



Common Delay Analysis Methods and Factors Influencing the Selection of Such Methods in Construction Projects in UAE

**"طرق تحليل التأخير الشائعة والعوامل المؤثرة في اختيار مثل هذه الطرق
في مشاريع البناء في الإمارات العربية المتحدة"**

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Abstract

Delays are one of the common issues faced in construction projects. While some cases might be easy to analyse, most of the cases are complex and difficult. In the past century, various delay analysis methods have been developed and used in the construction industry for the purpose of analysing the delay, their effects and the liability for their consequences.

With projects varying in nature and complexity and with multiple types of delay analysis methodologies, conflicts started arising in projects over which delay analysis method should be used and why. This dissertation examines the common used delay analysis methods in the UAE and the factors that would influence the decision as to the appropriate delay analysis method adopted by Contractors.

A conceptual model has been developed after reviewing the available literature on the subject. The model summarizes the common acceptable delay analysis methodologies along with the common factors influencing the selection of such methodologies. The conceptual model has been further enhanced through interviewing three delay analysis experts that have been involved in projects in the gulf region in the past ten years. An investigation has been carried out in the local market through analysing the data of five case studies and interviewing the relevant planners and delay analysts to investigate current practices and perceived effectiveness of the adopted methods.

The main finding of the research is that there is some sort of agreement on the general acceptable framework of performing delay analysis by Contractors. A clear set of factors for the selection of the delay analysis methods has been identified. The main identified factors were the attitude of the Clients, experience of the delay analyst, complexity of the project, time of performing the analysis, and the available time and cost for performing the analysis. The overall conclusion of the research was that the windows analysis method is generally considered as the most reliable and acceptable method in UAE. However, no generalization can be made in terms of the most appropriate delay analysis methodologies as this remains a discrete subjective decision of the delay analyst based on his view of the considered factors in each project.

Keywords: Delay Analysis, Extension of Time, Claims, Construction, acceleration, disruption, concurrent delay, Windows Analysis.

الملخص

التأخير هو احدى القضايا المشتركة التي تواجهها مشاريع البناء. في حين أن بعض الحالات قد يكون من السهل تحليل التأخيرات، فإن معظم الحالات معقدة وصعبة. في القرن الماضي، قد وضعت أساليب مختلفة لتحليل التأخير في صناعة البناء والتشييد لغرض تحليل التأخير، والآثار، والمسؤولية عن نتائجه.

مع مشاريع مختلفة في الطبيعة والتعقيد ومع أنواع متعددة من منهجيات تحليل التأخير، بدأت الصراعات الناشئة في المشاريع على أسلوب التحليل الذي ينبغي أن يستخدم والسبب في ذلك. تبحث هذه الأطروحة في الأدبيات المتوفرة حول موضوع أساليب تحليل التأخير والعوامل التي تؤثر على اختيار مثل هذه الأساليب. تبحث هذه الأطروحة الطرق الشائعة المستخدمة لتحليل تأخيرات المشاريع الانشائية في دولة الإمارات العربية المتحدة والعوامل التي من شأنها أن تؤثر على الاختيار لأسلوب التحليل المناسب الذي يعتمده المؤلفون.

وقد تم تطوير نموذج مفاهيمي بعد مراجعة الأدبيات المتوفرة حول هذا الموضوع. ويلخص النموذج المنهجيات المقبولة لتحليل التأخير جنباً إلى جنب مع العوامل التي تؤثر على اختيار مثل هذه المنهجيات. وقد تم تعزيز النموذج المفاهيمي أكثر من خلال إجراء مقابلات مع ثلاثة خبراء في تحليل التأخير في مشاريع في منطقة الخليج في السنوات العشر الماضية. كان قد تم إجراء تحقيق في السوق المحلي من خلال تحليل بيانات من خمس دراسات وإجراء مقابلات مع المخططين المختصين والمحللين للتحقيق في الممارسات الحالية وفعالية الطرق المعتمدة.

النتائج الرئيسية للبحث هي أن هناك نوع من الاتفاق على إطار مقبول لإجراء تحليل التأخير من قبل المؤلفين. تم التعرف على مجموعة واضحة من العوامل لاختيار أساليب تحليل التأخير. وكانت العوامل الرئيسية التي تم تحديدها هي موقف العملاء، تعقيد المشروع، وقت أداء التحليل، والوقت المتاح والتكلفة لأداء التحليل. وكان الاستنتاج العام من البحث أن أسلوب تحليل النوافذ يعتبر عموماً الأسلوب الأكثر موثوقية وقبول في دولة الإمارات العربية المتحدة. ومع ذلك، لا يمكن إجراء أي تعميم من حيث أنسب منهجيات تحليل التأخير لأن هذا يبقى قرار ذاتي محدد من المحلل بناء على وجهة نظره من العوامل في كل مشروع.

الكلمات الدالة: تحليل التأخير، وتمديد الوقت والمطالبات، البناء، التسارع، والتعطل أو التأخيرات المترامنة.

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I moreover extended my gratitude to my employer for its endless support and understanding during the period of my part time studies. The fact is that completing the studies has proven to be easier just because of the experience that I've gained through working in my employer's projects.

Dedication

I dedicate my dissertation work to my beloved wife Deema for her constant support, patience and love and to my daughter Julia for being the cause of my happiness. I also extend this dedication, with a special sensation of gratefulness, to my loving parents, Fawwaz and Qamar Abdelhadi for their continuous guidance and motivation.

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Abbreviations

UAE: United Arab Emirates.

UK: United Kingdom

KSA: Kingdom of Saudi Arabia

SCL: Society of Construction Law

CPM: Critical Path method

AED: Arab Emirates Dirhams

DAM: Delay Analysis Method

TIA: Time Impact Analysis

WA; Windows Analysis

EoT: Extension of Time

NoC: No Objection Certificate

FIDIC: Fédération Internationale Des Ingénieurs-Conseils

PMI: Project Management Institute

AACEI: Association for the Advancement of Cost Engineering International

CHAPTER ONE–INTRODUCTION

1.1 Background and Statement of the Problem

As part of the development of any country, construction projects are carried out to develop the infra-structure and building facilities. A common problem that have been identified in the past century was the delays in construction projects (Arditi & Pattanakitchamroon, 2006). In fact, researchers found out that it is rare that a project finishes on its scheduled completion date and without time overruns as Kaming et al. (1997) describe time overruns as the extended time after the intentional end dates.

While researchers focused on the type, frequency and the causes of the delay, less effort was made to explore the most appropriate delay analysis methodology in construction project. This is an extremely important topic given the usual complex nature of the projects and project's delays. For example, project delays can be the result of the action/instructions of owners, consultants, contractors or by other external factors to the project (Vidalis & Najafi, 2002). There are many potential causes of delay such as design delays and deficiencies, design changes, variation orders, subcontractor delays, adverse climatic conditions, unforeseen site conditions and others. Usually all such kind s of delay occur in a normal construction project (Assaf & Al-Hejji, 2006). Delay analysis is therefore essential to determine the critical causes of delay and to allow for proper allocation of delay damages.

Delay analysis methodologies, such as the 'Impacted as planned', 'Collapsed as built', 'Windows Analysis/Time Impact Analysis', 'as planned vs. as built analysis' and other methods, are believed to be essential tools for assessing the effect/ impact of any delay (Arditi & Pattanakitchamroon, 2006). As noted above, causes of delay, responsibility of such causes and the impact of such causes have been well researched in the past period. However, the most appropriate way to analyze such delays and causes of delay is still an arguable subject. While there seems to be an agreement on the possible ways of analyzing the delays (i.e. list of delay analysis methodologies and their capabilities and limitations), there appears to be a lack of agreement on which of the delay analysis methodologies is the best (if any) or at least which methodology would the most appropriate method for a certain type of projects or under certain circumstances. There is also some kind of confusion over the terminologies and titles used for each method. Arditi and Pattanakitchamroon

(2006) claimed that that none of the identified delay analysis methodology can be universally used in all situations, although they noted that the Windows Analysis/Time Impact Analysis is the most acceptable method and provides the most reliable results. Researchers have identified multiple factors affecting the selection and the results of the delay analysis methodology.

1.2 Aims and Objectives

This paper will investigate and identify the common used delay analysis methods in UAE and the main factors influencing the selection of the most appropriate delay analysis method. The following are the summarized target objectives of the research:

- 1- Investigate the different delay analysis methodologies used in construction projects in UAE,
- 2- Examine the criteria that should be used in determining the effective method to be adopted,
- 3- Investigate a framework that could be used to aid the selection process of a delay analysis method.

1.3 Scope of the Research

This research intends to create a framework that can provide a road map for delay analysts and experts for selecting the most appropriate delay analysis methodology in construction projects. A qualitative research will be carried out by developing a conceptual framework from the reviewed literature along with the input of three delay analysis experts and analyzing the data of five case studies.

The case studies considered are all projects from the United Arab Emirates' (UAE) construction sector and were all with fast track requirements, in which, according to Moazzami et al (2011), it is almost inevitable that delays will occur. Indeed, the selection was because these projects have all suffered from delays and certain delay analysis methodologies were used to analyze the occurred delays.

Research Questions

The following research questions have been developed as part of the main conceptual framework for the selection of the most appropriate delay analysis methodology. Those were not directly asked in interviews. However, they were the main focus of the research.

- 1- What are the common delay analysis methodologies in United Arab Emirates?
- 2- What are the factors influencing the selection of the delay analysis methodology and what role the delay analyst plays in the selection process?
- 3- What is the most appropriate delay analysis method, if any, and what are the relevant appropriate circumstances?

1.4 Research Structure

This document has been developed as six main chapters. Chapter one relates to the background and a statement of the problem on the topic of selecting the most appropriate delay analysis methodology, research questions and the overall research aims and objectives.

The second chapter contains the literature review and the gathered expert opinion data. Basically, this chapter contains the details of the literature and the recommended practices reviewed listing out and detailing the different views and opinions of researchers on the topic of the selection of the most appropriate delay analysis methodology in Construction Projects. The chapter also includes tables and figures summarizing all the identified factor and variables along with their joints and relationships.

The third chapter contains the conceptual framework of the research which is basically the connecting chapter between the identified factors through the literature review and the expert interviews and the aims and objectives of the research so that structured interviews can be conducted and systematic data gathering can be commenced.

Chapter four explains the nature of this research. The research will in fact be a qualitative research as the main source of data will be collected through interviews with project based personnel and international construction delay experts.

The fifth chapter contains the analysis of all data including the contrast and comparison of the factors and variables identified in the literature review and intellectualized in the conceptual framework chapter. The chapter will basically include the data collected from the case studies and gathered through the conducted interviews.

Finally, the last and sixth chapter contains the conclusions, recommendations and limitations of the research. This is a summary of the research and its main findings along with recommendations for future research on this topic.

CHAPTER TWO – LITERATURE REVIEW

2.1 Introduction

Projects are commonly defined as the need to complete a set of activities within a specified duration and to a certain level of quality. It is often that project durations are tight and that project completion dates are not achieved (Williams, 2003). As there are usually multiple parties involved in projects (e.g. owner, consultant and Contractor) and financial consequences would result from project delays, a need has arisen to find a way to determine the cause and responsibility of project delays.

The problem is that projects and the causes of project delays vary in nature and complexity. This has created a difficulty in determine the cause, effect and the liability of the delay events in projects and issues in determining the most appropriate delay analysis methodology in analysing such delays (Assaf & Al-Hejji, 2006). Before discussing the delay analysis methodologies and the factors affecting the selection of such methodologies, some delay related terminologies will need to be defined. Such terminologies are essential for understanding the research as the delay analysis process will depend on the definition of the concepts.

2.2 Some Delay Related Terminologies

2.2.1 Critical Path Method (‘CPM’) and Project Float

Nowadays, the common and standard (and almost the only) acceptable scheduling methodology is the Critical path method (CPM). There are other methodologies such as the bar chart and the critical chain methods which are less common. The CPM method basically groups the activities into paths based on the defined sequence of works and concludes criticality based on the resulting project float. CPM is the dominant method in the construction market and therefore understanding the CPM method is essential as it forms the basis for most of the delay analysis methodologies (Williams, 2003).

CPM schedules contain buffer periods for the activities and the project that are usually called float. The primary project float is usually called total and is defined as the duration an activity can be delayed without delaying the overall project. (Mohan & Al-Gahtani, 2006). Understanding the

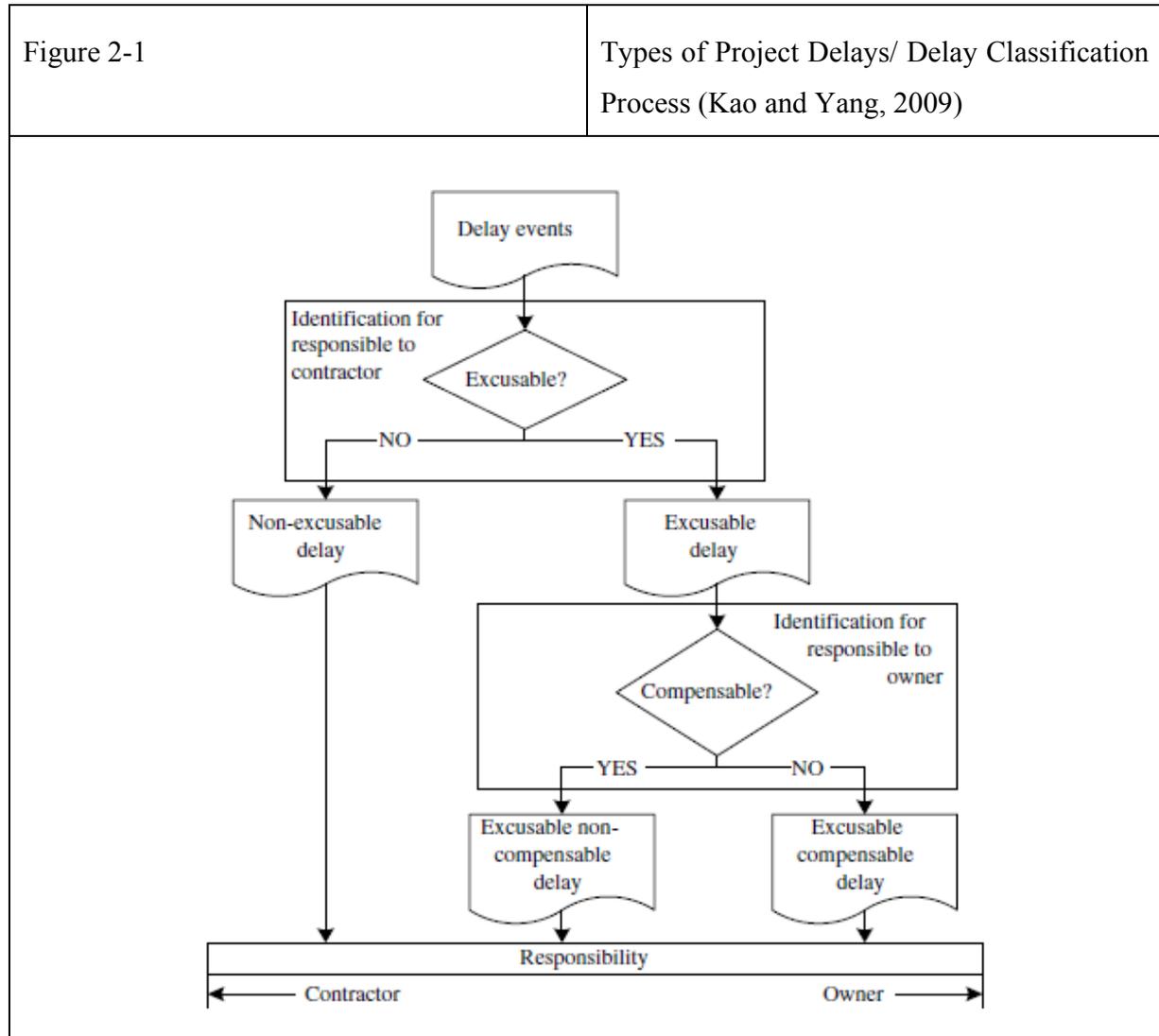
float and its effect on the project paths and delays is essential as it directly relates to the criticality of the activities. For example, the longest path in the project (i.e. the critical path), is usually defined as the path with all activities having a zero total float.

2.2.2 Delays in Construction Projects

In construction projects, delays may have a tremendous effect on the project that may reach to project termination. Hence, from here comes the importance of analysing the delays. This is particularly important when it comes to measure the consequences of the delay. This includes determining the criticality, the cause, the responsible party and the compensation for the delay. Kao and Yang (2009) categorize the types of project delays as excusable and non- excusable depending of the project owner as an originator. They have also made three categories of potential delay in projects. The first is the excusable compensable delays. These are the delays that are caused by the owner and the owner is responsible for making compensation for the Contractor's relevant damages. An example of this can be issuing a variation order to the Contractor that require the works to be extended after the original completion date. The owner would have then to compensate for the prolongation cost resulting from the extension of time.

The second type of delay is the excusable but non-compensable delays. This means the delays occurred due to reasons beyond the contractor's control but not necessarily caused by the project owner. This means the Contractor should be awarded an extension of time but would not be entitled for compensation of its damages, if any. An example of this may be an extremely adverse climatic condition where the Contractor had to stop the works for a certain period.

The last and third type is the non-excusable (and obviously non-compensable) delay. This is when a delay is simply is the default of the Contractor. This means the owner would be entitled to claim damages from the Contractor due to such delay. An example of this would be the slow progress and the failure to achieve the planned productivities by the Contractor for its own reasons and failures such as lack of skilled or sufficient numbers of resources. Please refer to figure 2-1 below.



2.2.3 Causes of Delay and Effects

As explained above, Project delays can be originated by owners, consultants, contractors and by other external factors to the project (Vidalis & Najafi, 2002). There are many potential causes of delay such as design delays and deficiencies, design changes, variation orders, subcontractor delays, adverse climatic conditions, unforeseen site conditions and others. Usually all such kind of delay occur in a normal construction project and would require reasonable delay analysis to be conducted before judging on their effect (Assaf & Al-Hejji, 2006).

2.2.4 Extension of Time (EoT)

When the project is delayed, the common terminology used for the resulting prolonged time period based on the delay analysis performed is called Extension of Time (EoT). Williams (2003) highlights that even though project parties usually avoid EoTs, EoT claims still occur and are usually difficult to assess, in complex projects in particular.

SCL (2002) and Yusuwan and Adnan (2013) define extension of the time as the extra time entitlement to contractor's after the concluding the original contract period. The purpose could be to justify the extended time periods, to claim additional prolongation cost and/ or to avoid paying damages or penalties for delay. A pre-requisite for such time extension entitlement is usually a fully substantiated extension of time claim. Substantiation in this context includes sufficient and thorough delay analysis to prove the contractor's case.

2.2.5 Acceleration and Mitigation

SCL (2002) notes that it is common in construction contracts that the Contractor would have an obligation to mitigate the effect of any delay in the project to the best level he can. Mitigation usually refers to the Contractor's efforts to recover its own delays and acceleration is usually referred to the Contractor's effort to recover or accelerate the works due to delays by other project parties and/ or instructions by the project owner. Delay analysis, by default, will have to consider the acceleration and mitigation efforts exerted.

2.2.6 Disruption

SCL (2002) explains the disruption in projects as the large effect of both the delays and acceleration in Projects. The general impact of the project delay and/ or the attempts to mitigate such delays is the disruption of the works by way of loss of productivity due to disrupted and/ or congested working environment.

2.2.7 Concurrent Delays

Kao and Yang (2009) define concurrent delay as the situation when multiple delay events, caused by at least two different parties to the project, occur at the same time so that if either of them occurred individually, it would have an effect on the project completion date. They also define concurrency as having two delay events caused by two different originators (e.g. Contractor and owner) at the same time and/ or having the effects of such delay events at in parallel. SCL (2002) however suggests using the term concurrent effects to avoid confusion, as they view concurrency as the parallel effects of the delay events rather than the delay events themselves.

Kraiem and Diekmann (1989) highlight the possibility of having complex cases with all types of delays happening concurrently and/ or having concurrent effects. Arditi and Pattanakitchamroon (2006) note that concurrent delays are one of the vague areas where there is no clear way of analysing the delays and assigning the responsibilities. Kraiem and Diekmann (1989) claim that concurrent delays affects Extension of time entitlement if they only fall on the critical path. However, they also say, if the damages and compensation is in question, analysing secondary paths and concurrent delays affecting such paths may become essential as it would be unfair to assign all cost damages to one party due to the delays to the main critical path of the project while the other party may have caused delay to a secondary path that could have been the most critical should the delays by the first part not have occurred.

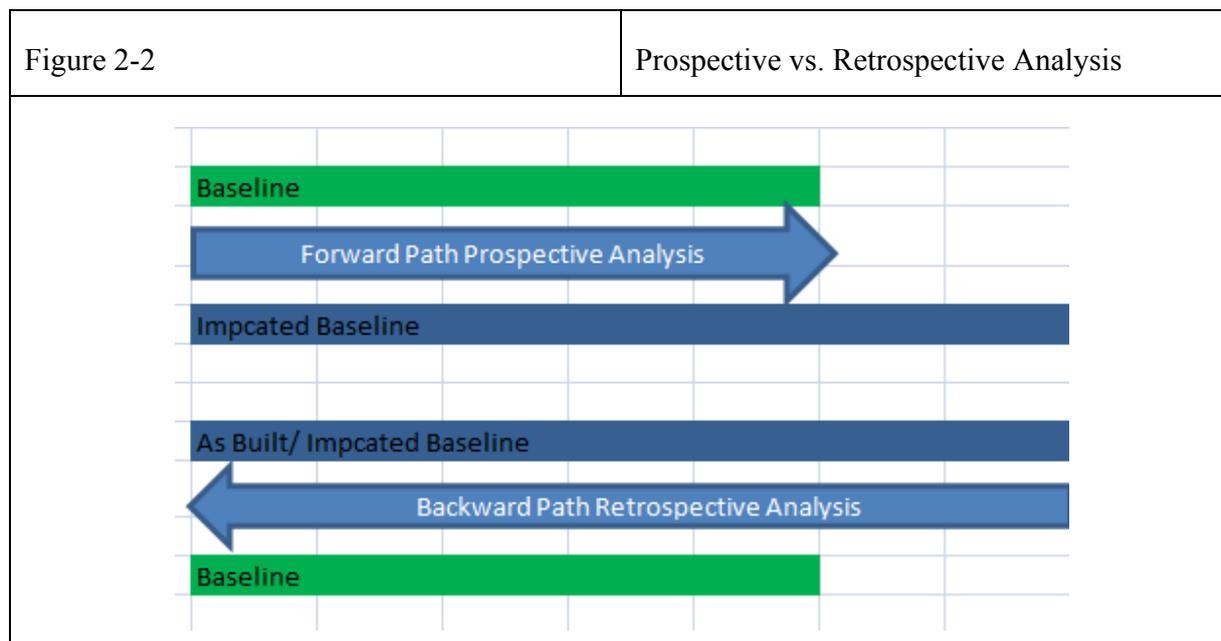
Mohan and Al-Gahtani (2006) and Kao and Yang (2009) expand the definition of concurrent delays and disruption explained above and introduced another type of delay, that is similar to the concurrent delay but seems to be ignored by all delay analysis methods, which is the pacing delay. This is when one party decelerate/ slow the progress of the works to keep pace with the other delayed works by the other party. The pacing delay can however be categorized as part of the disruption delay.

