other (please specify)

SECTION FOUR: Total Float Consumption

In following Scenario, as shown in Figure 5, EC and NE delay events both happened on day 18. They are not concurrent delays because the NE delay has not affected the overall project duration. Also, the EC delay on day 18 and the NE delay on day 19 have both affected the original project duration independently of each other; however, they are not concurrent delays because the delays must be "inextricably intertwined" and must overlap each other.

In this Scenario, EC delay (on day 18) has extended the path (A-B-C) up to day 21. Also, NE delays (on days 18 and 19) have contributed to extend path (A-D-E) up to day 21. Therefore, the schedule should be accurately analysed (among which of these delay events) to assign the right party who is responsible in extending the original completion date (one day) up to day 21.

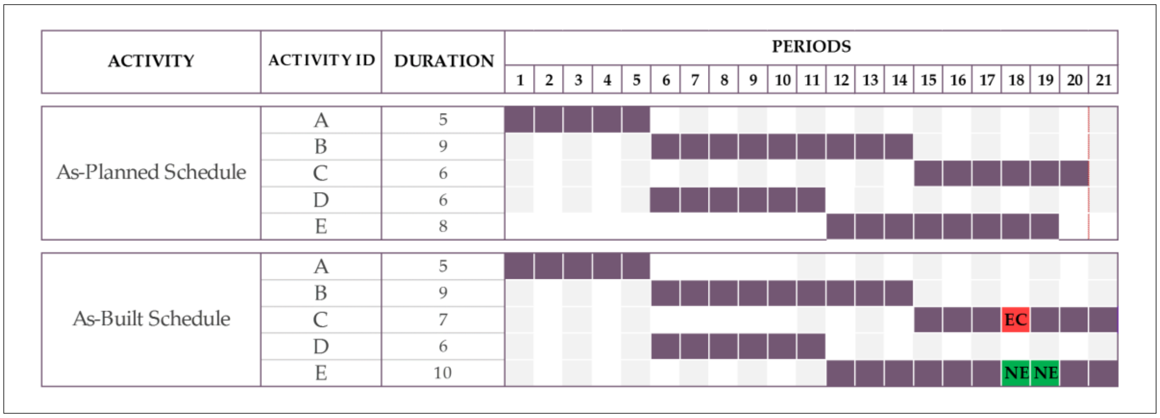


Figure 5: The issue of total float consumption

12. Which of the following decisions represents a fair and reasonable approach for Scenario G for apportioning the one-day project delay (day 21) among the contracting parties?
    - ○ Employer is solely responsible for the project delay
    - ○ Contractor is solely responsible for the project delay
    - ○ Neither party
    - ○ Both parties
    - ○ Other (please specify)

<u>SECTION FIVE: Acceleration</u>

In the following Scenario, an EC delay happened on day 16 that extended the original completion date up to day 21 and formed one extra day of total float in paths (A, D, E). The contractor noticed that and decided to decrease the amount of the work (NE delay on day 18 and 19).

However, the owner decided to accelerate the original critical path, so that the original completion date be met. In most delay analysis techniques, the owner would still be responsible for delaying the project up to day 21 due to EC delay on day 16.