2.2.8 Forward and Backward Path Calculations Methods

One of the early decisions the delay analyst has to make before selecting the delay analysis is whether he is going to perform a forward and backward path calculations. This decision, as will be explained below, is influenced by initial factors such as the timing of performing the analysis

and the purpose of performing the analysis. The decision may also be influenced by the factor of availability of project records (Kao and Yang , 2009).

Once decision is made, in terms of path calculation methods, selection of the delay analysis method can proceed further (SCL ,2002). As can be seen from Appendix B, there are certain types of delay analysis methodologies that are applicable to each type of calculations. In essence, the decision to be taken here is whether to perform a retrospective or a prospective analysis. Figure 2-2 below illustrates the concept of the retrospective and the prospective analysis



2.2.9 Complex and Simple Methods

As can be seen from the table in Appendix B, some of the methods are categorized as complex while others are considered simple methods. Complex in this context means requiring effort and time and cost. The delay analyst should consider all the inflecting factors before selecting complex methods as his decision, if not accurate, may have fatal consequence. An example of this having a delay analysis cost more than the overall claim value or failing to complete the delay analysis due to the lack of sufficient records (Brammah & Ndekugri ,2008) and Kumaraswamy & Yogeswaran ,2003).

2.2.10 High and Low Level of Detail

The level of detail of the analysis is one of the main decisions to make when deciding which delay analysis method to use and while performing any kind of delay analysis. As will be explained below, the main drivers for the decision on the appropriate level of detail for the delay are the availability of the records and the time and resources available to perform the analysis (Brammah & Ndekugri, 2008).

2.3 Delay Analysis Methodologies (DAM)

There are various types of delay analysis methodologies that are available. Williams (2003) considers that the network based methods are generally powerful and reliable for assisting the delay impacts in construction projects. Williams (2003) also explains that the main purpose of the delay analysis is to determine the cause, effect, responsibility and damages. Arditi and Pattanakitchamroon (2006) suggest that four methods are the most common in the construction industry which are the as planned vs. as built analysis, Impacted as planned, collapsed as built and the windows analysis methods.

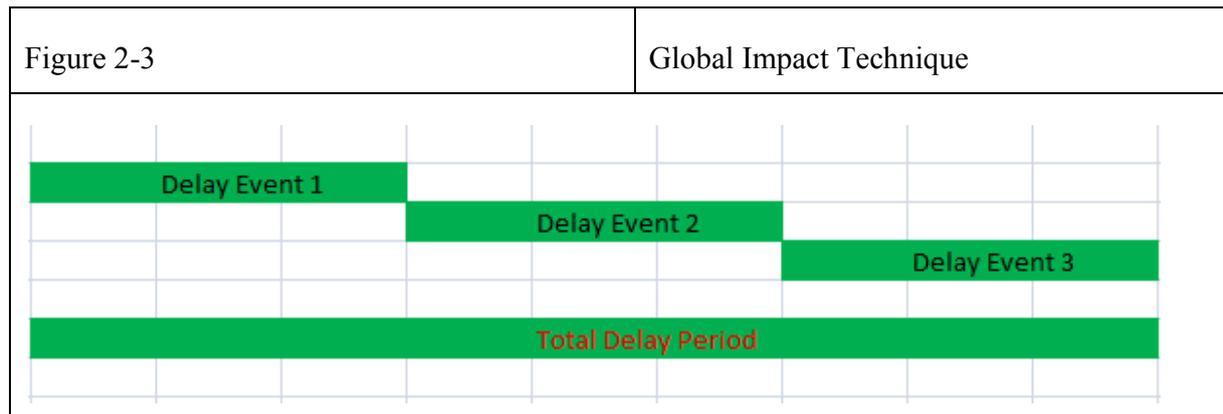
In a very recent study, Yang and Kao (2012) note that none of the existing delay analysis methodologies is perfect as they all require assumptions and contains theoretical forecasts and subjective assessments. The following paragraphs shall provide a brief description of each of the main delay identified delay analysis methodologies through the literature review highlighting the strengths and shortcomings of each method.

2.3.1 Global Impact Technique

Arditi and Pattanakitchamroon (2006) explain this method as analysing the delay through by all project delays in a bar chart and then make the summation of the overall delays assuming that all delays have equal effect of project completion. In other words, this method does not account for criticality of the events. Alkass et al. (1995) also note that this method simply sums all delays together which give a misleading and exaggerated amount of total delay. Kumaraswamy and Yogeswaran (2003) highlight that this method is used more frequently by Contractors than other

methods in their research in Hong Kong. However, they classify this method as too simple and unrealistic and therefore cannot deal with complex cases or produce accurate results.

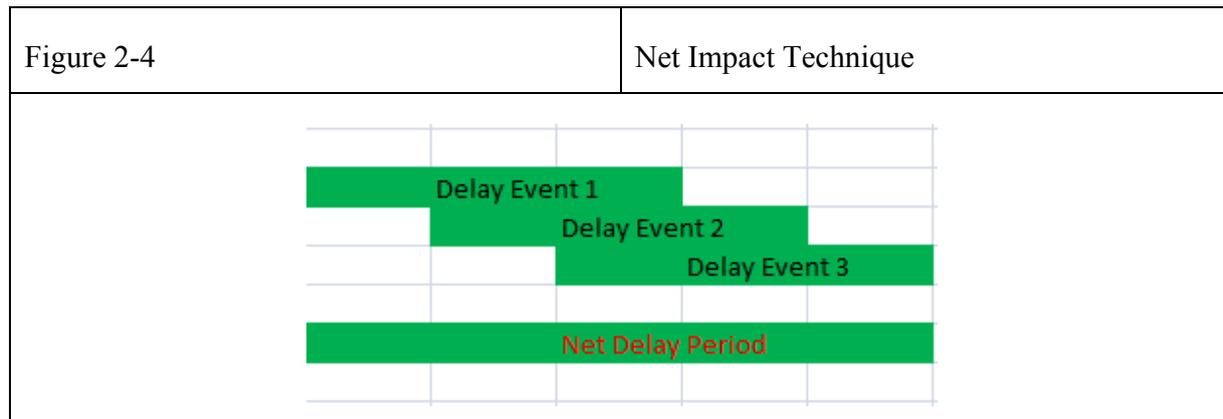
In summary, this method is simple method that allows for analysing the delay through plotting all delays in one bar chart and then summing all the delays up. It requires knowledge of the delay events. It is suitable for simple cases only. Figure 2-3 below, illustrates the concept of this method.



2.3.2 Net Impact Technique

Alkass et al. (1995) explain that this method is very similar to the global impact method as the delays are all put in one bar chart and analysed. However this method only calculates the net delay not the sum of all delays. Kumaraswamy and Yogeswaran (2003) highlight that this method is usually used by Contractors but its main shortcoming is that it does not deal with the different types of delay and the concurrency issues. Mohan and Al-Gahtani (2006) note that this method is also sometimes called as built technique.

In summary, this method is simple and similar to the global impact technique with one difference that it considers the net total of the delays only. It requires knowledge of the delay events. It is suitable for simple cases only. Figure 2-4 below, illustrates the concept of this method.



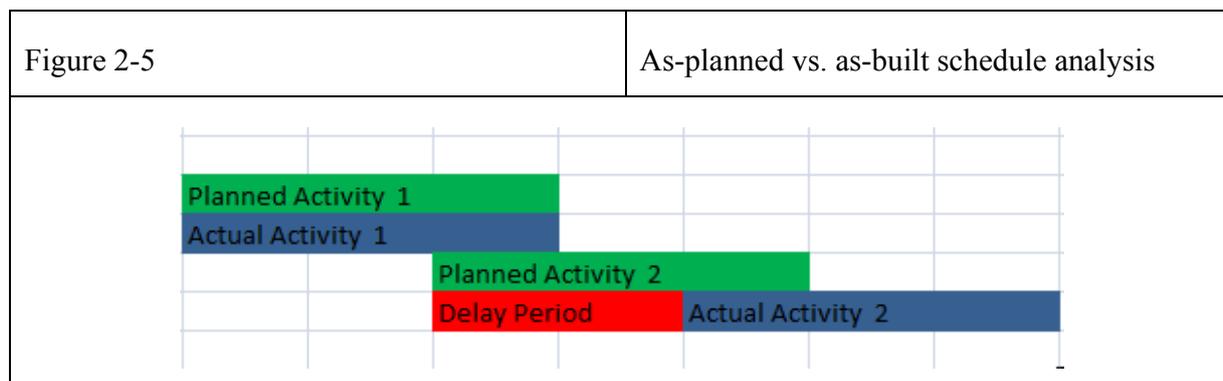
2.3.3 As-planned vs. as-built schedule analysis

This method basically compares the as planned activities (Baseline) with the as built activities. Yusuwan and Adnan (2013) describe it the most preferred method as it is simple and produces fair and reasonable results. Arditi and Pattanakitchamroon (2006) highlight that researches generally agree that this method is the simplest method. Its main drawback however is that it only present a simple comparison between the planned baseline and the actual as built schedule without performing any complex analysis. For this same reason, it could be viewed as one of the fastest and easiest methods as it does not require a complex set of programmes and progress updates or any adjustment to the existing programmes. It only requires a baseline and an as built schedule.

Similarly, Braimah and Ndekugri (2008) summarize the advantages of method by saying its simple, easy to perform, easy to understand and relatively less expensive than other methods. They however note that the disadvantages of the method are the inability to deal with concurrent delays and the failure to consider the changing and dynamic nature of the project critical path.

Yang and Kao (2009) describe two other methods that are the Bar chart analysis and the As Built bar chart methods as something very similar to the as planned versus the as built method. The main difference is that these methods ignores the logic between the activities/ bars, which might be a reason for the criticism of these methods. Another similar method described by Yang and Kao (2009) as well is the linear schedule analysis which basically compares the as planned schedule with the linear progress data. The method however is limited to projects with linear progression.

In summary, this method is simple. Its main concept is a comparison between the planned and the actual progress of the activities. It requires a baseline and an as built schedule. It might be suitable for simple and complex cases. Figure 2-5 below, illustrates the concept of this method.



2.3.4 Impacted as-planned schedule analysis

This method uses the baseline schedule as its basis. It simply impacts all delay events on the baseline schedule in a prospective way and provides a theoretical impact of the delay events, on the assumption that the baseline logic, sequence and durations have not changed. Arditi and Pattanakitchamroon (2006), Braimah and Ndekugri (2008) and Yusuwan and Adnan (2013) agree that all researchers have criticized this method. While the reliance on the baseline schedule may give some theoretical prospective forecast of the delay impact, it may give a misleading result when analysing a project that has been completed where the as built data differ from the original baseline schedule, which is usually the case.

Yang and Kao (2009) describe the method of 'After-the fact' and 'modified CPM' schedule' as something similar to the impacted as planned method but with a difference that a new baseline schedule is recreated retrospectively, sometimes based on the actual as built information. This may overcome the drawback of the impacted as planned method being that it assumes the original baseline logic, sequence and durations are correct. Kao and Yang (2009) also highlight the following other titles for the impacted as planned method: 'as planned', 'what-if', 'impacted baseline schedule', 'as planned plus delay analysis' and the 'affected baseline schedule' methods.

Williams (2003) is less conservative on the as impacted as planned method. However, he also highlight that in order to perform proper analysis using this method, there must be a correct and error free planned baseline schedule. He also notes that that there is always a difficulty in this method as the baseline programme will not be correct without modifications to consider the actual productivities and sequence.

In summary, this method is simple. An impacted scheduled is created by impacting the delay events on the baseline schedule. It requires a baseline schedule and knowledge of the delay events. It is not recommended for complex cases. Figure 2-6 below, illustrates the concept of this method.



2.3.5 Collapsed/ ‘But for’ as-built schedule analysis

Braimah and Ndekugri (2008) explain this method as analysing the delay using the final as built schedule or creating one including all delay events and their impacts and then start excluding the impact of the delay events to see what would have been the case but for such delay events. Arditi and Pattanakitchamroon (2006) explain this method as being based on the ‘what if’ theory. They view it as an evolution of the impacted as planned method, as the analysis are done similar but the collapsed as built method considers the factual information available in the as built programme which overcomes the main drawback of the impacted as planned methods as being theoretical analysis with misleading results.

Mohan and Al-Gahtani (2006) and Arditi and Pattanakitchamroon (2006) note that this method has been widely accepted by courts in the United States. The 'but for' method is usually selected when the project is lacking sufficient scheduling information or the scheduling records are not

readily available. The as built schedule can be created from the available as built records. The method relatively require less time than the others, the time impact analysis in particular. The method however, has been criticized by some of the researchers, mainly because it has the ability to be bias as the party conducting the analysis (e.g. the Contractor) would usually select the events that suit its case rather than the whole project events, which may include delays caused by itself. The method also is not dynamic as it assumes the original baseline logic is still correct after actual completion.

Another drawback of this method that has been identified by Arditi and Pattanakitchamroon (2006) is that it cannot identify other causes of delay that may have occurred during the course of the project, because it simply relies on the selected events by the analyst. The last drawback of this method, which is also a drawback of the impacted as planned method, is that the way the events are impacted is subjective as it requires the analyst to create the sequence and durations for the inserted impact/ new activities and changes. They conclude that this method would be the best when the parties have an agreement on the actual as built schedule and events and/ or limited recourse and time are available to perform the delay analysis.

Williams (2003) and Yusuwan and Adnan (2013), explain this method as having the as built schedule ready then taking out all the delays caused by the Employer, which will enable the delay analyst to see what would have been the completion date of the project had those delay not occurred. Braimah and Ndekugri (2008) however note that the main drawback of this method is that it does not consider the changing and dynamic nature of the project critical path in addition to the difficulties in finding out or creating the actual as built critical path.

On the other hand, Kao and Yang (2009) highlight that the 'but for' method could be performed prospectively or retrospectively. In essence, the difference between the two ways is like performing two different delay analysis methodologies. The first way is by impacting the delay events on the baseline schedule, similar to the impacted as planned method. They also describe the following names for the same method: modified as built, time impact technique, baseline adding impacts method and the forensic scheduling.

The other way of performing the 'but for' analysis as described by Kao and Yang (2009) is by doing a backward path calculations and just extracting the delay effects of the each of the delay

events, similar to what has been described above by the other researchers. They also highlight various other names for the ‘but for’ methodology such as the ‘Traditional method’, but for schedules’, collapsing technique, impacted as built, collapsed as built, as built less delay analysis and as built subtracting impacts method. In addition, Kao and Yang (2009) describe another version of the ‘but for’ method having the name of ‘modified but-for’ method. The basic concept is the same as the ‘but for’ method but with the addition of the consideration of the liable party while analysing the delay events.

Kao and Yang (2009) also explain a method called the apportionment delay method as a conciliation of the ‘but for’ and the net impact analysis. The basic concept here is the delay impact are apportioned according the types of the delay events causing the delay; i.e. excusable compensable, non- excusable non-compensable and the excusable but non-compensable delays.

In summary, this method is moderately complex. Delays are analysing through impacting the delay events or extracting the delay effects from the as built schedule. It requires an as built schedule and knowledge of the delay events. It is suitable for complex cases but cannot delay with concurrency issues and the changing nature of the critical path. It cannot be performed if no proper as built schedule is available. Figure 2-7 below, illustrates the concept of this method.



2.3.6 Windows/ Time impact analysis (TIA)

This method is a dynamic method that first allows for creating a separate impact for each events, which can be agreed between the parties, and then such impact(s) can be inserted into the project

updated schedule in each relevant time periods. In the final time period, there will a fully impacted schedule containing all delay events and considering all as built data (SCL, 2002).

Arditi and Pattanakitchamroon (2006) consider that this method is the most reliable as it provide the most reliable results. The main added value of this method is that it allows to test the actual impact of the delay events systematically at various points of time rather than analysing the impact at one point of time like the other methods such as the impacted as planned or the collapsed as built. The evaluation of the progress and the float consumption on day by day basis, will allow proper presentation and evaluation of the progress, delays, concurrent delay, acceleration and mitigation and other measures. SCL (2002) considers this method as the preferred one when complex cases are involved.

Another added value of this method is that it consider the project delays regardless of the originator (e.g. contractor or owner) or the type of the delay (excusable or non-excusable). The method also, when required as part of the contractual agreements, encourages the parties to keep good records and to update the project schedule on daily basis. The drawback however is that this method require complex analysis and effort and require substantial time to be performed. It will also highly depend on the availability and the quality of the project records. Arditi and Pattanakitchamroon (2006) conclude that, although the time impact analysis is the most sophisticated method and requiring more time and cost, but it is viewed as the most appropriate in most of the cases and is widely accepted by researchers and by courts.

Williams (2003) notes that some researchers assumes the TIA method can be globally used for all projects but he then highlights that this an over optimistic view as there are some limitations and difficulties in applying this method in certain type of projects and under certain circumstances. In the same paper, he describes three other methods in a way similar to the TIA, which are the windows analysis, snapshot analysis and the time impact technique. They are effectively the same but with different ways of looking at the delay events, delay effect, window periods and project progress.

Braimah and Ndekugri (2008) consider the TIA as the most reliable as well. However, they view it as variant of the Window Analysis method, with a difference that the TIA focuses on delay events while the windows analysis focuses on time periods. This is however quietly contradicting

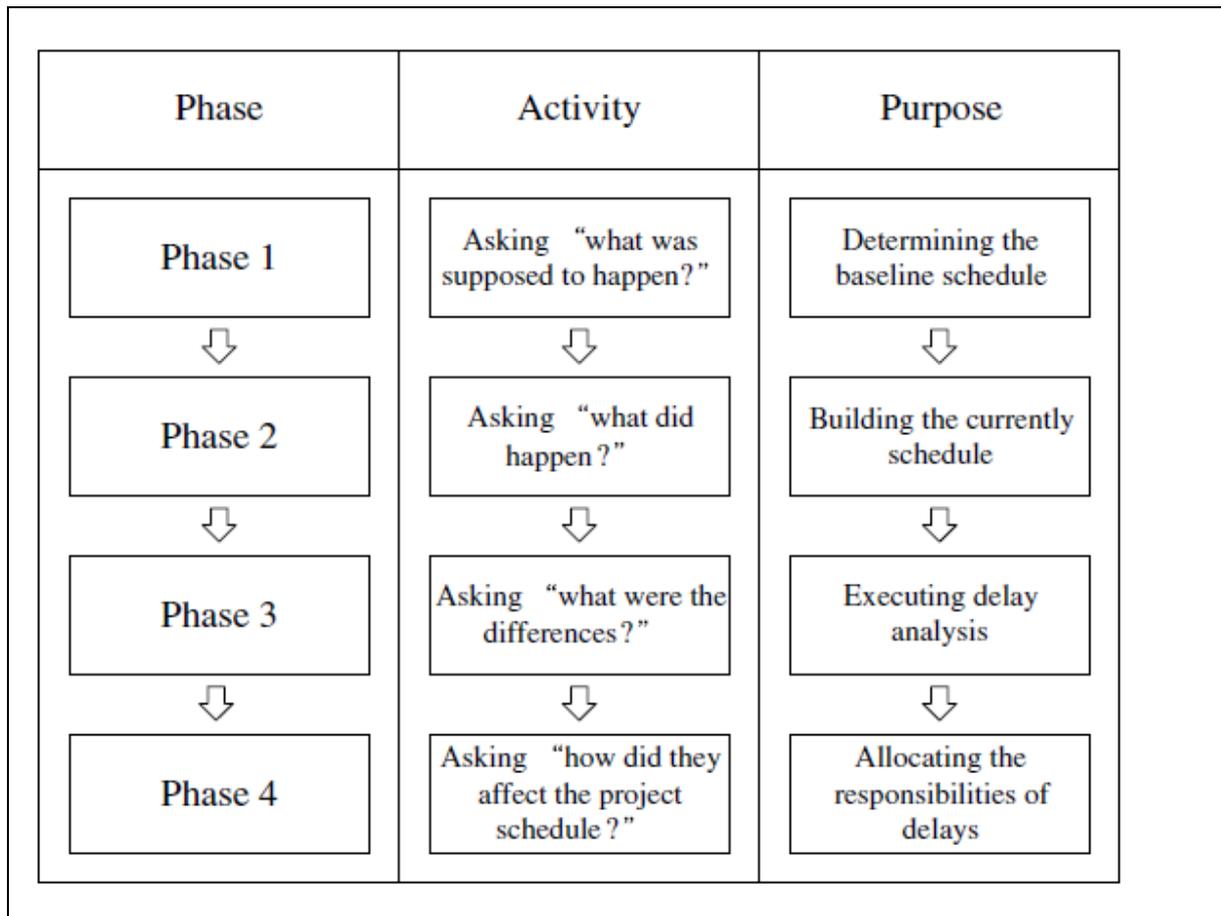
with what Arditi and Pattanakitchamroon (2006) explained above when they explained the TIA as focusing on day by day time periods rather than specific events.