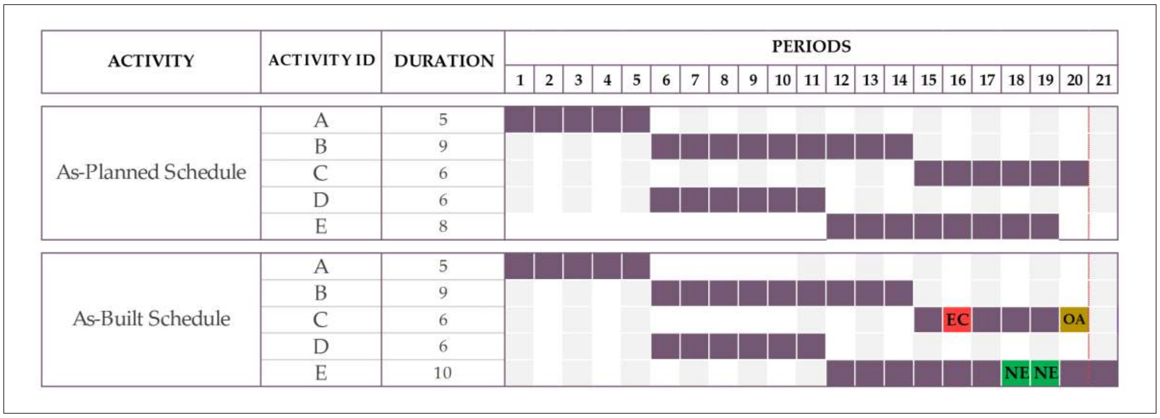


Figure 6: The issue of schedule Acceleration

13. To what extent do you agree with the view that the project has been delayed because the path (A-D-E) has been extended due to the delays on day 18 and 19?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

14. To what extent do you agree with the view that the contractor is solely responsible for day 21?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

15. To what extent do you agree with the view that without the acceleration event (on day 20) the employer and contractor are both responsible for day 21?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

16. To what extent do you agree with the view that accelerations of construction works are relevant and important issues that must be addressed in delay claims resolutions?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

SECTION SIX: Acceleration

The impacts of a delay, a change order or an acceleration of project activities are normally assumed to be equal; however, this is not accurate for analysing delay claims. Each delay has its own impact on the schedule. Furthermore, each project activity has a unique cost slope; for example, the cost of compression or the savings of decompression per unit of time. These distinctions should be reflected in a sound analysis of delay.

As shown in Figure 10, a project that is supposed to be completed on day 20 has been extended due to owner-caused delays (that happened on day 16) and contractor caused delays (that happened on days 18 & 19.

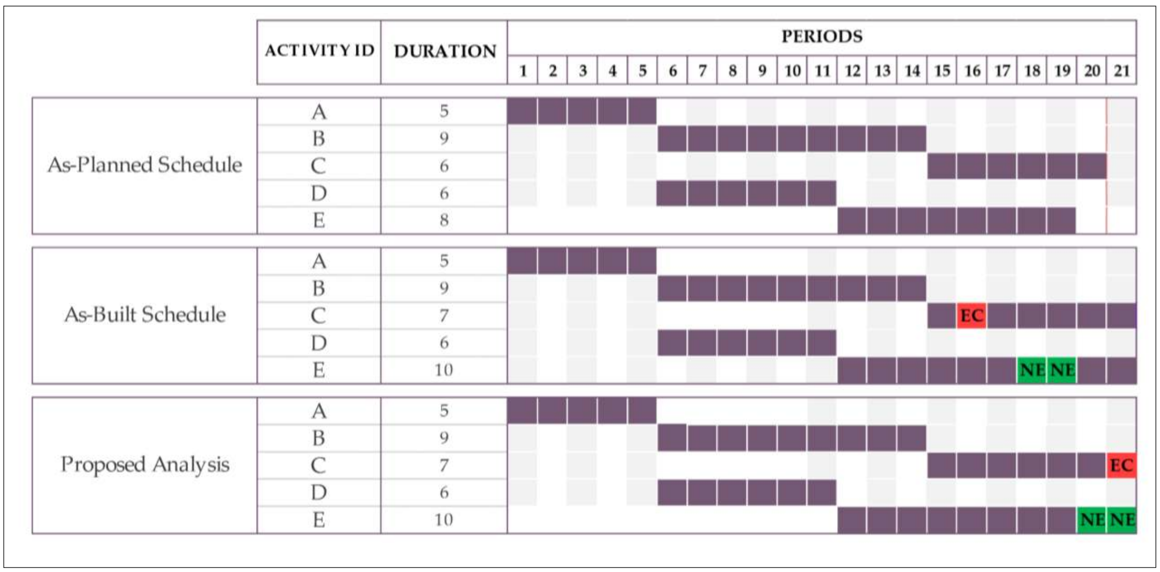


Figure 7: Assigning the real day for independent delay

17. To what extent do you agree with the view that: “the path (A, B, C) has been extended up to day 21 due to EC delay (on day 16) and the path (A, D, E) has been extended up to day 21 due to NE delays (on days 18&19)”?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)
18. To what extent do you agree with the view that: "day 21 will be shared between EC and NE”?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