Bordoli and Baldwin (1998) generally explain that the main problem with the common delay analysis methodologies is that they are not dynamic, do not consider the status of the progress of the works at the time when the delay occur, the fact that the critical path keeps changing as the project progresses further and the mitigation efforts exerted to reduce the impacts of the delays. Such mitigation efforts are, in standard forms of contracts such as FIDIC, usually a requirement. Bordoli and Baldwin (1998) therefore developed a delay analysis methodology which is very similar to the concept of the TIA. They basically perform the TIA but splits the time periods based on the occurrence on the dates when the events occur rather than having day by day analysis. They also make focus on the actual mitigation efforts which may require changed to the CPM network logic if such efforts, for example, were by re-sequencing the works.

Kumaraswamy and Yogeswaran (2003) note that the larger number of windows/ snapshots analysed, the more accurate the results of the TIA would be. They also describe the TIA as the time slice method. Kao and Yang (2009) claim that all window-based delay analysis including the TIA, can be performed through four systematic phases. As can be seen from figure 2-8 below, the first phase is basically asking the question of ‘what was supposed to happen?’ which leads to the determination or even the creation of the appropriate planned baseline programme.

The second phase is to determining what actually had happened by creating an as built schedule. Multiple as built (progress updates) schedules can be created to reflect the project status at each time period of the analyses. The third phase is to analyse the difference between what was planned and what actually happened. This is the time what the delay analysis is performed and the selection of the appropriate method can make a difference. The last and fourth phase is analysing the results of the delay analysis and allocating the responsibilities and damages of delay to the project parties.

Figure 2-8	Delay Analysis Phases (Kao & Yang, 2009)
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Although the windows analysis method is essentially the same as the time impact analysis method, Williams (2003) and Braimah and Ndekugri (2008) describe it, in a slightly different way, as dividing the as built project duration into periods and update these periods with the as actual as built data inclusive of the delay events and their impacts. The difference between the impacted completion date and the as built completion date in each time period would count as extension of time entitlement.

Kao and Yang (2009) claim that windows based analysis generally are the most reliable and accurate for analysing the project delay. They claim that the windows analysis method, as one of the window based delay analysis methods, can deal and resolve complicated delay analysis of complex projects better than other methods. Kao and Yang (2009) reviewed four different methods that are all can be categorised as the Window Analysis methods. These are the delay sections, traditional windows analysis/ contemporaneous analysis method, modified Windows Analysis and daily windows analysis.

The traditional windows analysis method is explained as extracting and analysing window periods from the project schedule rather than analysing the individual delay events. The modified windows analysis is an evolution of the traditional windows analysis method but is having the ability to determine the liability of the delay before analysing its effect by way of creating delay fragments for analysing the impacts. The traditional windows analysis method is viewed as best for real time impacts while the modified version of it is viewed as best for the retrospective delay analysis. Yusuwan and Adnan (2013) agree with this view and note this method sometimes is called contemporaneous period analysis.

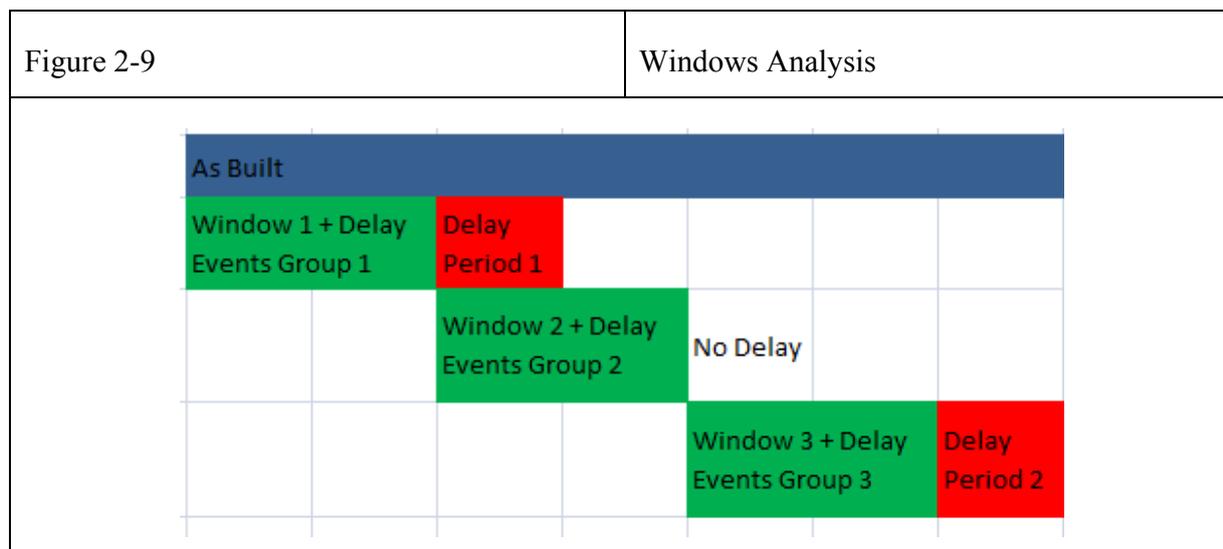
Kao and Yang (2009) then further describe the delay section delay analysis, which is barely mentioned by any other researcher. It is still similar to the traditional windows analysis method but with some improvements to overcome the two main limitations of the windows analysis method which are the inability to efficiently consider concurrency and acceleration. However, section delay method sounds a bit complicated. The last method they talk about is the daily Window Analysis, which is essentially the same as the traditional windows analysis but with a day as a fixed time period, which as explained above counts as the TIA in accordance with Arditi and Pattanakitchamroon (2006).

Kao and Yang (2009) highlight an important feature, which can also be seen as a drawback of the method, that is that the results of the analysis may change depending on the size of the window. It was therefore suggested that the analysis is made using daily time periods. Obviously, the problem here is the effort and the level of data required to perform such analysis. Yang and Kao (2012) suggest that all window based delay analysis methods can be either performed starting from the baseline and going forward or starting from the as built and going backward.

Another method, namely the CPM review method, was explained by Yang and Kao (2009) as something similar to the windows analysis, as the schedule updates are reviewed on systematic periods. The difference however is that no delay impacts are inserted into the schedule updates. Mohan and Al-Gahtani (2006) accept that the windows analysis method is widely used in analysing the delay in construction project but highlight that it has various issues and shortcomings and therefore must have some improvement. They suggest that delay analysis should account for all types of project delays, concurrent delays, pacing delays and acceleration. They also suggest

that delay analysis should always be performed on a day by day basis to account for the changing nature of the project critical path. Their main criticisms of the windows analysis method is that the critical path may change within a window period which may not appear in the results of the analysis.

In summary, this method is complex. Delay events are impacted/ analysed by dividing the project period into small time periods. There various types and ways for performing the windows analysis. It is the most reliable method available and may have the ability to deal with concurrent delay issues. It requires a baseline, progress updates, as built schedule and knowledge of the delay events. It is not recommended for project with poor records or limitations on time and budget but this may be resolved by limiting the level of detail of the analysis. Figure 2-9 below, illustrates the concept of this method.



2.3.7 Total float management/ Float Mapping

Kao and Yang (2009) explain this method as dependant on the original baseline schedule. The concept here is that this method analyses the float consumption of the project and then determines the actual project delay accordingly. Mohan and Al-Gahtani (2006) highlight that none of the other methods takes account of the activity float although it should be treated as an essential part of the analysis. They noted an important fact which is that the float of the none-critical activities keeps

changing during the project which may have a great influence on the project resource allocation. Resource might be the real driver of project delay but it is very difficult, if not impossible, to show this on a critical path.

Mohan and Al-Gahtani (2006) describe this method as a new method but has evolved from the windows analysis method but with the focus on the total float of the activities on daily basis rather than focusing on the activities themselves for certain time periods, usually longer than a day. The added value of this method, as described by Mohan and Al-Gahtani (2006), is that it can be performed at the real time of the delay events and that it deals with the concurrent delays. They also claim that it is the only method that can deal with the pacing delays as the secondary critical paths are also analysed in this method by way of monitoring the float consumption in all project activities.

2.3.8 Bordoli and Baldwin's delay analysis method

As explained above, Bordoli and Baldwin (1998) ('B&B') developed their own method and Kao and Yang (2009) has also analysed it in their study. In fact, it is very similar to the windows analysis and time impact analysis method. Its basic concept is considering the study of the project and the progress information at the time of the occurrence of each delay event and then simulating the impact of each event at the exact point of time of its occurrence. The process is repeated until the final event is analysed where the result would be a final impacted as built schedule along with event wise impacted updated schedules. The method also allows for the consideration of the actual mitigation or acceleration measure before assessing the delay impact which is viewed as an added value over the regular windows analysis method.

2.3.9 Effect Based Delay Analysis Method (EDAM)

Yang and Kao (2012) developed this method as a further evolution of their four developed window based delay analysis method explained above. It follows the same principle of the time impact and Windows Analysis but considers the impacts on the critical paths only. The other advantage of this method is that it performs the analysis on day by day only in the periods where the delay exists, not globally, and that it analyses acceleration measures and shortened activity durations in

the periods where there was no delay. A main advantage here is that the method can identify the actual shortened activity durations in the periods where delays actually occurred.

2.3.10 Casual Maps and System Dynamic Technique (SD)

Williams (2003) explains this method as an old mapping method with a quantitative analysis of the delay where causality, labiality and quantum calculation is considered. He describes this method as drawing maps to first find out why the delay occurred and the make the quantification and cost calculation of the impact of the delay. The method takes into account the Contractor’s acceleration measures but therefore may not be appropriate for showing the actual delay impact, as this might be hidden by the acceleration measures.

2.3.11 Adjusted As Built CPM

This method is described as relying on creating the as built schedule, if not already available, and inserting the actual impact of the events. The difference between the original planned completion date and the resulting completion date of the adjusted as built schedule would be the appropriate of extension of time entitlement (Mohan and Al-Gahtani, 2006). Kumaraswamy and Yogeswaran (2003) note that this method is the preferred method by consultants in Hong Kong. However, they also note that it does not deal with concurrency issues.

In summary, this method is simple and is similar to the collapsed as built method. The delay events are impacted on the as built schedule but considering the changes on the sequence of the works. It requires an as built schedule and knowledge of the delay events. This method is not very common. Figure 2-10 below, illustrates the concept of this method.



2.3.12 Isolated Delay Type Method

Yang and Kao (2009) describe the isolated delay type technique as something similar to the Window Analysis method explained above but mainly focuses on categorizing the delay event as per their types and then analysing their effect. Mohan and Al-Gahtani (2006) noted that this method starts with isolating the delay events based on their types and their impacts on the project schedule from both prospective; the contractor's and the owner's prospective.

2.3.13 Other Methods (Quantitative and Cost related methods)

While almost all the common delay analysis has been described above, Williams (2003) and Yang and Kao (2009) describe various other conceptual and practical methods which are less common methods. These methods will not be analysed in this paper. For example, some mathematical methods which focus on the quantitative aspect of the delay impact. An example of these is the equation-activity-based calculation method which is a method that aims in improving the estimation of the activity durations to enhance the results of the delay analysis.

Another method described by Yang and Kao (2009) is the 'Dollar to time relationship' method which relates the project cost to the delay. However, they explain the difficulties in linking the delay causation with the project cost. Mohan and Al-Gahtani (2006) noted that none of the mathematical delay analysis methods defines the liability of the delay which is viewed as a major drawback.

Table 2-1 below, which is an extract of Appendix B of this paper, summarizes the reviewed delay analysis methods in this section and provides a brief description of each method.

Table 2-1		Summary of Delay Analysis Methods (Extract from Appendix B)	
Summary of Delay Analysis Methods			
S.N.	Method	Other Names/ Similar Methods	General Description
1	Global Impact Technique		simply plots delays on a bar chart and determines the global impact of delay by summing up the total duration of all delays
2	Net Impact Technique	As built technique	This method is basically the same as the global impact technique but only the net impact of the delays is calculated.
3	Impact as-planned schedule analysis	After-the fact and modified CPM schedule as planned what-if impacted baseline schedule as planned plus delay analysis affected baseline schedule	uses only an as-planned or baseline schedule for delay analysis. It is based on the theory that the earliest date by which a project is completed can be determined by adding the delays into the as-planned schedule.
4	As-planned vs. as-built schedule analysis	Bar chart analysis As Built bar chart method linear schedule analysis	observation of the difference between an as-planned schedule and an as built schedule
5	Collapsed as-built schedule analysis	but-for-Forward Analysis modified as built time impact technique baseline adding impacts forensic scheduling but-for-Backward Analysis Traditional method but for schedules collapsing technique impacted as built collapsed as built as built less delay analysis as built subtracting impacts modified but-for Apportionment Delay Method	effects of delays are "subtracted" from an as-built schedule to determine what would have occurred but for those events. Apportionment Delay Method is a conciliation of the 'but for' and the net impact analysis
6	Adjusted As Built CPM		Delay events are impacted on the as built schedule.
7	Window analysis	Time impact analysis Contemporaneous analysis method contemporaneous period analysis snapshot analysis time impact technique time slice method delay sections traditional windows analysis modified window analysis daily windows analysis CPM review method Effect Based Delay Analysis Method (EDAM) Isolated Delay Type Method Bordoli and Baldwin's delay analysis	the assumption that delay impacts to a project can be assessed by running a series of analyses on schedule updates. It assesses delays effects on the project schedule by analysing the schedule periodically, generally on a day-by-day basis. Window analysis, a variation of time impact analysis, uses weekly or monthly updates to perform the analysis.
8	Other Methods	Total float management Float Mapping Lost productivity analysis methods Casual Maps and System Dynamic Technique (SD) equation-activity-based calculation Dollar to time relationship	The total Float Management method monitors the float consumption for all project activities and defines criticality based on float consumption

2.3.14 General Problems With all CPM Delay Analysis Methods

Williams (2003) highlights that a common effect of delay and disruption is the loss of productivity and motivation. Although this is a very important aspect in terms of the delay impact, none of the delay analysis methods defines a mechanism for assessing such effects. In addition, all methods including the TIA, considers that the delay impact will occur and that the management will take no action to mitigate it (to some extent). Usually, site management will take extra measures to mitigate delays or at least to avoid keeping idle resources as it might be difficult to deeply and reemploy the resources, when the work is ready to start.

Williams (2003) also highlights an important shortcoming of the common delay analysis methods which is that they do not consider resource constraints that may or may not be on activities on the critical path. The available software packages in the market are still incapable of dealing with this complex problem. Another problem he highlights is that all methods focus on the activity duration as the driver for the importance of the activity while in fact resources, cost and cost impact may be of more relevance.

Kumaraswamy and Yogeswaran (2003) also note that none of the methods may give an appropriate results alone and that each of the methods may provide different results. They suggest that a combination of methods is used to analyse the delays.

2.4 Factors to consider when Selecting Delay Analysis Methodology

Williams (2003) notes that before selecting a delay analysis methodology, questions should be asked to confirm which delay analysis method(s) can give the desired outcome and if the project circumstances are suitable for performing such method(s). Williams (2003) also notes that generally, all methods are having the same principle which appears to be easy in theory but is in fact difficult in practice. The baseline is usually used as the basis of the best estimated productivities and sequence of works before starting the project and baseline updates are used to reflect the actual productivities, sequence and delays/ acceleration that occurred. Delays are usually analysed using the baseline, the as built and/ or the project updates deepening the selected delay analysis methodology.

Braimah and Ndekugri (2008) identified 18 factors affecting the selection of the appropriate delay analysis methodology by delay analysts and then grouped those into six main categories. These categories were relating the project baseline quality and features, contractual obligations, project nature and circumstances, cost efficiency of the method, availability of records and the prospective of performing the analysis in terms of time. SCL (2002) also explains ten factors that have to be considered when selecting the appropriate delay analysis methodology. The paragraphs below explain the main identified factors affecting the selection of the delay analysis methodology.

2.4.1 Data, information and Records Available

This is one of the main factors influencing the selection of the delay analysis methodologies. As can be seen from Appendix B, each type of delay analysis methods require certain level of information to be properly performed. Investigation of all project records and the possibility of retrospectively recreating the missing records should be made before selecting the delay analysis method.

The type and level of information available, will heavily impact the selection of the most appropriate delay analysis methodology. Records may include correspondence, progress reports, meeting minutes, site inspection records, transmittal sheets, videos, photos and many others (Braimah & Ndekugri, 2008).

In fact, none of the delay analysis methodologies will give valid results if the project records are incorrect or invalid. It is therefore essential that delay analysts carefully review the provided records before selecting the delay analysis method and proceed with the delay analysis. Arditi and Pattanakitchamroon (2006) note, as an example, that when only baseline schedule is available, then the impacted as planned method would be the most appropriate. If no or little scheduling information is available, then the collapsed as built would be the most appropriate as an as built schedule would be easier and more realistic to create than creating a full set of planned programme (baseline) and periodic progress updates that would be required to perform other delay analysis methodologies. Another example is that if the project is relatively small and only simple bar chart was used, then a simple as planned vs as built might be the most appropriate. The time impact analysis is the methodology that is heavily depending on the available information.

Alkass et al. (1995) highlight that more than 70% of the delay analysis is usually exerted on gathering and organizing the information. The main issues they found were the lack of sufficient information to allow for proper categorization of the delays, real-time critical path analysis and proper records to allocate delay responsibility and deal with concurrent delays. Bubshait and Cunningham (1998) view the availability of data and the accessibility to such data as one of the main driving factors for the selection of the delay analysis methodology.

One of the main problems in projects is the missing periodic appropriate baseline updates and as built programmes. This will require the creation of such records before analysing the project delay in certain methods such as the windows analysis which is time consuming and will also affect the credibility of the results as the retrospectively recreated records will contain assumptions and estimations (Williams, 2003). Braimah and Ndekugri (2008) and Yusuwan and Adnan (2013), as well emphasis on the importance of having proper records for performing any kind of delay analysis. They also noted that their research revealed this as the most important factor, which was quite expected as all methods require certain level of information to be available.

2.4.2 Baseline quality and features

Braimah and Ndekugri (2008) note that this factor is the second in importance after the availability of proper records. Arditi and Pattanakitchamroon (2006) explain that having a proper baseline schedule reflecting the original intentions of how and when to perform the works is essential to perform the delay analysis, regardless of the selected methodology. However, as explained above, the collapsed as built method can be used if no adequate baseline schedule is available.

2.4.3 Contractual obligations

Braimah and Ndekugri (2008) and SCL (2002) note that the delay analysis methodology might be specified in the Contract documents and may also be influenced by the applicable legislation. So, there might be some limitations on the available options for the delay analysts. Kao and Yang (2009) note that although project delays are often in construction projects, construction contracts usually do not have a specified delay analysis methodology. They note that the windows analysis method has been widely accepted by courts.

Arditi and Pattanakitchamroon (2006) explain that critical path method as a scheduling technique and delay analysis tool has been widely accepted by courts. However, Braimah and Ndekugri (2008) note that, in UK for example, there is no clear acceptance of a method over another by courts. Nevertheless, they also highlight that courts had considered the factors considered for selecting the delay analysis methodology before deciding if its application and results are appropriate.

In summary, the first factor to consider is whether the project contract require the delay analysis using a certain method. In such case, the delay analyst may have limited options on the selection of the delay analysis methods. It may however have the option to decide on the level of detail of the analysis.

2.4.4 Project nature, complexity and circumstances

Braimah and Ndekugri (2008) and Kumaraswamy and Yogeswaran (2003) note that the characteristics of the projects such as the size, design, duration, cost and complexity will heavily influence the selection of the delay analysis method. However, they explain that this may impact in two different ways. Complex and large projects may require a complex delay analysis method to be able to analyse the delays. However, in some cases, the project might be too complex or having unnecessary complex information which may requires a less sophisticated method to analyse the delay. It is therefore suggested that this factor is considered along with the other factors in a case by cases bases.

To ensure the selected delay analysis methodology will procure the desired results, the delay analyst will have to carefully understand the project and its circumstances. The more complex the project, the more sophisticated the delay analysis would be. Complex projects would normally require a complex delay analysis methodology (refer to Appendix B).

2.4.5 Nature, type and number of the delay events

SCL (2002) and Kraiem and Diekmann (1989) categorize the delays based on their liability to Compensable, Excusable and non-excusable delays. Kumaraswamy and Yogeswaran (2003) note

that the majority of the causes of delay are originated by employers and are therefore excusable and compensable.

Kao and Yang (2009) suggest that the type of project delay have a great influence of the delay impact and the selection of the delay analysis methodology. They emphasize that the types of delays should be indemnified and categorized before selecting and performing the delay analysis method.

The delay events themselves vary in terms complexity. For instance, while an event may be a clear instructions for additional works, another event could be resolution of the design issue which may require a substantial experience and effort to analyse the delay. Such complex delay events will normally require a complex delay analysis method to reveal the factual effects. On the other hand, if the delay is simple, it would then be a waste of time and effort to employ a sophisticated delay analysis method while a simple and cheaper method could have been used. The delay analyst will therefore have to make a rational decision for the selection of the delay analysis method he is going to use and to stay alert for the necessity to change the method at any time if he feels his choice was not right.

2.4.6 Skills of the Analyst

SCL (2002) and Braimah and Ndekugri (2008) consider the skills and abilities of the delay analyst as a factor influencing the selection of the delay analysis method as some methods require some complex analysis and require certain level of experience, particularly when it comes to make reasonable assumptions, interpretations and understandings.

This might be a secondary factor to consider, but the delay analyst should ensure that he has adequate experience and capabilities to perform the delay analysis method he is going to perform.

2.4.7 The attitude of the opponent party

While this factor may not impact the way the analysis itself is carried out, it must be considered by the delay analyst before selecting the delay analysis method. For example, a fair and reasonable project owner that is aware of the delay events it caused to the project, may just accept to grant a reasonable extension of time to the Contractor, even if the latter provided simple analysis of the

delay. In this case, it won't be appropriate to perform a sophisticated and experience delay analysis. On the other hand, if the project owner is aggressive and is not admitting its own faults, then there must be a comprehensive delay analysis in place to pursue the owner to change its position or to be ready for the next dispute resolution if necessary. (Bramah and Ndekugri, 2008).

2.4.8 Time, cost and Resource Constrains for Performing the Analysis

Claims are usually governed by certain deadlines and milestones. They are also usually have limited budget. It is therefore essential that the delay analyst judge on the time and cost required to perform the delay analysis before selecting the delay analysis methodology.

There is huge variance on the level effort required to perform each of the delay analysis methods. This will also depend on the project size and the quality of the available records. Arditi and Pattanakitchamroon (2006), for example, highlight that the as planned vs as built method would require the least time and effort as it simply require a comparison between the existing baseline and as built activities. However, some other methods such as time impact analysis would require a relatively huge time when compared to other methods as it require the creation of fragment impacts of the delays and them periodic impacts of the delays.

Bramah and Ndekugri (2008) note that the cost proportionality should be considered when selecting the delay analysis as the cost of performing certain complex delay analysis methods, such as the windows analysis, maybe relatively expensive when compared to overall claimed cost damages due to the delay. It would then be rational to use a simpler and less expensive method. SCL (2002) calls this factor as the value of the dispute.

Bubshait and Cunningham (1998) also note that the timing of performing the delay analysis and the resources available to perform such analysis is one of the driving factors for the selection of the delay analysis methodology.

The more complex the delay analysis method is, the more effort is require and the more expensive it is. A rational decision has to be made before selecting the delay analysis is whether the effort and time to be sent are worth spending, For example, if the cost of performing a detailed complex

delay analysis would cost more than the claim value itself, then it would be rational to choose a simple and cheaper method.

2.4.9 Capabilities, Shortcomings and strength points of the Method

If the analysis relates to a simple or a small project, then most likely all methods will give the same or very similar results. However, in large projects with complex networks and multiple sources of records, each methodology will most likely provide a different result and such results will heavily affect the determination of damages. The choice of the appropriate analysis methodology is therefore fundamental. This will also depend on the nature of the project and the nature of the project activities. Arditi and Pattanakitchamroon (2006) highlight that each method has its own strength and weaknesses depending on the project circumstances and requirements. For example, if the project critical path was changing over the time periods, which is usually the case in construction projects, then a method that analyses the delay impact at different time spans of the project such as the Time Impact Analysis would be the most appropriate as the other methods with an impact at one point of a time would be misleading.

Kao and Yang (2009) note their preference of the window-based delay analysis methodologies as they have the capability of performing a real time analysis while the other methods lacks such feature. They also note that such window based methods has the capability to track the dynamic changing nature of the critical path which is also an essential element for an accurate and reliable delay analysis result.

In summary, after verifying all the factors and short-listing the candidate delay analysis methodologies, the delay analyst will need to verify the capabilities of each method and ensure that he selects the ones that is capable of dealing with the analysis he requires.

2.4.10 Status of Project and Point of Time

Delay analysis can be performed at any point of time before, during or after completion of the project. However, this will affect the selection of the delay analysis methodology (Arditi & Pattanakitchamroon, 2006). For example, if a forecast of a prospective delay is required, then the impacted as planned would be the most appropriate method. However, if a retrospective analysis

is required and as built data is available then the other methods such as the collapsed as built or the windows analysis/ time impact analysis would more appropriate. In cases where the project is still running and a real time delay analysis is required, then the time impact analysis might be the most appropriate as the other option would only be the impacted as planned method, which is heavily criticised for its theoretical results.

Mohan and Al-Gahtani (2006) suggest that any delay analysis should be performed at the time of the event occurrence and should use the active and effective critical path schedule at the time. However, although it is always better and sometime required as per the Contract to analyse the delays as they occur, commonly, delay analysis is performed retrospectively as the parties usually won't be clear or because sometimes contractors would prefer not perform delay analysis during the project as this may upset owners. Braimah and Ndekugri (2008) emphasis on the importance of the time factor for the selection of the appropriate delay analysis method. Looking at causes of their delays in a prospective way is completely different than analysing them contemporaneously or analysing them retrospectively.

An important factor to consider performing finalize the selection of the delay analysis method is the status of the project at the time when the analysis is to be performed. The delay analysis of a potential impact of a delay event for a project that did not start or just about to start is completely different than performing a delay analysis for a project that has been completed or have already progress substantial amount of work. If a simple delay analysis method, such as the impacted as planned method, is used in the latter case where a project is already completed, would open the door for huge criticism of the performed delay analysis as the method completely ignores the facts and the as built records assuming the baseline schedule logic, sequence and duration are remained as is. On the other hand, this assumption could have been reasonable if the project did not start or have just started. Thus, the delay analyst will have to judge on the reasonableness on the method and its relevant assumptions based on the actual status of the project.

2.4.11 Concurrent delays, Disruption and Acceleration Issues

Williams (2003) notes that if the project do not have concurrent delays and events caused by the Contractor in particular, then simple delay analysis method can be used rather than using a complex

and time consuming method such as the windows analysis. Mohan and Al-Gahtani (2006) claim that concurrent delay, disruption and acceleration consideration is an essential part of the delay analysis and that such consideration would make a huge difference when allocating damages and cost.

Mohan and Al-Gahtani (2006) also highlight that a proper delay analysis should take into account the acceleration measure taken during the project. Those should also be categorized to contractor's acceleration/ mitigation measures, Owner's instructed acceleration measures and schedule acceleration measures.

When the project is having multiple delay events and there is a possibility of concurrent and pacing delay issues, simple delay analysis methodologies, such as the impacted as planned method, may not be able to provide an accurate analysis. This may also affect the decision of the level of detail of the analysis, as the analyst may need to investigate the full details of the project activities in order to reach a fair conclusion in terms of concurrent delays and liabilities for the project delays. The concept here is that the more concurrency issue are possible, the more sophisticated the delay analysis may be.

Similar to the concurrent delay issues, one of the complex issue in delay analysis is the consideration of the acceleration and mitigation efforts taken to recover the delays. Again, complex methods only, such as the time impact analysis methods, may be able to deal with such issues. This may also influence the decision of on the level of detail and the windows periods of the analysis.

2.4.12 Purpose and Reasons for Delay Analysis

Braimah and Ndekugri (2008) note that the purpose of the delay analysis will influence the selection of the delay analysis methodologies. Purposes of analysis are usually extension of time, prolongation cost, and acceleration and disruption entitlements. Depending on each method capabilities, the selection should then be made. For example, if acceleration entitlement is the purpose of the analysis, methods such as the impacted as planned or the collapsed as built may not serve the purpose. However, methods such as the windows analysis may effectively present the acceleration measures.

The purpose of performing the delay analysis is an important factor to consider before selecting the delay analysis method. If for example, the purpose of the analysis is just to get a prospective forecast of the delay, then a simple cheap impacted as planned analysis would serve the purpose while if factual retrospective delay effect is to be analysed then one of the more sophisticated methods such as the time impact analysis or the collapsed as built methods would be more appropriate.

2.4.13 Ownership of the Float

The ownership of the project float will heavily impact the criticality of the activities. While the parties usually agree that the float is owned by the project and that it can be used on first use basis, if no such agreement is there, then the whole analysis and project paths will change. It is therefore essential that the delay analysis gets this cleared out and even try to get the consent of the parties on the ownership of the project float before selecting the delay analysis method.

Float ownership might become a complex issue and affect the result of the delay analysis if not agreed or is having complex apportionment requirements. Arditi and Pattanakitchamroon (2006) summarize the various positions on float ownerships, as the float ownership will have a direct effect on the delay analysis and its results. Their conclusions suggest that there is no agreement between the researchers on who owns the float and how it should be dealt with in analyzing the delay. While some researchers considered the float to be owned by the project and that it should be used on first come first use basis, some others considered that the float should be completely owned by the Contractor. Few others suggested that some other fair ways should be considered such as the allocating float percentages to the activities or assigning the float ownership based on the contract type and the profit risk. It was however highlighted that some contracts now contains clear clause defining who owns the float.

Mohan and Al-Gahtani (2006) and Kao and Yang (2009) also emphasize on the importance of the clear understanding of the float ownership as this would have a great influence on the selection of the delay analysis methodology. Owners usually takes advantage of the project float to accommodate additional works and variation orders while Contractor's usually consumes float due to their slow progress of works and/ or to control the project's time and cost.

2.4.14 Software Used and Scheduling Settings

While some projects may be small and simple, many projects are large and complex. There are various scheduling software in the market that allow for scheduling large number of tasks and activities using the CPM logic. The dominant software used are the Primavera project planner (P3) and the Primavera Project Management (P6). Such software contains various options that affects the calculation and determination of the critical path.

Arditi and Pattanakitchamroon (2006) highlight that specific attention should be given to software settings such as the scheduling options: retained logic and progress over ride. In progress updates, such scheduling option would make huge difference on the critical path as the latter option would allow activities to schedule out of sequence. The correctness of such options would depend on the nature of the project and the views of the delay analysis. However, in any case, such options should be considered while determine which method to use while analysing the delay and while performing the delay analysis.

Another software option is the calendar settings. Different calendars with different defined holidays can be assigned to the various activities and resources of the schedule. This will make the calculation of the project float and the determination of the project critical path a complex task and will affect any kind of delay analysis performed. It is therefore one of the issue that should certainly be checked, before determining the delay analysis methodology (Arditi and Pattanakitchamroon, 2006).

Other setting such as the definition of the critical path would also make a huge difference. While the default setting is that the critical path is the path containing the activities with a zero total float value, the software packages usually allows for change the critical float value. Other settings and issues like using of constrains, mandatory functions and unconventional relationships (start to finish for example), long lead and lag times and others will all affect the delay analysis of the project and must therefore be considered before selecting the delay analysis methodology (Arditi and Pattanakitchamroon, 2006).

2.5 Practical Expert Input

In order to improve the findings of the literature review and to develop a more localized conceptual model, interviews were carried out with three delay analysis experts in the context of their experience in the gulf and Middle East region. The following paragraphs provide the details of these interviews. To allow for smooth data collection, the questions were structured in categories based on their relevance to the topic and based on the developed conceptual framework developed in chapter four of this dissertation. The categories were as follows:

- Background and General Information
- General Delay Analysis Methodologies
- Additional Questions for the Project Case Studies/ Senior Planners
- Factors Influencing the Selection of the Methodologies: Specific

Appendix A of this dissertation contains the list of the primary questions asked during the interviews. Table 2-2 below provides a list of the interviewed experts.

Table 2-2 – List of Interviewed Delay Analysis Experts		
Nr.	Interviewee	Criteria for selection
1	E1	Expert in the field
2	E2	
3	E3	

2.5.1 Analysis – Interview - Expert 1 (E1)

This interview is with E1 who is 65 years old male delay expert having over 40 years of experience out of which 25 are in delay analysis. E1 is holding a Bachelor degree in quantity surveying and a master degree in project management. He is a fellow member of the chartered institute of arbitrators and a member of the chartered institute of building. E2 is currently working as delay

expert with a dispute resolution consultancy firm in Dubai and his main role is to perform and review delay analysis.

E1 was asked to define the delay analysis process from his point of view and his response was: *“Delay analysis in my view is the process of reviewing the whole project to identify the delay events and their effect on the project”*. E1 was also asked to describe the common used delay analysis methods in practice, which are the global impact technique, the net impact technique, as planned vs as built schedule analysis, impacted as planned method, collapsed as built and windows analysis.

His responses was as follows: *“The global impact and the net impact methods are just simple bar charts with calculation of the delays based on the amount of the delay not based on its effect on the critical path. The global method take the gross total of the delay and the net impact method takes only the net total of the delays”*. He then added in relation to the as planned vs as built schedule analysis: *“this method ignores the sequence of the works and just compares the planned and the actual durations and dates of the impacted activities”*.

With the regards to the Impacted as planned method, E1 said: *“this is a simple unreliable method that impacts the delay events on the baseline schedule assuming that it was ideal and everything should have gone was planned”*. E1 then described the collapsed as built method as: *“it can be either taking the as built schedule and impacting it with the delay events or taking the actual as built and excluding the delay effects”*.

E1 finally described the Windows Analysis as: *“The windows analysis is in fact multiple methods as it can be performed in various ways. The principle is that we split the project schedule to multiple periods and then impact each period as an individual schedule. The periods and the way we impact the events can be made in multiple ways depending on the needs and the nature of the case”*.

E1 explained that he used the as built vs as planned method the most and that he also used all other methods. His view is that the as built vs the as planned method is generally the most appropriate. E1 was then asked about how he decides which method to use and he responded as follows; *“As a quick answer, I study the project and then decide, studying the project in the context means*

checking all the factors such as the nature of the project and the delay events, the available records, the quality of the information, the involved parties, the time available to perform the analysis and many others”.

A question was then raised about how E1 decides the level of detail of the analysis and his response was: *“This is just part of the decision I take when I consider the same factors for selecting the delay analysis method”*. The final general question asked was on how E1 decides the calculation method of the delay analysis in terms of the backward and the forward calculation. He said: *“If the project is already started, then I always use backward calculation. However, if any forecast is required, then I have to use forward path calculation”*.

A series of questions relating to the potential factors affecting the selection of the delay analysis mythology were asked to E1. The first question was relating to the importance of project records in terms of the selection of the DAM and his response was as follows: *“Project records are the key to a successful delay analysis and is one of the main factors to consider before selecting the delay analysis method. In essence the delay analyses is just an interpretation of the project records”*. With regard to the type of records E1 would normally be looking for, he said: *“I would look at everything available”*.

With regards to the importance of the baseline schedule, E1 said: *“The baseline schedule is indeed important. However, I see it as a secondary source of information as it would rarely reflect the actual sequence of the works”*. He was then asked about the contract documents and he explained: *“as I explained earlier, I would always review everything available including the contract documents. If the contract asks for certain type of delay analysis method to be used, then I would do my best to use. However, if there is a problem with such method, then I would challenge the contract requirements”*.

E1 was then asked about the influence of the project and delay events' complexity on the selection of the DAM and he responded as follows: *“in my view, the more complex the project is, the more complex the delay analysis should be”*. A question was then raised in relation to the experience of the delay analyst, he said: *“a common problem I face when I review cases of project is that delay analysis was performed by an unexperienced people which result in inaccurate results. You must have adequate experience to perform the delay analysis”*. When asked about the effect of the

attitude of the other party, he said *"it may make winning the claim easier but I don't think it has any impact on the delay analysis"*.

E1 was asked about the time, cost and resources limitations and their effect on the selection of the DAM, He responded as follows: *"this is a big issue for me, Quality and accuracy of the analysis is something fixed in my view and should not be restricted by time and cost constraints. I faced situations where I refused to perform the analysis because I was not given sufficient time to perform the analysis"*.

When E1 was asked about the capabilities of the delay analysis method, he explained: *"this is of course something that must be considered in contrast with the desired results"*. E1 further added when asked about the effect of the actual status of the project; *"the actual status of the project is the real driver in my view. If only a forecast of a potential delay at the start of the project is required, the analysis would be completely different than the analysis of the actual delay that occurred in a completed project"*. He then added when asked about the timing of performing the analysis: *"as explained in the previous answer, the time when you perform the analysis is subject to the purpose of the analysis and will influence the selection of the delay analysis method."*

E1 was asked about the concurrency and acceleration issues and how they affect the selection of the delay analysis. He responded as follows: *"concurrency and acceleration issues are much more complex than delays. Their impact is usually difficult to be identified and analyzed. The complex methods such as the windows analysis would usually produce better results in such cases but not necessary completely accurate"*.

In terms of the purpose of the analysis, E1 said: *"the purpose of the analysis is the first think I look at before selecting the delay analysis method"*. As to the project float ownership, E1 said: *"if this is not agreed, the analysis would become nightmare. I've never seen a case where the parties were in disagreement over the ownership of the project float"*. When asked about the software E1 usually uses, he said: *"I used many software packages such as sure track, power project, Microsoft project and Primavera. The software usage in my experience varies according to the geographical area. Sure track for example is one used mostly in UK and Primavera is dominantly used in the Middle East and Arabian Gulf region. For the scheduling settings, I tend to review the project"*

records before deciding to use the retained or the progress override logic, as both settings has their own advantages and disadvantages”.

2.5.2 Analysis – Interview - Expert 2 (E2)

This interview is with E2 who is 65 years old male delay expert having over 32 years of experience out of which 30 are in delay analysis. E2 is holding a Bachelor degree in civil engineering, a master degree in business administration and a master degree in construction law. He is a fellow member of the chartered institute of arbitrators and the royal insatiate of chartered surveyors. E2 is currently working as delay expert with a project management consultancy firm in London, United Kingdom and his main role is to perform and review delay analysis.

E2 was asked to define the delay analysis process from his point of view and his response was: *“in simple, words, delay analysis is finding out what happened and why it happened”*. E2 was also asked to describe the common used delay analysis methods in practice, which are the global impact technique, the net impact technique, as planned vs as built schedule analysis, impacted as planned method, collapsed as built and windows analysis.

His responses was as follows: *“I don’t know what the global and net impact techniques are”*. He then added in relation to the as planned vs as built schedule analysis: *“this is the best method when it comes to simplicity and to permeations. You just get the baseline and the as built schedules and present the difference between the activities”*.

With the regards to the Impacted as planned method, E2 said: *“as the name implies, you just impact the planned activities with the delay events. The result would be an impacted baseline that forms the basis for the extension of time entitlement”*. E2 then described the collapsed as built method as: *“as built schedule excluding delay effects. The result would be an extracted as built schedule that shows how and when the projected would have completed if there were no delay events”*.

E2 finally described the Windows Analysis as: *“The windows analysis is where you breakdown the project in time slices and analyses the delay in each time slice individually”*. E2 explained that he used the windows analysis method the most and that he never used the global or the net

impact techniques. His view is that the windows analysis method is always the most appropriate, with adjustments for each project depending on the circumstances.

E2 was then asked about how he decides which method to use and he responded as follows; *“there are various factors involved in such decision. The first thing I would look at is what the purpose of the analysis is. After that I would look at other factors such as the time of performing the analysis and the availability of records”*.

A question was then raised about how E2 decides the level of detail of the analysis and his response was: *“the level of details usually depend on the complexity of the project and the available time to perform he analysis”*. The final general question asked was on how E2 decides the calculation method of the delay analysis in terms of the backward and the forward calculation. He said: *“this will depend on the status of the project. Forecasts usually require a forward path causations while actual analysis should be analyzed through a backward calculation method such as the collapsed as built method”*.

A series of questions relating to the potential factors affecting the selection of the delay analysis mythology were asked to E2. The first question was relating to the importance of project records in terms of the selection of the DAM and his response was as follows: *“delay analysis can produce good results if only you get good records”*. With regard to the type of records E2 would normally be looking for, he said: *“all available project schedules, progress reports, inspection requests, design documents, contract documents and others would form the basis for the analysis”*.

With regards to the importance of the baseline schedule, E2 said: *“as the baseline schedule will be used to evaluate the delays, it must meet a certain level of quality and accuracy before it can used”*. He was then asked about the contract documents and he explained: *“if they contract documents asks for a certain method, then this should solve the selection problem”*.

E2 was then asked about the influence of the project and delay events' complexity on the selection of the DAM and he responded as follows: *“project complexity in terms of design and number of delay events is a driving factor for the delay analysis”*. A question was then raised in relation to the experience of the delay analyst, he said: *“in my view, you need to be an expert to be able to perform the delay analysis. Although most of the method appear to be simple, the application of*

the analysis usually requires assumptions and judgments to be made. Such things requires experience". When asked about the effect of the attitude of the other party, he said "*you just need to make the effort required to satisfy the other party*".

E2 was asked about the time, cost and resources limitations and their effect on the selection of the DAM, He responded as follows: "*time and budget issues are certainly a constraint. Delay experts, such as myself, are usually working on hourly basis and are expensive. Also, they require substantial amount of time before they can reach to a conclusion*".

When E2 was asked about the capabilities of the delay analysis method, he explained: "*each method has its own advantages and disadvantages and those have to be considered at the time of the selection of the method*". E2 further added when asked about the effect of the actual status of the project; "*performing an analysis on running project would produce a more realistic analysis than a project that has not started or has been already completed. On running project, you would have real time access to the people and the records. The actual status of the project would also influence that way you analyses the delay*". He then added when asked about the timing of performing the analysis: "*we have to perform the analysis as the events occur. If your perform two years after the completion of the project, the results will not be as accurate as if you had performed the analysis during the project*".

E2 was asked about the concurrency and acceleration issues and how they affect the selection of the delay analysis. He responded as follows: "*you need to perform one of the advanced delay analysis methods such as the windows analysis, which is called time impact analysis sometime, to be able to delay with concurrency issues, Acceleration issues would require specific attention and specific analysis based on the actual records*".

In terms of the purpose of the analysis, E2 said: "*your delay analysis must achieve the desired purpose. You therefore have to consider the purpose*". As to the project float ownership, E2 said: "*Generally, contracts specific that the schedule float is owned by the project. I have been in ne situation where the contract specified that the float should be apportioned on 50/50 based between the project owner and the contractor. The analysis of this project was a nightmare!*". When asked about the software E2 usually uses, he said: "*I prefer Primavera, but I do use other software*".

package from time to time. I always use the retained logic scheduling setting as it give the proper results. Progress override setting simply does not work for construction projects”.

2.5.3 Analysis – Interview - Expert 3 (E3)

This interview is with E3 who is 51 years old delay expert having over 25 years of experience out of which 20 are in delay analysis. E3 is holding a Bachelor degree in civil engineering. He is a member of chartered institute of arbitrators. E3 is currently working as delay expert with a project management consultancy firm in Abu Dhabi, UAE and his main role is to perform and review delay analysis.

E3 was asked to define the delay analysis process from his point of view and his response was: *“delay analysis is the process of first finding out what delay events occurred in the project. The second step is finding out the effect of such delays. The last step is then to determine the responsibility of such delay and award damages”.* E3 was also asked to describe the common used delay analysis methods in practice, which are the global impact technique, the net impact technique, as planned vs as built schedule analysis, impacted as planned method, collapsed as built and windows analysis.

His responses was as follows: *“The global impact technique is the simplest method and it is one of the methods that do not rely on the critical path scheduling method. The concept of it is that the delays are plotted and summed up. The net impact technique is exactly the same but the delays are plotted on time bar chart and only net delay is summed up”.* He then added in relation to the as planned vs as built schedule analysis: *“this method is the simplest. You first analyze the bassline schedule and identify the activities that might have been affected by the delays. You then produce the as built bar of the same activities and compare them with the planned bars. The differences would present the delay or the acceleration to each of the activities”.*

With the regards to the Impacted as planned method, E3 said: *“the impacted as planned method is the method generally adopted by project contractors. After identifying the delay events, they are inserted into the baseline schedule and the project completion date is shifted accordingly. It*

assumed the project planned sequence is correct, even if the facts says otherwise. The argument generally made here is that this was the original intention and it could have been achieved had those delay events not occur". E3 then described the collapsed as built method as: *"The collapsed as built method is a bit complex method. The as built schedule should be created, if not already available, and then the effects of all delays must be inserted into the schedule as part of the as built data. The delay effect are then extracted one by one to visualize the as built schedule without the delay effects. If for example, the completion date was still after the original completion date after the exclusion of all the owner's delays, then this gives the impression that the project was delayed due to the Contractor's concurrent delay events or slow progress"*.