19. To what extent do you agree with the view that: "the proposed analysis (as shown in Figure 9) will solve the issue of delay damages"?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

20. To what extent do you agree with the view that: "the proposed analysis (as shown in Figure 9) will solve the issue of total float consumption"?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

21. To what extent do you agree with that force majeure delay pose major sources of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

22. To what extent do you agree with that concurrent delays pose major sources of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

23. To what extent do you agree with that pacing delay pose major sources of difficulties in construction delay claims resolution and thus represent potential sources of conflict?
    - ○ Agree
    - ○ Neither
    - ○ Disagree
    - ○ Other (please specify)

24. To what extent do you agree with that total float consumption pose major sources of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties?
    - Agree
    - Neither
    - Disagree
    - Other (please specify)

25. To what extent do you agree with that schedule acceleration of construction works pose major sources of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties?
    - Agree
    - Neither
    - Disagree
    - Other (please specify)

26. To what extent do you agree with that cost slope of delay damages pose major sources of difficulties in construction delay claims resolution and thus represent potential sources of conflict among contracting parties?
    - Agree
    - Neither
    - Disagree
    - Other (please specify)

27. To what extent do you agree with the view that some of the current delay analysis techniques are not capable of properly addressing some issues in delay claims settlement?
    - Agree
    - Neither
    - Disagree
    - Other (please specify)

28. Elaborate on your experience in relation to the overall topic of the survey have no comment to make in that respect
    - I have no comment to make in that respect
    - Other (please specify)

Appendix (III)

A Validation of New Delay Analysis Technique

Dear [Name],
a construction expert in the areas of claims,

Subject: assistance from experts on validation of a new method for analysing construction delay claims.

You may recall the questionnaire survey on delay claims analysis issues that was sent to you for feedback some 12 months ago. As a part of my PhD at Brunel University London, this survey was carried out as part of a wider research work aimed at identifying current problems with delay claims analysis towards the development of an appropriate method for analysing the responsibility for any potential damages resulting from the schedule impacts. However, to ensure that the method is valid for use in practice, there is the need for its validation from delay claims analysis experts.

The purpose of this letter is therefore to seek your assistance on this task of expert evaluation. In this respect, I have enclosed a video clip (on YouTube) of the method together with a worked example to clarify its application process. Also enclosed is a questionnaire indicating areas where your comments are sought.

We do appreciate that this validation will take some of your valuable time, but without the kind contribution of experts like yourself, the continuing search for solutions to problems of delay analysis would not be successful.

Many thanks and look forward to hearing from you soon.

Yours sincerely

Saud Ayid (PhD Research Student)

Brunel University London

Background of Respondent

Participant information (Optional)

Please enter the following Information in the form below. Summaries and statistical analyses of responses will be presented to the University. Your contact details will be kept strictly confidential

Name:

Organization:

Position:

Address:

City/Town:

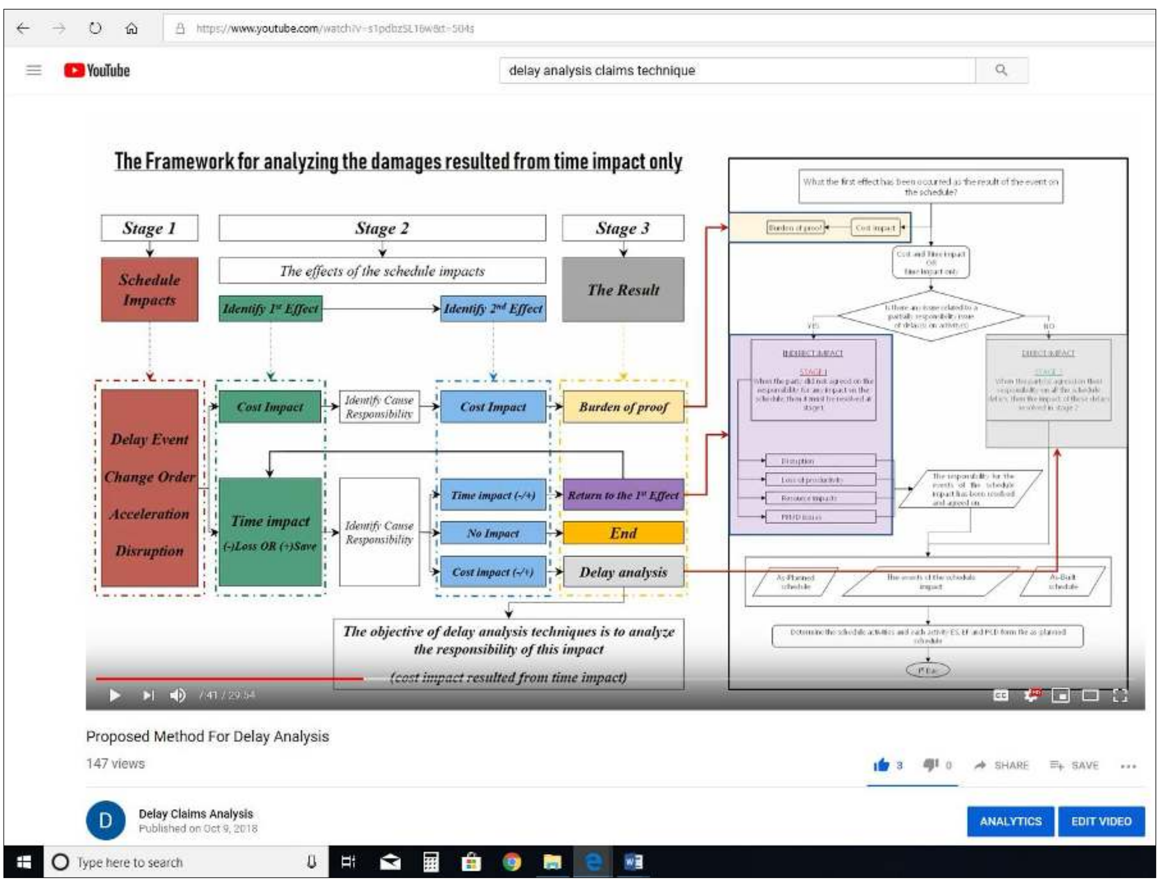
P.O. Box:

Email:

Contact No.:

The Validation Questions

Press on the video to watch on YouTube (Full Screen)



1. What is your opinion on the framework adopted by this research?
   - ○ very suitable
   - ○ suitable
   - ○ not suitable
   - ○ not sure of its suitability
   - ○ Other

2. What is your opinion on the proposed technique for analysing the responsibility for any potential damages result from the schedule impacts?
   - ○ very suitable
   - ○ suitable
   - ○ not suitable
   - ○ not sure of its suitability
   - ○ Other

3. What is your opinion on the description of the method and its lay out?
   - ○ comprehensive
   - ○ adequate
   - ○ poor
   - ○ Other

4. Would you say the method is simple, clear and easy to understand and use with little or no practical difficulties?
   - ○ Yes
   - ○ No
   - ○ Other

5. Would you say the method is capable of assisting analysts in the construction delay claims?
   - ○ Yes, highly capable
   - ○ Yes, capable

- ○ No, not capable
- ○ Not sure of its capability
- ○ Other

6. Does the method address an important delay analysis issues in the field of delay claims analysis?
   - ○ Yes, quite significant
   - ○ Yes, but not significant
   - ○ No, would make no difference
   - ○ Not sure of its significance
   - ○ Other

7. What is your opinion on the resources needed to apply the method in real life selection exercise?
   - ○ Would be too costly to operate
   - ○ Would not be too costly to operate
   - ○ The benefits of using the method justify any requirements
   - ○ Other

8. In your opinion, are there any further matters of importance which ought to be included in the method or considered?
   - ○ Yes
   - ○ No
   - ○ Other:

Please provide any other general comments that you have on the method or suggestions for improvement.

<u>Thank you very much for your time.</u>