E3 finally described the Windows Analysis as: *"the windows analysis method is the most acceptable by clients as far as I know. Its main advantage is that it consider the criticality of the project path at various periods of the project. So, while some delays may have caused critical delays at the start, they may have become less critical at later periods because of the mitigation measures or because other events become more critical"*. E3 explained that he used the windows analysis method the most and that he used most of the other methods. His view is that none of the methods is good alone, while a combination of two or more methods might serve the purpose.

E3 was then asked about how he decides which method to use and he responded as follows; *"if the contract is asking for a specific method, then that is the method I use, with some medications if necessary. Factors such as the availability of records and the actual status of the project will influence my decision of which method or combination of methods I should be using"*.

A question was then raised about how E3 decides the level of detail of the analysis and his response was: *"time available and available project records. If I have unlimited time, then I would analyze every single detail I can"*. The final general question asked was on how E3 decides the calculation method of the delay analysis in terms of the backward and the forward calculation. He said: *"I always use backward path calculation method, the windows analysis method, unless the contract asks for otherwise or just a forecast of the delay is required"*.

A series of questions relating to the potential factors affecting the selection of the delay analysis mythology were asked to E3. The first question was relating to the importance of project records in terms of the selection of the DAM and his response was as follows: *"as I explained in my answer*

to your earlier question, project records is very important". With regard to the type of records E2 would normally be looking for, he said: *"everything should be analyzed. Facts could be hidden any ware"*.

With regards to the importance of the baseline schedule, E3 said: *"I always start my analysis by reviewing the baseline and fixing its errors. The selection of the delay analysis method might be affected of the quality of the baseline is not adequate"*. He was then asked about the contract documents and he explained: *"I review them all and follow the clauses relating the delay analysis"*.

E3 was then asked about the influence of the project and delay events' complexity on the selection of the DAM and he responded as follows: *"if the project is complex, this may not only require a complex delay analysis method, but also might require other experts in different fields to assist"*. A question was then raised in relation to the experience of the delay analyst, he said: *"you must reasonable experience to perform the analysis. Projects planners are usually not qualified to perform delay analysis."* When asked about the effect of the attitude of the other party, he said *"the delay analysis will not be affected but the selection of the method might be affected. You don't need to spend unnecessary money on an analysis that is not required"*.

E3 was asked about the time, cost and resources limitations and their effect on the selection of the DAM, He responded as follows: *"as a professional delay analyst, you must adhere to the quality, time and cost assigned to the task. You would normally select the method that can cope with such requirements. If you have reservations, you just need to make them clear. If it is not possible with such contains, then just refuse the job"*.

When E3 was asked about the capabilities of the delay analysis method, he explained: *"capabilities of the method is something you must consider while selecting. In my view, this is a default factor that you consider each time to consider one of the other factors"*. E3 further added when asked about the effect of the actual status of the project; *"this would also affect the selection process. For example, the impacted as planned method can be used for analyzing the delay on a project that have not started but collapsed as built cannot, as there is no as built schedule to collapse"*. He then added when asked about the timing of performing the analysis: *"the earlier the better. The more you delay, the less credible you are. Selection of the method will certainly be affected"*.

E3 was asked about the concurrency and acceleration issues and how they affect the selection of the delay analysis. He responded as follows: *“this question relates to the previous question regarding the method capabilities. You need to select a method that is capable of analyzing concurrent delays and acceleration”*.

In terms of the purpose of the analysis, E3 said: *“as explained in my earlier answers, you have to choose the method based on the purpose”*. As to the project float ownership, E3 said: *“from my experience, parties usually agree on the float owner ship. If not agreed, the analysis might become difficult regardless of the method used”*. When asked about the software E3 usually uses, he said: *“I always use Primavera with the retained logic as the scheduling setting”*.

CHAPTER THREE –THE CONCEPTUAL FRAMEWORK

3.1 Introduction

This chapter is intended to work as linkage between the reviewed literature along with the practical feedback gathered from the delay experts and the aims and objectives of the research. While various delay analysis methods and factors affecting the selection of such delay analysis methods have been identified, conceptual model will need to be developed to work as a map for understanding each type of the delay analysis methodologies and each of the relevant factors. The model shall also provide a guidance on how to each of the factors may influence the selection process of the delay analysis methodologies.

3.2 Conceptual Framework

The reviewed literature revealed that multiple methods for analysing the delay in construction projects are available. However, there is an obvious agreement between the researchers on their disagreement on the categorisation and usage of the delay analysis methodologies. The following paragraphs shall provide a conceptual model of the main categories of the delay analysis methodologies and the factors affecting the selection of such methodologies. Appendix B to this dissertation provides a summary table of the identified delay analysis methods and the Appendix C provide a summary table of the main identified factors. Table 3-1 below provide a summarized version of main identified delay analysis methods and table 3-2 presents a summarized version of the main identified factors.

S.N.	Method
1	Global Impact Technique
2	Net Impact Technique
3	Impact as-planned schedule analysis
4	As-planned vs. as-built schedule analysis
5	Collapsed as-built schedule analysis
6	Adjusted As Built CPM

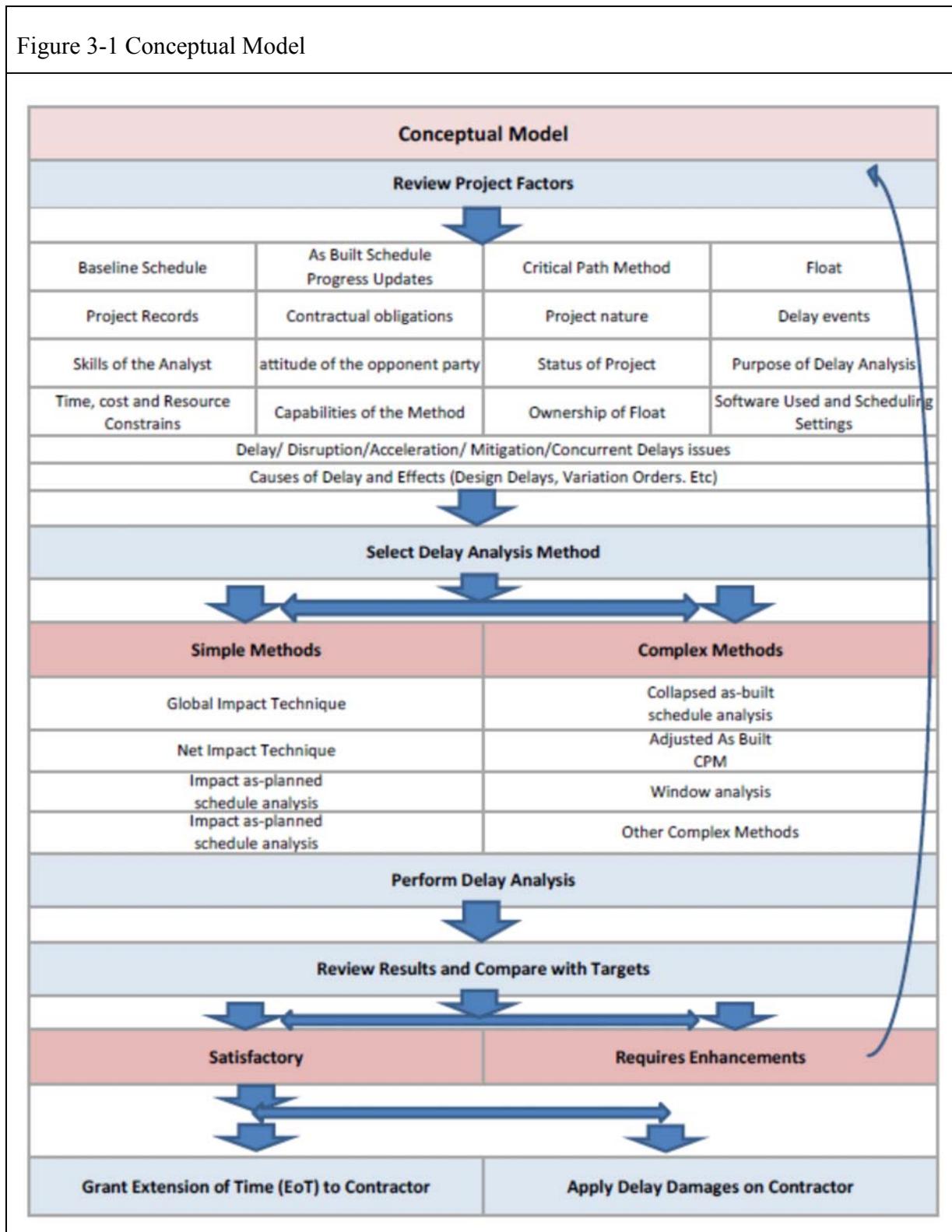
7	Windows Analysis	
8	Other Methods	

Table 3-2 Main identified factors (extract from Appendix C)

Main Identified Factors		
S.N.	Factor	Reference
1	Data, information and Records Available	(Braimah & Ndekugri, 2008) Arditi and Pattanakitchamroon (2006) Alkass et al. (1995) Bubshait and Cunningham (1998) (Williams, 2003) Braimah and Ndekugri (2008) Yusuwan and Adnan (2013),
2	Availability and Quality of Baseline Schedule	Arditi and Pattanakitchamroon (2006) Braimah and Ndekugri (2008)
3	Contractual obligations	Braimah and Ndekugri (2008) SCL (2002) Arditi and Pattanakitchamroon (2006)
4	Project nature, complexity and circumstances	Braimah and Ndekugri (2008)
5	Nature, type and number of the delay events	SCL (2002) Kumaraswamy and Yogeswaran (2003) Kraiem and Diekmann (1989) Kao and Yang (2009)
6	Skills of the Analyst	SCL (2002) Braimah and Ndekugri (2008)
7	The attitude of the opponent party	Braimah and Ndekugri (2008)
8	Time, cost and Resource Constrains for Performing the Analysis	Arditi and Pattanakitchamroon (2006) Braimah and Ndekugri (2008) SCL (2002) Bubshait and Cunningham (1998)
9	Capabilities, Shortcomings and strength points of the Method	Arditi and Pattanakitchamroon (2006) Kao and Yang (2009)
10	Status of Project and Point of Time	Arditi and Pattanakitchamroon (2006) Braimah and Ndekugri (2008)
11	Concurrent delays, Disruption and Acceleration Issues	Williams (2003) Mohan and Al-Gahtani (2006)
12	Purpose and Reasons for Delay Analysis	Braimah and Ndekugri (2008)
13	Ownership of the Float	Arditi and Pattanakitchamroon (2006) Mohan and Al-Gahtani (2006) Kao and Yang (2009)
14	Software Used/ Scheduling Settings	Arditi and Pattanakitchamroon (2006)

Figure 3-1 below, which is an extract of Appendix D of this research provides the conceptual model derived from the reviewed literature and the gather information practical information from the interviewed delay analysis experts. The model suggests that that the factors are considered on stages based on their relative importance before selecting the one of the various delay analysis methodologies, as the selected factors may also have an influence on each other.

Figure 3-1 Conceptual Model



CHAPTER FOUR– RESEARCH METHODOLOGY

4.1 Introduction

This intention of this dissertation as a research document is to examine current practices and their effectiveness in selecting the most appropriate delay analysis methodology and to add further knowledge based on the data gathered through the research on ground. This is consistent with McGrath & Brinberg (1983) and Saunders et al. (2009) definition of the research as a systematic approach for increasing the knowledge. The research will be basically through searching the existing knowledge on the subject and also by applying descriptive analysis and explanations for the research findings. Such research methodology will have a direct impact on the validity of the results and findings. This is in line with Bryman and Bell (2003) and Fellows and Liu (2008) suggestions in terms using multiple approaches in research.

In addition to examining the available literature and knowledge on the topic, an emphasis in this research was given on practical issues and problems in selecting the most appropriate delay analysis methodology in construction projects. This will add value to the research as the potential users of the results would most likely be practitioners in the construction industry whom will use such results as a substantiation for their selection of certain delay analysis methods during the course of their daily activities.

Given the nature of this research and the topic of the research, certain questions require answers by limited experienced category of professional experts in the construction industry along with analytical and interpretive analysis of the data collected. For this reason, the qualitative research approach was selected over the quantitative research approach as the latter would most likely give misleading results in this research topic and may not lead to the desired outcome. Following Fellows and Liu (2008), an attempt will be made to develop concepts based on the conducted interviews and the analysed case studies.

4.2 Research Approach

As explained above, the common classification of the research approaches is either qualitative or quantitative (Kothari, 2004). The qualitative approach has been selected for this research as the

topic requires collection of sensitive information from experienced professional and then detailed interpretational analysis shall be carried out before concluding the results.

As suggested by the literature, this research has been designed in advance in order to ensure gathering of appropriate data that is aligned with the research question. Yin (2003) clearly stated that not only the research should be properly designed before commencing any research activities, but also noted that the research approach and way of collecting the data should be accurately defined to ensure that all collected data is in line with the desired information. This research has been indeed designed accurately to achieve the best outcomes. As the topic of selecting the most appropriate delay analysis method in construction project is a specialized topic and require certain level of experience, the interviewees and the case studies have been carefully selected based on their experience, knowledge and actual delay analysis practise.

The basic research questions in this research are what are the common delay analysis methods in the UAE construction industry and what are the factors influencing the selection of such delay analysis methods. As the answer to such questions require exploration and the interpretation of the data gathered, further emphasise is given on the value of following a qualitative approach than the quantitative approach. Hancock (1998) indeed noted that such research questions containing the why and what would normally better be researched through qualitative approach. The qualitative approach will also allow for proper investigation of the topic through analysing and understanding the feedback from the professional experts and the case studies as personal opinions and views (Fellows and Liu, 2008).

4.3 Case Study Research

Saunders et al. (2009) highlight that the qualitative research can be approach through analysing case studies and interviews for the purpose of studying a specific topic by way of multiple sources of evidence. Thus, as part of the research design explained above, the following methodology has been adopted. A conceptual model using the gathered data from the reviewed literature and the interviewed delay analysis experts has been developed and used as the basis for analysing the date of five project case studies and interviewing the relevant personnel. Data analysis of the gathered information through the interviews will be fully explored in chapter 5 of this research.

4.4 The Interviews Structure

Following the conceptual framework developed in chapter four of this research, the interviews with the project personnel were structured giving the main focus on the identified potential methods for analysing the delays in construction projects and the relevant factors influencing the decision for the selection of the appropriate delay analysis methodology. Following the suggestion of Yin (2011), careful attention was given to all interviewees in terms of listening and underrating of their answers and explanations, well preparation and study of the topic before conducting the interviews and proper data management.

As explained above, the questions asked to the interviewees basically covered the topic of the main available delay analysis methodologies and the factors influencing the selection of such methodologies. The interviews were structured in a smooth way with only three main questions on the main topic but allowing for discussions over the subject. The following are the main three questions asked:

1. Explain how you decided on the method to assess delays in this project?
2. What were the key factors that have influenced the choice of method?
3. In what way has the selected method has enabled/impeded your effort to assess delays more effectively and achieve the desired results?

The interviews were conducted in a semi-structured way taking the form of a discussion and each lasted for about 30 minutes. The interviews were conducted as face to face interviews which is the preferred interview method given the complexity of the topic and the amount of explanation and interpretation required, following the suggestions of Gill and Johnson (2002, p/103). All interviewees highlighted that the data provided is strictly confidential and that they are all tied with confidentiality contracts. Therefore, no real names or actual records are provided in this research.

4.5 The Data Collection

As explained above, the data for this research was mainly collected through conducted interviews with personnel that have participated in the delay analysis of five case stated of projects from UAE construction industry,. Table 4-1 below, provide a list of all case studies and the relevant interviewees.

S.N.	Project	Type	S.N.	Interviewee	Occupation	Used Method(s)
1	A	Hotel	1	A1	Project Planner	Impacted As planned
			2	A2	Delay Analyst	Float Mapping
			3	A3	Delay Analyst	Windows Analysis
2	B	School	4	B1	Project Planner	Impacted As planned
			5	B2	Delay Analyst	Windows Analysis
3	C	Road	6	C1	Project Planner	Windows Analysis
4	D	Plant	7	D1	Delay Analyst	As Built Vs As Planned Windows Analysis
5	E	Tower	8	F1	Project Planner	Impacted As planned

The interviewees were selected based on their involvement in the five analysed case studies. A1 was the project planner in project A and is a 37 years old project planner. He's having around 12 years of total experience, out of which 6 are in project planning. A2 is a 55 years old delay analyst. He's having around 30 years of total experience, out of which 20 are in project planning. A3 is a 52 years old delay analyst. He's having around 29 years of total experience, out of which 15 are in project delay analysis. B1 is a 40 years old project planner with 15 years overall experience out of which 5 are in project planning. B2 is a 60 years old delay analysis expert with over 30 years of experience in delay analysis. C1 is a 43 years old project planner with 15 years of experience in project planning. D1 is a 52 years old delay analyst. He's having around 32 years of total experience. F1 is a 30 years old project planner. He's having around 7 years of total experience.

An emphasis here is made to the fact that the topic of this research is a real life issue. This was the inspiration for the researcher and the literature review which formed the basis for the data collection. In essence the objectives of the research will be achieved through the contrast and comparison between the reviewed literature and the case studies and between the case studies themselves. In line with the conceptual model developed in section 3 of this research (figure 3-1 and Appendix D), the interviews' questions were framed and organising following the identified steps reaching to the performance of the delay analysis.

The first step was the review of the identified factors. Therefore, the starting question for all interviewees was "Explain how you decided on the method to assess delays in this project?". Depending on the answer of each interviewee, a group of follow up questions were asked for the purpose of investigating of the identified factors in the conceptual module have been considered.

The second step as illustrated in the conceptual model is the selection of delay analysis complexity level and method. The main question asked for investigating this component of the model was: "What were the key factors that have influenced the choice of method?". Follow up questions were then raised for the purpose of understanding how the various factors influenced the selection of the delay analysis method.

The third and last step as per the conceptual model is the verification of the results in contrast and comparison with considered factors and the desired results. For this purpose, the following question was asked: "In what way has the selected method has enabled/impeded your effort to assess delays more effectively and achieve the desired results?" Follow up questions were asked for the purpose of investigation the potential failures and draw backs of the method.

While conducting the interviews through the above mentioned three areas of questioning, the research was guided by the conceptual model to enable the analysis to be informed by the relevant literature. The interviewees were guided with further questions to allow the researcher to investigate all elements of the conceptual model.

4.6 Validity and Reliability

In terms of validity, the results of this research is considered as having high validity as the data collected through the design research approach and interviews directly relates to the research questions. Flick et al., 2004 Lancaster (2005) emphasized on the importance of having a research design that can lead to the desired outcome and can effectively answer the research questions. In this particular research, as the interviewed were selected based on their experience and actual performance of delay analysis, the validity of their feedback is of great significance.

As for the reliability of the research, the fact that the interviewees were carefully selected based on their experiences in the field of the delay analysis in the construction sector, will ensure that the results would have always been similar even if a different set of experts in the field are selected for the study. As suggested by Flick et al. (2004), this research has been conducted by the researcher as a report of the events without giving its own interpretation or own views on the subjects. The impracticality has been strictly adhered to ensure subjectivity of the research.

CHAPTER FIVE–DATA ANALYSIS, RESULTS AND FINDINGS

5.1 Introduction

This chapter contains the outcomes of the collected data and the conducted interviews along with the analysis of such information in contrast and comparison with the reviewed literature and the gathered expert feedback. The last section provides further and cross case analysis and summary of findings.

5.2 Analysis – Project A (5 Star Hotel)

Project A is a 5 star hotel and is one of the iconic projects in Dubai UAE. The value of the project is around 65 million US Dollars. Project A suffered from various complex delay events, particularly design issues. Table 5-1 below presents a summary of the details of project A.

Table 5-1 Project A - Summary of Information	
Type	5 Stars Hotel
Location	UAE
Approximate Value	65 million US Dollars
Planned Start	8 March 2006
Actual Start	8 March 2006
Planned Completion	15 October 2007
Actual Completion	28 July 2010
Main Cause of Delay	Late Design and Variation Orders
Delay Analysis Purpose	Support a Statement of Claim in an Arbitration case, for an extension of Time dispute

The records of project A reveal that the first claim filed by the Contractor was using the Impacted As Planned Delay Analysis method and that the claim was never agreed by the client. A dispute arisen and an arbitration case was then filed where the Float Mapping method was used. At a late stage of the arbitration, a new expert was involved and the Windows Analysis Method was used. The case was then settled.

The Impacted As Planned method concluded that the Contractor was entitled for compensation of damages during the whole prolonged period of 1109 days. Both the Float Mapping and the Windows Analysis methods concluded that project was prolonged by 1173 days. However, the Float Mapping method concluded that the Contractor was entitled to 1173 days of EoT while the Windows Analysis method concluded that the Contractor is entitled for 913 days of EoT only.

5.2.1 Interview with Project Planner A1

A1 was the project planner for project A. A1 was first asked to explain how he decided on the method to assess delays in the project and what were the factors that influenced the choice of the method. He explained that the first thing he looked at was the purpose of the analysis and if the contract specifies the method to be used to analyze the delays. The purpose was to prove the Contractor's extension of time entitlement and the Contract did not require any specific method. He then explained that at this stage he made his choice that the Impacted as Planned should be suitable. he also noted that the Impacted As Planned method was the recommended method with the organization.

He also noted that he was under pressure to complete the analysis in a very short time and he was under the impression that no detailed analysis will be required as the Client was aware of the delay events and was willing to settle. This has also influenced the decision on selecting the Impacted As planned method. He performed the whole analysis in six weeks.

A follow up question was raised to A1 in relation to the complexity of the project and the delay events as a factor. He explained that this is something he considered while performing the analysis not before selecting it. A1 then added that he would obviously require an adequate baseline schedule along with a clearly defined set of delay events so that he can perform the delay analysis, which was the case in project A.

Referring to the list of the 14 main identified factors exhibited as Appendix D and the conceptual model presented as Appendix D to this research, A1 has considered most of the factors before selecting the method. However, the factors that he missed or ignored could be the reason for the Client rejection of his analysis. For example, Williams (2003) suggested that Concurrent delays issued should be considered before deciding the delay analysis mythology and the complexity of such method. A1 complete ignored this factor and therefore selected a simple none-complex method, which the Impacted As Planned Method. It could be that he selected this method as it considers the Client delay events only which gives more EoT entitlement to the Contractor.

A1 has correctly considered the attitude of the opponent party, i.e. the Client, before selecting the method as recommended by Braimah and Ndekugri (2008). However, this factor turned out to be misleading as the Client, even if he was willing to settle the case, still wanted a fairly complex analysis before he accepts the EoT entitlement.

When A1 was asked about how the way he selected method has enabled his effort to assess delays more effectively and achieve the desired results, he explained that the Impacted As Planned is the fastest and the easiest method which was one of the main objectives. This is indeed in line with the recommendations of Braimah and Ndekugri (2008) as to the purpose of the analysis and the time available to perform the analysis.

A1 also explained that, in his view, the results of his analysis are very reasonable considering the relatively short time and minor effort he took noting that it took him four weeks only to perform the analysis. In fact, this implicitly implies that A1 has considered the project complexity and circumstances factor as suggested by Braimah and Ndekugri (2008) and the time available to perform the analysis as recommended by Arditi and Pattanakitchamroon (2006).

However, the Client and the project Engineer eventually did not accept the results of the analysis claiming that it was too theoretical and that it did not address. Although A1 view is that the real reason for the rejection was that the Client was trying to undermine the claim so that he can settle with lesser amount, it appears, considering the fact that the client eventually accepted revised analysis as will be explained below, that A1's failure to consider certain factors and his incorrect judgment on certain other factors led to rejection of the results of his analysis. In particular, A1

failed to consider the Concurrent delays, Disruption and Acceleration Issues factor and misjudged on the attitude of the opponent party and the purpose of the analysis.

In fact, it appears that A1's decision for the selection of the method was influenced by the organization's requirements of performing analysis that can produce the maximum EoT entitlement from the Contractor's perspective. This could be viewed as a hidden purpose of the analysis which may explained A1's decision for the selection of the method but may raise a question of the impartiality of his decision.

A1 was finally asked about why he did not perform a revised analysis that could satisfy the Client's requirements and achieve the desired results. He explained that he did not have sufficient experience to perform a complex method such as the Windows Analysis, which is in line with Braimah and Ndekugri (2008) suggestion to consider the skills of the analysis as part of the selection process.

It therefore appears that the Contractor's decision to involve expert delay analysis consultants was to overcome the shortage in A1's experience and most importantly to ensure impartiality while performing the analysis.

5.2.2 Interview with Delay Analyst A2

As a result of the Client's rejection, the Contractor hired A2 as an independent delay analysis consultant and asked him to review the performed analysis and produce a report of his own findings including a revised delay analysis, if necessary. A2 noted that the first thing A2 did was to review the available records along with the baseline and as built schedules. His intention was to utilize the float mapping method as, in his view, it is the best method in finding out the real critical path throughout the project period.

A2 highlighted that, in his view, there is no right or wrong answer to any kind of delay analysis. The real question is whether all facts were considered in a far and appropriate way. It appears from the analysis of case study A and the subsequent case studies, that the decision of selecting the most appropriate delay analysis method, though could be influenced by the parties, is at the sole discretion of the delay analyst, particularly when the analysis is an independent consultant.

A2 confirmed that he generally uses the Float Mapping method in all projects but that he considers the various factors in deciding the level of detail of the analysis and the analysis of the causations of the project delays. While the pre-determination of the delay analysis method may appear as a subjective opinion of A2, his consideration of the factors as part of the decision on the level of detail of the analysis rather than the selection of the method itself is supported by some of the researchers such as Braimah & Ndekugri (2008).

The factors A2 considered were basically (mainly?) the availability and accessibility of records, the complexity of the project, the fact that he is one of the few experts that are experienced in float mapping method, status of the project and the purpose of the analysis. According to Braimah and Ndekugri (2008), the availability and accessibility of records and the complexity of the project are essential factors to consider as those would mean that more experience is required and more detailed analysis should be carried which results in the need of using a complex delay analysis method.

However, the delay analysis may still have to have a subjective opinion on these factors as the project might be too complex and a simpler method should be utilized. For example, if the analysis become too complicated and hence raise the question of whether the cost of the process outweigh the benefits, the use of a simpler method complemented by the judgement of an experienced delay analyst may be sought. Adding to this, if the project records are insufficient or too simple or basic, the delay analyst may just decide that simple or even no analysis can be carried out (Arditi & Pattanakitchamroon, 2006).

The factor of the 'status of the project at the time', according to Braimah and Ndekugri (2008), may influence the way the delay analyst looks at the delays, i.e. prospectively or retrospectively Braimah and Ndekugri (2008). In this case, knowing that the project is already completed, a retrospective analysis, such as the Float Mapping performed by A2 may sound more appropriate which further explains why the analysis of A1 above may have been rejected.

The fact that A2 is experienced on the Float Mapping methods relates to the 'skills of the analysts' factor, which is, according to SCL (2002), having a great importance when sophisticated methods are used. A2 also highlighted that one of the major factors to consider in this method is the

ownership of the float, which is in line with the developed conceptual model and the suggestions by Kao and Yang (2009).

A2 thinks that the Float Mapping delay analysis performed in project A is the true reflection of what actually happened in the project. A2 also explained that the method, although may take longer time and require specific experience when compared to other methods, demonstrated the actual critical paths and the delays occurring on such paths on the project which enabled him to subjectively analyze the delays and assign responsibilities to the project parties. A2 advised that it took him 14 weeks to perform the analysis.

Nevertheless, although the Float Mapping method is a fairly complex method and A2 is an independent delay analysis consultant, the Client and the Project Engineer were still not persuaded with the results. The client and the project Engineer main justification was that the analysis lacked any consideration of the concurrent delay issues.

Kao and Yang (2009) highlighted that the Float Mapping method does deal with the Concurrent delays issues and A2 indeed confirmed that he analyzed all concurrent delay events as part of the process. However, he explained that he attended various meetings with the Client and explained the results to him but the latter was reluctant to accept that there were no critical delays by the Contractor.

From the analysis of the interviews of A1 and A2 so far, it appears that the factors of the attitude of opponent party and the purpose of the analysis suggested by Braimah and Ndekugri (2008) are of great importance in addition to the declared factor of the consideration of the concurrent delay issues. For the Float Mapping method, the rejection of the method could be because it is still a new method and is too complex to understand as explained by Mohan and Al-Gahtani (2006) which may explain, as will be explained below, why the Windows Analysis method was more acceptable.

5.2.3 Interview with Project Delay Analyst A3

After making various attempt to resolve the matter amicably with the Client, the Contractor declared that a dispute has arisen and filed an arbitration case against the Client. A3 was involved in the project as an expert to assist the arbitration tribunal in making their decision on the dispute over the project claim. A3 explained that his appoint was directly made by the Arbitration tribunal to ensure impartiality and that he was instructed to rely on inputs from A1 and A2 but not their opinion.

It can be seen here that A3 described the results of A1 and A2's analysis as an 'opinion' which supports the allegation made earlier that the selection of the method and the produced results contains lots of subjective views. This also explains why each delay analyst selects different method although he considers the same factors and why each delay analyst may produce different results although he would be considering the same facts. A3 agreed with statement.

However, knowing that delay analysis had already been performed twice in this project, A3 said that it was his intention to review the performed analysis and utilize as much as possible of the information available before deciding which method should be used and if revised analysis is required. His first impression that there was no appreciation given to the complexity of the project design and the complexity of the delay events when the methods were selected. This refers to the Project nature, complexity and circumstances suggested by Braimah and Ndekugri (2008), which may influence the delay analyst's decision on the complexity of the method to be selected and the level of detail of the analysis

A3 explained that technical input should have been acquired in order to adequately estimate the impact of the complex delay events. The factor of the "nature, type and number of the delay events" suggested by Kraiem and Diekmann (1989) applies in this context, as when there are large number of events and when such events require technical expertise to understand their impact, more detailed and complex analysis will be required and this may require a complex method to be selected. It may however, subject to the delay analyst's judgment, require a less complex method to be used but with detailed narratives added.

A3 highlighted that the fact that there are some concurrent delay events and that the events were spread over a long period meant that a periodic delay analysis method, such as the windows analysis, must be performed. A3 commented that this does not necessarily mean A1's and A2's selected methods or results are wrong. It is just that A3 felt that the delay analyst should use the method that can best describe what actually happened. He also added that Contractor's and Project planners, such as A1, have the cultural understanding that each part should analyze the other party's delay events excluding the impact of the other party's events or any actual mitigation efforts exerted.

In simple words, A1 selection of the Impacted As Planned Method assumes that the project suffered only from delay events caused by the Client and that the Contractor did not exert any mitigation effort. The usual defense of such analysis is that the Client should make their own analysis and positive case if they believe the project suffered from delays other than those caused by them. It worth noting here as commented on the analysis of A2 input above, the Windows Analysis performed by A3 sound more appropriate, when considering the factor of the current status of the project', which further explains why the analysis of A1 above may have been rejected.

In relation to the Float Mapping analysis, A2 said that he has two main issues with it. The first is that it is too complex and not common in the industry. This in line with the comments made on A2's analysis above. The second criticism A2 has on the Float Mapping method is that it heavily rely on the logic of the schedule which is rarely accurate or fixed as the sequence of the activities changes as the Contractor progress the works further. While this may be relevant to the factor of Availability and Quality of Baseline Schedule suggested by Arditi and Pattanakitchamroon (2006), none of the researchers mentioned the specific effect of the quality of the schedule logic on the Float Mapping method.

A3 indeed selected and performed the Windows Analysis as a delay analysis method. He said that the method revealed that the Contractor's concurrent delays were the critical at some stages of the project. He however said that this maybe the result of the way he performed the analysis rather than the selection of the method itself. This is indeed in line with the drawback of the Windows Analysis method highlighted by Kao and Yang (2009) that the results may change depending on the selected size of the window.

A3 also noted that it took him around 25 weeks to review the project documents and perform the revised analysis. He also noted that it could have taken him more time if the previously performed analysis were not available. As an independent expert, A3 had to choose to take all the time necessary to perform the analysis he believes is most appropriate. The case however was different with A1 and A2 who had the time and cost as limiting constraint to their analysis. This is a clear example of the effect of the ‘Time, cost and Resource Constrains for Performing the Analysis’ suggested by Arditi and Pattanakitchamroon (2006) and SCL (2002). It would be also noted that the periods taken by A1 and A2 may not be accurate reflection of the required time for the analysis as they both relied on the previously performed analysis which saved them time.

During the arbitration process, the Client also appointed a third part delay analysis consultant whom also performed a separate Window Analysis. A3 explained that they had some disagreement over the impact of some of the events but they were in agreement over the selection of the method and the way of performing it. Eventually, the consultants agreed on the overall delay period of the project which is 1173 days and that the Contractor entitled for 913 days of EoT as he was liable for 260 days of the delays.

In conclusion of project A, it appears that although all interviewees have considered the appropriate factors while selecting the delay analysis method, the selection process and even the way of the analysis is performed remains a subjective opinion of the delay analyst. However, as suggested by researchers such as Arditi and Pattanakitchamroon (2006) and Williams (2003), the Windows Analysis was the most acceptable method.

5.3 Analysis – Project B – International High School

Project B is the construction of an international high school compound in UAE. The project value is around 120 million US Dollars. There were delays in getting design ‘No Objection Certificates’ (NoCs) by the client and there were issues with the technical design. The Client also issued multiple variation orders for changes in the design. Table 5-2 below presents a summary of the details of project B.

Table 5-2 Project B - Summary of Information
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Type	International high school project
Location	UAE
Approximate Value	120 million US Dollars
Planned Start	1 September 2007
Actual Start	1 April 2009
Planned Completion	2 January 2009
Actual Completion	2 April 2011
Main Cause of Delay	Late NoCs and Design and Variation Orders
Delay Analysis Purpose	Support the negotiations through a mediation process for an extension of time and acceleration case.

The records of project B show that a claim was submitted by the Contractor to the project Engineer using the Impacted As Planned method. This claim was rejected by the Engineer claiming that no consideration was given to the concurrent delays and that the effects of the client's delay events were exaggerated. A third party consultant was appointed by the Contractor at a later stage during the settlement negotiation process and he performed a revised Windows Analysis. The case was eventually settled through mediation. Both methods concluded that the Contractor is entitled to 820 days of extension of time.

5.3.1 Interview with Project Planner B1

B1 was the project planner and he performed an Impacted As Planned delay analysis as part of the Contractor's claim for extension of time. B1 explained that he selected the Impacted As Planned method as he was aware that no concurrent delays exist in this project based on his direct involvement since the start of the project. Thus, B1 has in fact considered the factor of the 'concurrent delay issues' which, according to Williams (2003), could mean that a more complex

method is required. However, B1 decided that a simple method would be sufficient to perform this analysis. B1 explained that the project was complex but the events were fairly simple though they were too many. It can be seen here that the delay analyst, i.e. B1, decided to use a simple delay analysis method although he described the project as complex in nature which, according to Braimah and Ndekugri (2008), would normally mean that a complex method would be required. As to the nature and number of delay events, it seems that this what influenced B1's decision as Kao and Yang (2009) recommended a simple method where simple delay events are in question

Although B1 seems to have considered the appropriate factors before selecting the delay analysis method, noting the analysis of case study A above, the project Client may have had the impression that B1 has selected the Impacted As Planned method to hide the delays of the Contractor, not as a result of careful consideration of the various factors.

B1 noted that he performed and presented the analysis professionally and that he was satisfied with the results as it provided the basis for the Contractor's EoT fair entitlement. B1 however highlighted that the client representative was convinced with the results but it could not persuade his stakeholders that the Contractor had no concurrent delays. This gives another perspective of the importance of the consideration of the 'purpose of the analysis' and the attitude of the opponent party' as factors for selecting the delay analysis method before selecting the method.

At this stage the Contractor was willing to do whatever it takes to settle the claim amicably as it knew that the cost of the arbitration or litigation processes would be too expensive. Through direct negotiations with the Client, it was agreed that a third party consultant is hired by the Contractor to perform a revised analysis that can demonstrate that there were no critical delays caused by the Contractor. B1 highlighted here that he could have performed Windows Analysis if he was requested to do so but he understood that the Client internal stakeholders wanted a third party report from independent expert so that they can rely on in their decision. Braimah and Ndekugri (2008) highlighted the skills of the delay analysts as a factor to consider but no researcher considered the 'Reputation and the assured impartiality of the delay analyst' as a factor which has proven to be the case here in case B as appears in both interviews with B1 above and B2 below.

5.3.2 Interview with Project Planner B2

B2 was hired by the Contractor as an independent consultant to produce a report demonstrating that the Contractor had no critical delays in the project or otherwise. The project was already handed over and in the school was in operation at that stage. B2 explained that the first thing he did was reviewing the already performed analysis and the whole project records with particular attention to the baseline programme. This is found in line with the recommendation of the conceptual model for the considerations of the 'Data, information and Records Available' factor suggested by Yusuwan and Adnan (2013) which could influence of decision of the possibility of performing a successful analysis, selection of the method, complexity of the analysis, level of detail of the analysis and the results of the analysis.

The 'Availability and Quality of Baseline Schedule' as suggested by Arditi and Pattanakitchamroon (2006), is also of great importance in all methods. For example, if the baseline schedule does not exist or is very poor, the delay analyst may decide that none of the methods can be used or that a none-conventional method or way of performing a method has to be adopted.

B2 explained that as an expert, he immediately noticed that it is unlikely that the Contractor's concurrent delays, if any, would cause critical delay to the project. However, as he was aware that the client was not willing to settle without having a sophisticated delay analysis method that can prove no concurrent delays are there, he decided to perform the windows analysis method but at a high level of detail so that it can be performed within reasonable effort, time and cost. It can be seen here that delay analyst, i.e. B2, has made a subjective decision considering two factors in parallel. He decided that the 'The attitude of the opponent party' factor suggested by Braimah and Ndekugri (2008) is more important than the factor of the 'concurrency issues' suggested by Williams (2003).

As can be seen from the above paragraph, the Windows Analysis method is generally applicable in all cases but requires more time and effort than other methods as noted by Arditi and Pattanakitchamroon (2006) who also suggested that in such cases where the factors are overrules by other factors, they may be again considered for the decision of the level of detail of the analysis, which is indeed what B2 has done as noted above.

B2 explained that the high level of detail in context means, for example, that instead of impacting all affected paths by the events, he impacted only those obvious critically affected paths. Another example is that instead of impacting every single event of the delay events, only those with a clear and obvious impact were impacted. B2 managed to produce the revised analysis in 5 weeks only.

It worth noting here that the decision on the level of detail explained in the paragraph above is obviously a subjective opinion and that only expert delay analysts with good reputation in the market may getaways with such subjective input. Another point worth noting here is that there is no specific time period that a method require to be performed. This will heavily depend on project nature and circumstances along with the same factors influencing the selection of the delay analysis methods. For example, the Windows Analysis took 6 months in project A but it took 5 weeks only in Project B.

B2 concluded that the results of the impacted as planned analysis were correct and that there were no critical concurrent delays by the Contractor. B2 commented that sometimes the results will be clear since the start of the analysis but you need to provide the parties with an analysis that can make them able to justify their decisions with their own organizations.

5.4 Analysis – Project C – Highway Road

Project C is the construction of a highway road in UAE. Its value is around 113 million US Dollars. It suffered from delays in approving the material and equipment. Table 5-3 below presents a summary of the details of project C.

Table 5-3 Project C - Summary of Information	
Type	Highway Road
Location	UAE
Approximate Value	113 million US Dollars.
Planned Start	8 July 2009

Actual Start	8 July 2009
Planned Completion	1 December 2011
Actual Completion	1 February 2012
Main Cause of Delay	Design and Variation Orders
Delay Analysis Purpose	Support an extension time claim

The project records reveals that a claim was submitted by the Contractor using the Windows Analysis method. The claim was for 62 days of EoT and it was accepted by the Project Engineer and Client.

5.4.1 Interview with Project Planner C1

C1 was the planner for Project C throughout the project period. He explained that the design of project was not really complex but there were lots of delay events mainly resulting from the Client's and Engineer's late selection and approval of the material and equipment of the project. Those events were also not too complex. According to Braimah and Ndekugri (2008), a none-complex project requires a simple analysis, lots of delay events require a complex method and anyone-complex events requires simple analysis.

C1 said that he believed that any simple delay analysis method could evidence the Contractor's entitlement. This is in line with the suggestions of the developed conceptual model in Chapter 3 of this dissertation. But it can be seen that the delay analyst, i.e. C1. Had to take a subjective view of on the importance and influence of the factors. Nevertheless, C1 chosen the Windows Analysis method, which is considered as a complex method.

C1 justified his decision by saying that having experience in similar projects in UAE, clients would normally require a sophisticated delay analysis method before they give their consent on the analysis. Considering the analysis of case study B above, this decision seems to be justified as the Client in Case study B indeed has such requirement. The factor off 'the attitude of the opponent party' suggested by Braimah and Ndekugri (2008) appears to be covering the consideration of the

client internal requirements, which proven to be successful in both case studies B and C. It can be seen here that the delay analyst, i.e. C1 has taken a decision to select a method based on one factor only, which is the ‘the attitude of the opponent party’ and almost ignored all other factors.

C1 performed the Windows Analysis on the project but he explained that he kept things at a high level of detail so that the effort, time and cost of performing the analysis remains reasonable. It took him just three weeks to complete the whole analysis. Referring to the feedback of delay analysis expert E2 in Chapter 2 of this research and to Braimah & Ndekugri (2008) suggestions, it was explained that the level of detail of the analysis of equal importance of the selection of the delay analysis method.

C1 explained that it had several meetings and discussions with the Client representative whom had some comments on some of the events. They eventually reached an agreement and the client accepted the analysis and awarded the EoT of 62 days as claimed.

While case study C appears to be a straight forward case, it is noticeable that the amount of EoT on stake is relatively minor when compared to the previously analyzed case studies. Braimah and Ndekugri (2008) viewed the claim value as a factor to consider as part of the ‘Project nature, complexity and circumstances’ considerations. C1 indeed implicitly considered this factor when selecting the level of detail of the analysis.

5.5 Analysis – Project D – Sewage Treatment Plant

Project D is the construction of a large sewage treatment plant in UAE. Its value is around 406 million US Dollars. It suffered from huge delays due to design issues and variation orders. Table 5-4 below presents a summary of the details of project D.

Table 5-4 Project D - Summary of Information	
Type	Sewage Treatment Plant
Location	UAE
Approximate Value	1.5 billion US Dollars.

Planned Start	15 April 2007
Actual Start	15 April 2007
Planned Completion	15 April 2009
Actual Completion	15 October 2009
Main Cause of Delay	Design and Variation Orders
Delay Analysis Purpose	Support an extension time claim

The project records reveals that there was no claim filed during the project execution. A claim was only raised after project completion using the As Built vs As Planned Method but was not accepted by the other party. An Arbitration case was then filed and a revised delay analysis was presented using the windows analysis method. Both delay analysis methods suggested an EoT entitlement of 183 days. The case is still ongoing but there are positive signs that the client is going to accept the revised analysis. Details of the process of selecting the delay analysis methods is given

5.5.1 Interview with Delay Analyst D1

D1 is a third part delay analyst that was involved in the project to prepare the delay analysis as part of the final claim submission by the Contractor. He explained that he got involved late after project completion. Before selection of the appropriate delay analysis methodology, he first checked if there is any contractual requirements. This in line with the suggestions of Braimah and Ndekugri (2008), SCL (2002) and Arditi and Pattanakitchamroon (2006) for the consideration if there is any contractual obligation or if there is any clause within the contract documents specifying the delay analysis methodology that should be performed in case of any delays as such requirement could mean that the delay analyst will have no choice but to use the specified method or to justify why he selected any other method, as explained in section 2.4.3 in Chapter 2 of this dissertation. It worth noting here that although this factor was not particularly mentioned by the delay analysts but was understood that it was implicitly verified in all cases.

D1 then reviewed project records along with the project baseline and the delay events to judge on the nature and complexity of the case. As explained in the analysis above, such factors would influence the decision of the selection of the delay analysis method. He explained that that he found the case very complex and that performing a sophisticated delay analysis such as the time impact analysis or the windows analysis would consume huge time and effort and may not produce presentable results.

He therefore decided to use the As Built vs As Planned analysis as it provides sophisticated analysis of the as built data and the delay events but remain relatively simple. Arditi and Pattanakitchamroon (2006) indeed suggested that the As Built vs As Planned analysis could be used in case very sophisticated cases but they highlight that the method is still not widely verified and accepted. It can be seen that complexity of the delay analysis method is heavily influenced by the factors, the decision of selecting the delay analysis method itself remains under the discrete judgment and opinion of the delay analyst which could be based on the project factors, his own experience and/ or a combination of both.

D1 confirmed that the performed analysis using the As Built vs As Planned method was successful and that it allowed him to consider all the facts and the events within a relatively short time, which was 7 weeks. However, the client appointed an opponent delay consultant whom insisted on performing the windows analysis method as he claimed that it is the only method that can uncover and deal with the Contractor's concurrent delays. D1 explained that he did not accept this statement but found it easier to perform a second analysis than trying to persuade the opponent consultant with the results of the first analysis, especially that the case is going through arbitration proceedings.

He then performed revised delay analysis using the windows analysis method in full coordination with the other party's expert which took around 32 weeks to complete. D1 highlighted that the projects had 120 delay events. When he was asked about the main difference between the two analyses', he explained that in the As Planned vs As Built method he analyzed the project delays separately and then search for the potential causes of delay within the 120 events which proven be 12 critical events only. However, in the Windows Analysis, he had to analyze the whole 120 events as if they were all critical before discovering that only 12 events were critical and achieving the

same results. This explains the huge difference in the time required to perform the analysis using the two different methodologies. D1 however, added that unfortunately you would never know or be confident of such result unless you complete the analysis.

The client's expert is now satisfied with the results and there are positive signs that the client is reconsidering his stance. Referring to the feedback collected from the delay analysis experts in Chapter 2 of this research, an added value in this case study along with case studies A and B was the fact each project was analyzed using at least two different delay analysis methodologies which could be seen as a convincing factor to clients.

5.6 Analysis – Project E – Residential Tower

Project E is the construction of a 32 levels residential tower in Dubai, UAE. Its value is around 25 Million US Dollars. It suffered from delays due to variation orders. Table 5-5 below presents a summary of the details of project E.

Table 5-5 Project E - Summary of Information	
Type	Residential Tower
Location	Dubai, UAE
Approximate Value	25 Million US Dollars.
Planned Start	15 April 2006
Actual Start	15 April 2006
Planned Completion	10 October 2008
Actual Completion	16 December 2008
Main Cause of Delay	Variation Orders
Delay Analysis Purpose	Support an extension time claim

The project records show that there was only one claim submitted and approved in this project. The claim was for extension of time using the Impacted As Planned Method and it was for 67 days of EoT.

5.6.1 Interview with Project Planner F1

F1 was involved in the project since the start and he prepared the extension of time of claim using the Impacted As Planned method. F1 explained that knowing the small size of the project and the limited number of events, he decided to use a simple method that can produce simple results. This sounds reasonable in line with the suggestions of (Bramah & Ndekugri, 2008) and Arditi and Pattanakitchamroon (2006) who suggested that having a simple case requires a simple method.

F1 also noted that the Impacted As Planned method sounded suitable at the time as the Contract clauses does not require specific method while the project was running and the effects of some of the events required a theoretical perdition. F1 performed the whole analysis in 1 week. It is worth noting that here that the F1 has verified an important factor here which is ‘Status of Project and Point of Time’. According to Arditi and Pattanakitchamroon (2006), this factor is of great importance when it comes to the decision of performing a prospective or retrospective analysis. In this case study, the fact that the project was still ongoing may have been the main influencing factor for the selection of the Impacted As Planned Method and the successful acceptance of the method, as Yusuwan and Adnan (2013) has described that a theoretical prospective analysis of potential delays may be the only justified case of using the Impacted As Panned method.

Referring to the conceptual model developed in Chapter 3 of this research, D1 seems to have considered the main factors influencing the selection of the delay analysis methodology. F1 however supported the claim with extended narratives explaining the nature and effect of each of the events so that the analysis can sound more credible than just a theoretical and artificial analysis. It appears that such extended narratives are reasonable considering the criticisms raised by researches such as Yang and Kao (2009) about the artificial nature of the Impacted As Planned. The project Engineer and the Client eventually accepted the claim as presented.

5.7 Further Analysis

A wide range of similarities and differences were identified between the analyzed case studies. The paragraphs below summarize the main outcomes of the data analysis and interviews highlighting the main similarities and differences between the case studies following the conceptual framework developed in chapter 3 of this research and comparing the results with the reviewed literature along with the gathered expert information in chapter 2. Table 5-6 below summarizes the findings of the 5 case studies.

Project	Interviewee	Used Method(s)	Main Factors Considered before selection
A	A1	Impacted As planned	Available records Project Complexity Contractual Requirements
	A2	Float Mapping	Available records Project Complexity Attitude of Opponent Party Skills of the Analyst Ownership of the Float
	A3	Windows Analysis	Available records Project Complexity Contractual Requirements Status of Project Capabilities of the method Number of Events Concurrent delays,
B	B1	Impacted As planned	Available records Project Complexity Contractual Requirements Number of Events
	B2	Windows Analysis	Available records Project Complexity Contractual Requirements Skills of the Analyst Capabilities of the method Concurrent delays,

C	C1	Windows Analysis	Available records Project Complexity Contractual Requirements
D	D1	As Built Vs As Planned Windows Analysis	Available records Project Complexity Contractual Requirements Attitude of Opponent Party Status of Project Capabilities of the method Number of Events Concurrent delays,
E	F1	Impacted As planned	Project Complexity Contractual Requirements Attitude of Opponent Party Status of Project Capabilities of the method Number of Events

5.7.1 Delay Analysis Methodologies (DAM)

In terms of the common used delay analysis methodologies, it can be seen that the windows analysis method is more popular and desired delay analysis method in 4 of the 5 analyzed case studies. The surprising fact was that the Impacted As Planned method, although heavily criticized by the researchers and rejected by clients, is still commonly used and was believed to be effective at least in one of the case studies.

The float mapping method was used in one of the projects but did not deliver the desired results due to its over-complexity and lack of ability to deal with concurrent delays which is in line with the suggestions of Mohan and Al-Gahtani (2006). Similarly, the As Built vs As Planned method was used in one of the case studies and, exactly as suggested by Arditi and Pattanakitchamroon (2006), Yusuwan and Adnan (2013) and Williams (2003), was not successful because it is not yet popular and clients are still having doubts about its abilities and results.

As noted above, the overwhelming fact is that the Windows Analysis and the impacted As planned methods are the dominant methods within the 5 analyzed case studies in UAE and the windows analysis method is the most acceptable. This is indeed in line with the suggestion of researchers such as Kumaraswamy and Yogeswaran (2003), Arditi and Pattanakitchamroon (2006) and Braimah and Ndekugri (2008). This also in line with the recommendation of the three delay

analysis experts interviewed in chapter 2 of this dissertation. Most of the interviewed project planners expressed their view that the Impacted As Planned method should be used when appropriate, particularly when the analysis is from the Contractor's perspective. This area may need further practical investigation, as the conclusion reached in section 2.3.4 of chapter 2 of this research suggests that the researchers are generally against the use of the Impacted As Planned method.

5.7.2 Factors to consider when Selecting Delay Analysis Methodology

Although some differences appear between the case studies and the interviewed professionals in terms of the importance and consideration of the factors before selecting the delay analysis method, they appear to be in agreement on how such factors affect the selection of the method and the level of detail of the analysis.

While all interviewees explained that the consideration of the factors will vary depending on each project circumstances, the main factors considered were the availability of records, the time available to perform the analysis, the attitude of the other party, the contractual requirements and the actual status of the project at the time of performing the analysis. The main factors that were found to be influencing the acceptance of the method were the attitude of opponent party (the client in this context) and the purpose of the delay analysis which were highlighted by Braimah and Ndekugri (2008). An important finding however was that the selection of the method itself is a subjective decision of each delay analyst based on his own understanding, interpretation and appreciation of the various factors.

Interestingly, the reputation and the impartiality of the delay analyst were found as a driving factor for the acceptance of the delay analysis methodology. Such factors have not been addressed in the literature review although clients seem to be heavily relying on them when making their decision which means they should be considered as part of the selection process of both the delay analyst and the delay analysis methodology.

There was an agreement that the first factor to check is that if the contract documents specify which delay analysis method should be used. Although SCL (2002) suggests that new forms of contract nowadays specify the delay analysis methodology, none of the analyzed case studies

had such requirement. The primary factor for the selection of the delay analysis method, however, was the availability of project records and the time available for performing the analysis. The interviewees also viewed the availability of an adequate baseline schedule as part of the project records as an essential element for performing the delay analysis. This finding was not surprising, as Arditi and Pattanakitchamroon (2006) and Braimah and Ndekugri (2008) suggested that a baseline schedule would be required to perform any kind of delay analysis, although its importance may vary.

The interviewees also agreed on the importance of the complexity of the project and delay events as a factor as of all them have consider it as part of the selection process or at least during the performance of the analysis. In fact, the case studies revealed that this factor was considered while selecting the delay analysis method and while deciding the level of detail of the analysis. An example of this can be seen in case study C where the analysis was performed at a high level of detail (less information required) as project was relatively not complex and the claim amount (claimed EoT days) were reliantly minor

Only one of the interviewees, which is A2, gave great importance to the experience of the delay analyst while others viewed it as a secondary factor. This could be because he was performing the float mapping method which is not a common method and may require special experience. SCL (2002) and Braimah and Ndekugri (2008) emphasized on the importance of this factor as it may affect both the decision of selection of the method and the results of the analysis. Referring to above mentioned emerging finding of the reputation and impartiality of the delay analyst; those could be viewed as part of the skills of the delay analyst though not directly relevant.

Cost and time limitation were viewed as a driving constraint for both the selection of the delay analysis method and the level of detail of the analysis. Braimah and Ndekugri (2008) view this factor as the dominant factor for the selection of the method. The analyzed case studies, although the interviewees did not emphases on the importance of the factor, reveal that it is indeed a driving factor. Contractor seems to tend to utilize the Impacted As Planned Method, not only because it gives them favorable results, but also because it requires the least time and effort which means less cost.

The capabilities of the delay analysis method was considered as a default factor that have to be reviewed early in the selection process. Although the reviewed literature in Chapter 2 of this research revealed various advantages and disadvantages of the various delay analysis methodologies, in all case studies, the capabilities of the delay analysis method appeared to be a secondary factor that affect the level of detail of the analysis rather than the selection of the method itself. However, in case studies A, B and D, it was clear, for example, that the As Planned Method was rejected for its inability to deal with the concurrent delay issues. In fact, this factor could viewed as relevant to the ‘consideration of the concurrency issue’ factor suggested by Williams (2003) as the delay analysts should first check if there potential concurrent delays in the project then search for a method that can deal with such concurrency issues.

The actual status of the project and the time of performing the analyzing were viewed by most of the interviewees as the second primary factor after the availability of project records. It was mentioned by all of them and seems to have influenced the actual selection. For example, for the only running project with a predictable impact of the delay events in case study E, F1 appears to have relied on this factor while selecting the method.

The last thing to mention is that all interviewees were using Primavera as a software and preferred the retained logic as a scheduling setting, but none of them considered this to have any influence on the selection of the delay analysis method. This may require further investigation as Arditi and Pattanakitchamroon (2006) emphasized on the importance of this factor and highlighted that changes on the scheduling settings of the software may change the results of the whole analysis.

CHAPTER SIX– CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This research has investigated the common used delay analysis methods in construction projects by Contractors in the United Arab Emirates and the factors influencing the selection of such method through analyzing five case studies of construction project in UAE. The research resulted in a need to distinguish between the delay analyses methodologies and the level of detail of the analysis as the same factors may affect both variables.

The main finding of the research was that only two delay analysis methods are dominantly used in the five analyzed case studies construction market which are the Impacted As Planned and the Windows Analysis method. The research also revealed that the Windows Analysis is the most acceptable method by Clients in these case studies.

It also revealed one practical factor that was not addressed in the reviewed literature, which is the reputation and impartiality of the delay analyst, as can be seen in 3 of the analyzed case studies which are case studies A, B and D. This factor was not raised at all in the revised literature but appears to be a driving factor for the acceptance of the delay analysis method. In fact, although all delay analysts considers most of the relevant factors, the analysis of the case studies shows that the selection of the delay analysis method has a subjective view depending on each delay analyst experience, knowledge and understanding. This may explain the how the additional factor of the ‘reputation and impartiality of the delay analyst’ has emerged. Thus, before selection of the delay analysis method, the delay analyst profile should in contrast with the attitude of the opponent part (e.g. the client).

The consideration of the specified delay analysis methodology in the project contract documents was found as the initial factor to consider before the selection of the delay analysis methodology. However, none of the case studies contains such specific requirement in its contract documents. The attitude of the opponent party was found as the most important factor to consider, in the context of the analyzed case studies, as it may affect both the selection of the method and the level of the detail of the analysis, the consideration of the other factors and it will have an impact on the final acceptance of the analysis. At this stage, the delay analyst should also consider the capabilities

of the delay analysis methodology so that it can make rational decision during the selection process though none of the interviewees gave great importance to this factor.

The availability of project records, the availability and quality of the baseline schedule, the actual status of the project and the time of performing the analysis were the primary factors for the selection of the delay analysis methodology. The project and delay events complexity were secondary factors for the selection of the delay analysis method but are primary for the decision on the level of detail of the analysis.

Issues relating the concurrent delay, acceleration and mitigation although considered as considered as secondary in the review literature, should be analyzed at an early stage in the selection process in parallel with the process of considering the attitude of the opponent party' factor.

Time and budget limitations are also an important factor that equally influence the selection of the delay analysis method and the level of detail. However, it is viewed as a limited factor as the delay analyst will have to stand against the compromise on quality and details when this may affect the accuracy, fairness and reasonableness of the delay analysis results. The case studies in fact show that when the delay analysts are an impartial third party, this factor becomes secondary while when the delay analyst is an in-house planner, such factor along with the influence of the organization culture and motivations become the primary selection factor.

Skills of the delay analyst is found as a minor influencing factor on the selection of the delay analysis methods. If the selection of the method might be hindered due to the lack of sufficient experience by the delay analyst, then the delay analyst should be replaced by an experienced delay analyst that can perform the appropriate selected delay analysis method. This factor should be considered in parallel with considering the factors of the 'attitude of the opponent party' and the 'reputation and impartiality of the delay analyst'.

Although researchers suggested that Float ownership, software used and scheduling setting are factors affecting the selection of the delay analysis methods, the practitioners view, the analyzed case studies, is that these elements may affect the complexity and the way the analysis is carried out but not the selection of process of neither the delay analysis method nor the level of detail.

In summary, the research demonstrate that although the advantages and disadvantages of each of the delay analysis methods are clear, the appropriateness of using any method remains at the discrete subjective view of the delay analysts based on their own understanding and appreciation of the factors, delay analysis methods and facts of the project. An emergent factor relating to the experience, reputation and the implicitly of the delay analyst to mitigate the impact of his inevitable subjective views on the case.

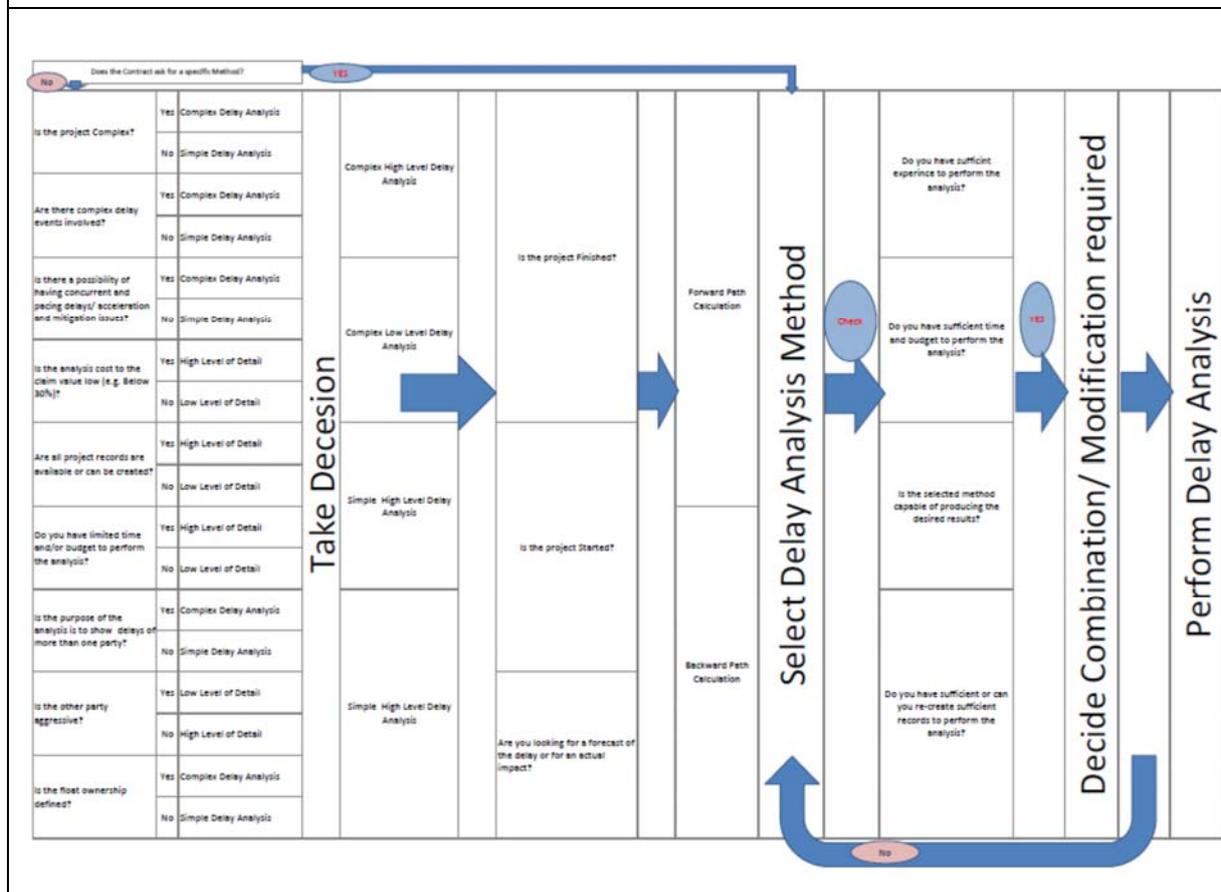
The literature review, the interviewed experts and the analyzed case studies show that using different delay analysis methods may produce different results. However, none of them claim that any of the methods is completely wrong. The ultimate goal of the delay analyst is to persuade all relevant parties that his analysis produced the best and most reasonable estimate of the impact of the delay events regardless of the utilized delay analysis method but in light of the circumstances of each case along with the various influencing factors.

6.2 Recommendations

Following the conclusion reached in section 6.1 above, some recommendations and suggestions for decision makers and practitioners have been developed for the purpose of ensuring the acceptance of the results of the delay analysis and facilitating the selection process of both the delay analysis method and the level of detail of such method. If the following recommendations are followed, it is expected that the selected delay analysis method and the performed delay analysis will produce more accurate and fair results, may be less criticized and may be easier to persuade the other party, tribunals and/ or courts.

Figure 6-1 below, which is an extract from Appendix E to this dissertation, contain a selection map for the delay analysis methodologies. The selection map first depends on the selection of an appropriate delay analyst having the appropriate experience, reputation and reasons for impartiality so that he make and justify subjective views on the factors and the delay analysis methods. The selection map addresses all the relevant factors and the potential effects of such factors; however, it does not provide specific instruction for the selection of the delay analysis method as such decision relies on the subjective view of the delay analyst.

Figure 6-1 – Delay Analysis Methods – Selection Map



As soon as the delay analyst gets involved in a delay analysis case, it should make an initial high-level review of the case and review the contract documents to establish if there is any specific requirements for a certain delay analysis method within the Contract documents. The analyst should then understand the attitude of the other party and see if this may have an influence of the selection of the delay analysis method.

If there is a specified delay analysis method in the contract document, the analyst should investigate its validity and use it if found acceptable, If there is no specification or the method was found invalid for whatever reason, then the analyst should provide reasoning for his decision and then start the selection of the appropriate delay analysis methodology.

At this stage, the analyst should consider the availability of project records, the actual status of the project, project complexity, delay events number and complexity and the time of performing the

analysis and then short list the potential delay analysis methodologies. The analysis then has to consider the time and budget available for the analysis and further shortlist the delay analysis methods. If the time and cost limitations are not adequate, then the analyst should make this clear to its client/ employer at this stage.

The analyst should make sure it has sufficient experience and skills to perform the analysis. The recommendation for the decision makers in projects is that they ensure the selected delay analyst is impartial independent and having adequate experience and reputation so that his subjective decisions and assumptions can be justified.

Based on the reviewed literature and the analyzed case studies, the ultimate suggestion however is that windows analysis method is used in any case as it has the minimal criticisms. However, considering the factors above, the delay analyst should decide which sub-method and type of the windows analysis method and the level of detail of the analysis, to overcome the main drawback of the Windows Analysis method being that it take huge effort and time to be performed. Tables 6-1 and 6-2 below, which are extracts from Appendix F to this dissertation, provide a summarized set of recommendations for delay analysts while considering the main identified factors.

Factor	Conditions/ Circumstances	Recommended Method(s), listed on
Records availability, accessibility and Quality	Baseline only	Impacted as Planned
	As Built only	Collapsed as built
	Baseline and As Built only	Collapsed as Built OR As Built Vs As Planned
	Baseline, progress periodic updates and As Built	Windows Analysis OR Collapsed As Built
Contractual Requirements	Specific Method	Use Specified Method OR Most Acceptable by Courts OR modified Version of it OR Challenge it
Complexity of Project and Delay Events	Simple	Windows Analysis/ law level of detail OR Any Method/ law level of detail

	Complex	Windows Analysis/ High level of detail OR Any Method/ High level of detail
Skills of the Analyst	Expert	Perform Analysis
	Intermediate/Beginner	Get Support OR Refuse
The attitude of the opponent party	Lean	Windows Analysis/ law level of detail OR Any Method/ law level of detail
	Aggressive	Windows Analysis/ High level of detail OR Any Method/ High level of detail
Time, Resource and Budget Constrains	High	Windows Analysis/ law level of detail OR Any Method/ law level of detail OR Challenge Constrain(s)
	Law	Windows Analysis/ High level of detail OR Any Method/ High level of detail
Capabilities of the method	Complex	Complex/ High level of detail
	Simple	Simple/ Law level of detail

Table 6-2 – Summary of Recommendations (2-2)

Factor	Conditions/ Circumstances	Recommended Method(s), listed on
Time of Performing Analysis	Before Start	Impacted as Planned OR Any forward path
	During Construction	Windows Analysis OR any dynamic method
	After Completion	Windows Analysis OR Collapsed as Built Or As built Vs As

Concurrency, disruption and acceleration issues	Present	Windows Analysis/ High level of detail OR any modified version
	Not Present	Windows Analysis/ Law level of detail OR any other simpler method
Purpose of the Delay Analysis	Complex	Windows Analysis/ High level of detail OR any modified version
	Simple	Windows Analysis/ Law level of detail OR any other simple method
Ownership of Project Float	Disagreed/ Complex Apportionment	Windows Analysis/ High level of detail OR any complex method
	Agreed/ Simple Apportionment	Windows Analysis/ Law level of detail OR any other simple method
Scheduling Settings	Special Settings/Constrains	Windows Analysis/ High level of detail OR any complex method
	Common Settings/Constrains	Windows Analysis/ Law level of detail OR any other simple method

6.3 Limitations of the Study

The study analyzed five case studies only from the Construction section in the United Arab Emirates. The results may therefore be limited to UAE and to similar type of projects only. In addition, the research data and interviews are all coming from the Contractor's perspective which may also limit the application of the results when it comes to clients and project Engineer's. More credible results could be achieved if a wider range of interviewees from different perspective were studied.

The research also focuses on the main identified categories and methods of delay analysis rather than the specific delay analysis sub-methods. For example, as can be seen from chapter two of this dissertation, the windows analysis method has multiple ways of being performed. A more detailed study of each of the specific sub-methods may provide more accurate results.

6.4 Recommendations for Future Research

It is recommended that a further research is carried out on this subject to be able to achieve better and more generalized results. The first area that can be further researched is the types and ways of performing each delay analysis method and the sub-methods of each method in addition to the investigation of the factors influencing the selection of the methods and the sub-methods. This may provide a better understanding of the subjective element that has been identified in this research and may provide a way of transferring it to an objective and systematic approach in the selection process.

The other area that is recommended for further research is the study of a real life case study and the performance of multiple delay analysis methods on the same project. This should provide a more justified results and may put light on other factors that have not been identified in this research.

Finally, as can be seen from section 6.1 above, the As Planned vs As Built method is still not investigated in depth. It is therefore recommended that further research is carried out on this specific method, as it appear to be having the potential of overcoming various disadvantages, such as the huge effort require, of the other widely used methods such as the Windows Analysis.

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APPENDICES

APPENDIX (A) Expert interview questions

Interview Form	
A	Background and General Information
A1	Gender (Male/ Female)
A2	What is your Overall Years of experience in the construction industry
A3	What is you Overall years of experience in Delay Analysis
A4	What are your main qualifications.
A5	Do you hold professional memberships/ certificates?
A6	What is your current designation
A7	What are you currently doing
B	General Delay Analysis Methodologies
B1	Can you please define the delay analysis process from your point of view?
B2	Would you please describe the following delay analysis methods, mentioning the main criticisms you have, if any?
	Global Impact Technique
	Net Impact Technique
	As-planned vs. as-built schedule analysis
	Impacted As Planned
	Collapsed As Built
B3	Which One(s) you have used the most?
B4	Which ones you have never used?
B5	Which one is the best or most appropriate?
B6	Generally, how you decide which DAM to use?
B7	How do you decided the level of detail of the DAM.
B8	How do you decide to use backward or forward calculation methods?
C	Additional Questions for the Project Case Studies/ Senior Planners
C1	Which method you have used in this project and why?
C2	Which method was better and why?
D	Factors Influencing the Selection of the Methodologies: Specific
D1	How important is the projects records when it comes to the selection of DAM?
D2	What are the main records you would be looking at? Please explain.
D3	How important is the baseline schedule to the analysis?
D4	At what stage you would review the quality and features of the baseline schedule?
D5	Do you review the contract documents before selecting DAM?
D6	If the project contract asks for a specific DAM, what do you do?
D7	Does the project complexity have an influence on your DAM selection? Please explain.
D8	Does the nature and number of delay events affect your selection of the DAM? Please explain.
D9	Have you ever faced a situation where your experience was not sufficient to perform a certain DAM? Please explain
D10	Would the attitude of the opponent part affect your decision of selecting the DAM?
D11	What do you do if you have limited time to perform the DAM?
D12	How about if you have resource and cost limitation?

Interview Form	
D13	At what stage of the DAM selection you consider the capabilities of the DAM?
D14	What influence the actual status of the project would have on your selection?
D15	Does the time of performing the analysis make any difference on your selection?
D16	Do you commonly face cases where concurrent and pacing delays and Acceleration and mitigation issues and involved?
D17	How would this affect your selection of the DAM?
D18	What is the usual purpose of delay analysis?
D19	Would this have any impact on the DAM selection?
D20	Have you faced a situation were the parties were in disagreement over project float?
D21	Have you ever faced a situation where it was agreed that the project float was owned by one party only or apportioned between the parties?
D22	Would this affect your DAM selection and your analysis?
D23	What is the common software you use for delay analysis and why?
D24	What scheduling settings you usually use? Please explain.
D25	Do you think this would have any influence on the DAM selection?

APPENDIX (B) Summary of Delay Analysis Methods

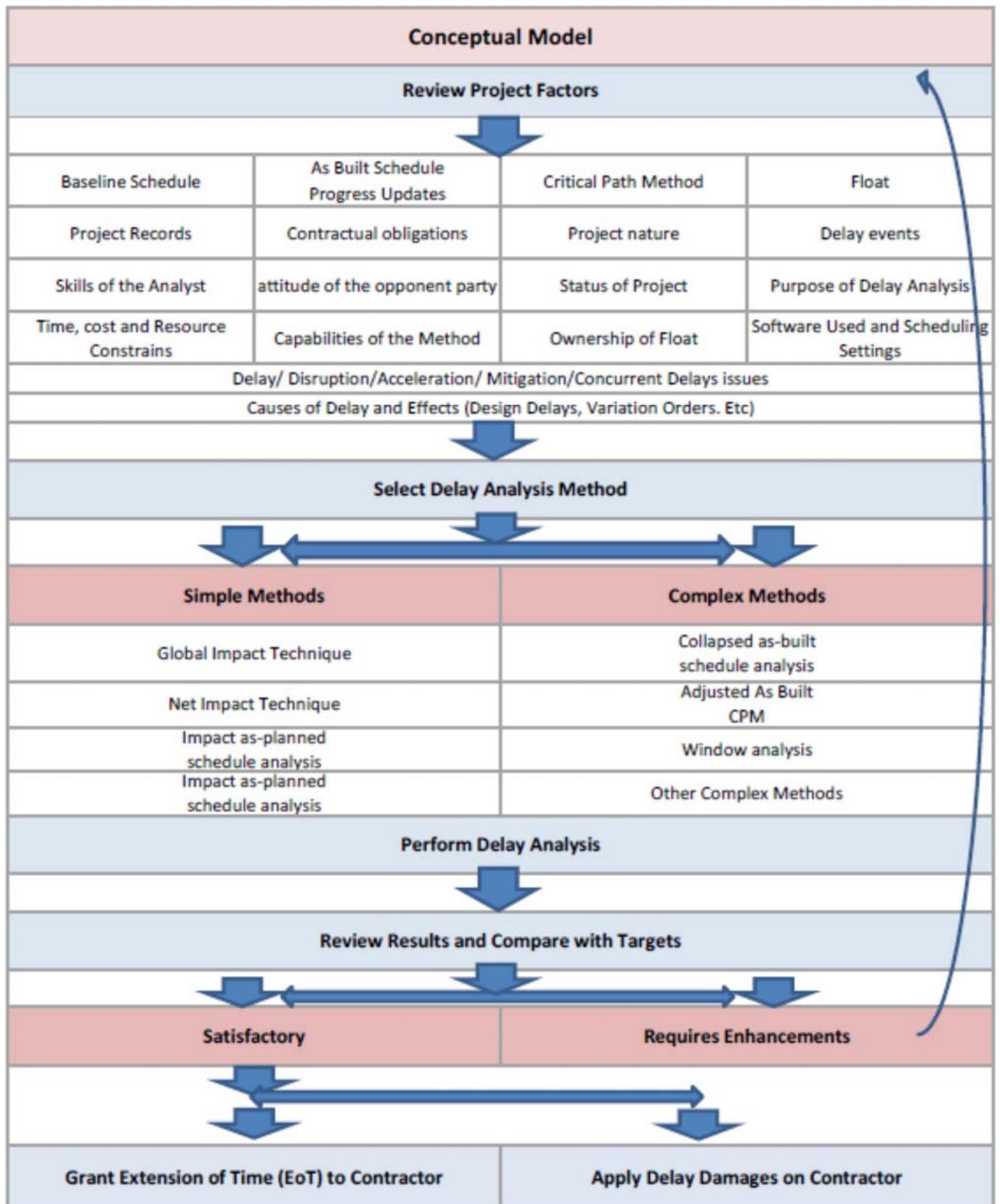
Summary of Delay Analysis Methods							
S.N.	Method	Other Names/Similar Methods	Reference	General Description	Calculation Method	Tools Required	Complexity
1	Global Impact Technique		Arifli and Patanajakhamoon (2006) Akus et al. (1995) Kumaraswamy and Yogeswaran (2003)		Forward	Delay events Substantiation Records	Simple
2	Net Impact Technique	As built technique	Kumaraswamy and Yogeswaran (2003) Mohan and Al-Ghailani (2006)	This method is basically the same as the global impact technique but only the net impact of the delays is calculated.	Forward	Delay events Substantiation Records	Simple
3	Impact as-planned schedule analysis	After-the fact and modified CPM schedule as planned What-if Impacted baseline schedule As planned plus delay analysis Affected baseline schedule	Arifli and Patanajakhamoon (2006) Brahmah and Mideghri (2008) Yusuwan and Adnan (2013) Yang and Kao (2009)	Uses only an as-planned or baseline schedule for delay analysis. It is based on the theory that the earliest date by which a project is completed can be determined by adding the delays to the as-planned schedule.	Forward	Baseline Schedule As Built Schedule Delay events Substantiation Records	Simple
4	As-planned vs. as-built schedule analysis	Bar chart analysis As built bar chart method Linear schedule analysis	Arifli and Patanajakhamoon (2006) Yusuwan and Adnan (2013) Williams (2003) Brahmah and Mideghri (2008) Yang and Kao (2009)	Observation of the difference between an as-planned schedule and an as-built schedule	Backward	Baseline Schedule As Built Schedule Delay events Substantiation Records	Simple
5	Collapsed as-built schedule analysis	But-for-Forward Analysis modified as built Time Impact technique baseline adding impacts for erisks scheduling but-for-backward Analysis Traditional method but for schedules collapsing technique impacted as built collapsed as built as built less delay analysis as built subtracting impacts modified but-for	Kumaraswamy and Yogeswaran (2003) Arifli and Patanajakhamoon (2006) Brahmah and Mideghri (2008) Williams (2003) Yusuwan and Adnan (2013) Zuo and Yang (2009) Mohan and Al-Ghailani (2006)	Effects of delays are "subtracted" from an as-built schedule to determine what would have occurred but for those events. Apporbsment Delay Method is a variation of the but-for and the net impact analysis.	Backward	Baseline Schedule As Built Schedule Delay events Substantiation Records	Complex
6	Adjusted As Built CPM	Apporbsment Delay Method	Kumaraswamy and Yogeswaran (2003) Mohan and Al-Ghailani (2006)	Delay events are impacted on the as built schedule.	Backward	As Built Schedule Delay events Substantiation Records	Complex

Summary of Delay Analysis Methods							
S.N.	Method	Other Names/ Similar Methods	Reference	General Description	Calculation Method	Tools Required	Complexity
7	Window analysis	Time Impact analysis Contemporaneous analysis method Snapshot analysis Time Impact technique Time slice method delay sections traditional windows analysis modified window analysis daily windows analysis CPM review method Effect Based Delay Analysis Method (EDAM) Inclined Delay Type Method Bardoli and Bardoli's delay analysis	Andri and Purnawidharmo (2006) Kuo and Yang (2009) SCL (2002) Williams (2003) Brimmah and Al-Jalaf (2008) Bardoli and Bardoli (2008) Kumaraswamy and Toogweon (2003) Kuo and Yang (2009) Yang and Kuo (2012)	the assumption that delay impacts to a project can be assessed by running a series of analyses on schedule updates. It assesses delays effects on the project schedule by analyzing the schedule periodically, generally on a day-by-day basis. Window analysis, a variation of time Impact analysis, uses weekly or monthly updates to perform the analysis.	Backward	Baseline Schedule As Built Schedule Periodic Progress Updates Delay events Substantiation Records	Complex
8	Other Methods	Total float management Float Mapping Lost productivity analysis methods Causal Maps and System Dynamic Technique (SD) equation-activity-based calculation Dollar to time relationship	Kuo and Yang (2009) Moham and Al-Ghantil (2006) Williams (2003)	The total Float Management method monitors the float assumption for all project activities and defines criticality based on float consumption.	Backward	Baseline Schedule As Built Schedule Periodic Progress Updates Delay events Substantiation Records	Complex

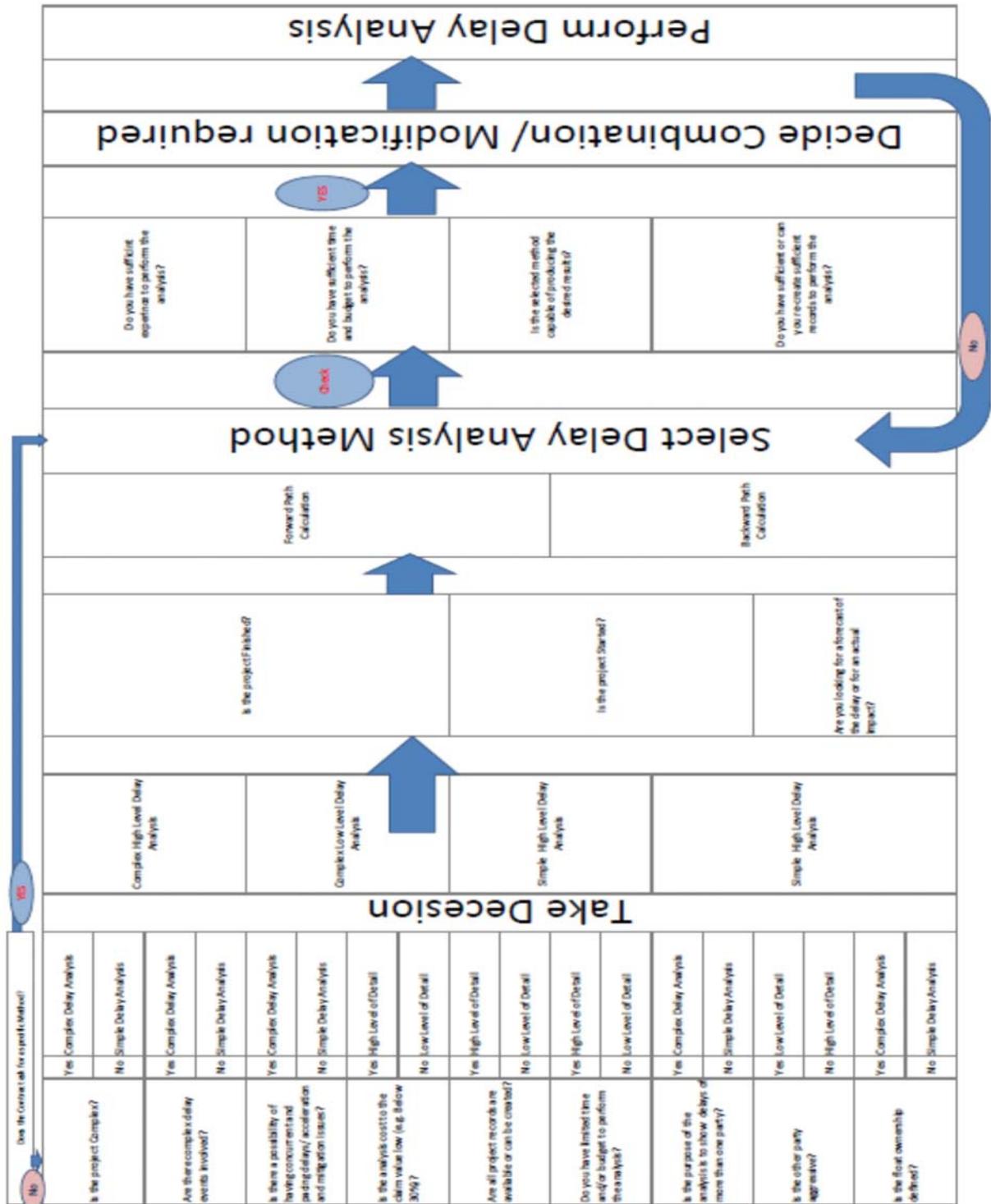
APPENDIX (C) Main Identified Factors

Main Identified Factors		
S.N.	Factor	Reference
1	Data, information and Records Available	Bubshait and Cunningham (1998) Alkass et al. (1995) Williams (2003) Arditi and Pattanakitchamroon (2006) Braumah & Ndekugri (2008) Braumah and Ndekugri (2008) Yusuwan and Adnan (2013)
2	Availability and Quality of Baseline Schedule	Arditi and Pattanakitchamroon (2006) Braumah and Ndekugri (2008)
3	Contractual obligations	SCL (2002) Arditi and Pattanakitchamroon (2006) Braumah and Ndekugri (2008)
4	Project nature, complexity and circumstances	Braumah and Ndekugri (2008)
5	Nature, type and number of the delay events	Kraiem and Diekmann (1989) SCL (2002) Kumaraswamy and Yogeswaran (2003) Kao and Yang (2009)
6	Skills of the Analyst	SCL (2002) Braumah and Ndekugri (2008)
7	The attitude of the opponent party	Braumah and Ndekugri (2008)
8	Time, cost and Resource Constrains for Performing the Analysis	Bubshait and Cunningham (1998) SCL (2002) Arditi and Pattanakitchamroon (2006) Braumah and Ndekugri (2008)
9	Capabilities, Shortcomings and strength points of the Method	Arditi and Pattanakitchamroon (2006) Kao and Yang (2009)
10	Status of Project and Point of Time	Arditi and Pattanakitchamroon (2006) Braumah and Ndekugri (2008)
11	Concurrent delays, Disruption and Acceleration Issues	Williams (2003) Mohan and Al-Gahtani (2006)
12	Purpose and Reasons for Delay Analysis	Braumah and Ndekugri (2008)
13	Ownership of the Float	Arditi and Pattanakitchamroon (2006) Mohan and Al-Gahtani (2006) Kao and Yang (2009)
14	Software Used/ Scheduling Settings	Arditi and Pattanakitchamroon (2006)

APPENDIX (D) Conceptual Model



APPENDIX (E) Map for selecting the Delay Analysis Methods



APPENDIX (F) Recommendation Summary

Recommendations

Factor	Conditions/ Circumstances	Recommended Method(s), listed on priority basis
Records availability, accessibility and Quality	Baseline only	Impacted as Planned
	As Built only	Collapsed as built
	Baseline and As Built only	Collapsed as Built OR As Built Vs As Planned
	Baseline, progress periodic updates and As Built	Windows Analysis OR Collapsed As Built OR As Built Vs As Planned
Contractual Requirements	Specific Method	Use Specified Method OR Most Acceptable by Courts OR modified Version of it OR Challenge it
Complexity of Project and Delay Events	Simple	Windows Analysis/ law level of detail OR Any Method/ law level of detail
	Complex	Windows Analysis/ High level of detail OR Any Method/ High level of detail
Skills of the Analyst	Expert	Perform Analysis
	Intermediate/Beginner	Get Support OR Refuse Job
The attitude of the opponent party	Lean	Windows Analysis/ law level of detail OR Any Method/ law level of detail
	Aggressive	Windows Analysis/ High level of detail OR Any Method/ High level of detail
Time, Resource and Budget Constrains	High	Windows Analysis/ law level of detail OR Any Method/ law level of detail OR Challenge Constrains
	Law	Windows Analysis/ High level of detail OR Any Method/ High level of detail
Capabilities of the method	Complex	Complex/ High level of detail
	Simple	Simple/ Law level of detail

Recommendations

Factor	Conditions/ Circumstances	Recommended Method(s), listed on priority basis
Time of Performing Analysis	Before Start	Impacted as Planned OR Any forward path calculation method
	During Construction	Windows Analysis OR any dynamic method
	After Completion	Windows Analysis OR Collapsed as Built Or As built Vs As Planned OR any dynamic method
Concurrency, disruption and acceleration issues	Present	Windows Analysis/ High level of detail OR any modified version
	Not Present	Windows Analysis/ Law level of detail OR any other simpler method
Purpose of the Delay Analysis	Complex	Windows Analysis/ High level of detail OR any modified version
	Simple	Windows Analysis/ Law level of detail OR any other simple method
Ownership of Project Float	Disagreed/ Complex Apportionment	Windows Analysis/ High level of detail OR any complex method
	Agreed/ Simple Apportionment	Windows Analysis/ Law level of detail OR any other simple method
Scheduling Settings	Special Settings/Constrains	Windows Analysis/ High level of detail OR any complex method
	Common Settings/Constrains	Windows Analysis/ Law level of detail OR any other simple method