Schedule Quality – Delay Analysis Perspective

Research into defending the forensic schedule analysis to protect EPC contractor's true entitlement

Varun Aasish Yerramreddy

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Master Thesis TU Delft

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PREFACE

This thesis report completes my Master of Science (MSc) in Construction management and Engineering. In May, 2013, I met Dick Roodenberg, Project Controls Director, CB&I where he gave me an opportunity in his company to work for the graduation project. He explained me the EPC contractor's problem of delay disputes from a schedule point of view. The problem was challenging and my experience in scheduling in my previous work experience gave me additional boost to take up the thesis subject. I accepted his subject for research the very moment.

Immediately, I met Professor Monika Chao from the university, TU Delft, and explained about the subject I was ready for my graduation project. Professor Monika Chao showed immense enthusiasm to chair my thesis. Also I met Professor Leon Hombergen and Professor Matthijs Prins to be a part of my committee supervisors. With the support from all of them I started my thesis full-fledged. As time progressed, I learnt that dealing disputes was challenging and extremely difficult. Initially, I thought the research can be filled by improving the schedules. Later on I found out that there were many other aspects to deal in supporting those schedules. Thus my thesis became much broader and complex. My company and university supervisors constantly supported me throughout the thesis which made me now possible to accomplish it.

This thesis is the outcome of my work from September 2013 to June 2014. I hope this report brings in a positive change in the EPC industry and especially for the EPC contractors.

DANK U WEL

I dedicate this special section to the people I would like to express my appreciation. Firstly I would like to thank my committee members from the University for driving me into the right direction towards the finishing of this thesis. I offer my special thanks to Professor Monika Chao for helping and supporting me through at every stage of my thesis. I would also like to extend my thanks to Professor Matthijs Prins and Professor Leon Hombergen for providing me special help at times of difficulties. I offer my big thanks for all the committee members for the guidance provided and also for the trust in my research work.

I would like to thank Dick Roodenberg, Project Controls Director, CB&I, for providing me an opportunity in working on the research subject. I also extend my thanks to Alessandro Grande, Project Controls Manager, CB&I, for providing me immense guidance and trust throughout my thesis work. Thank you for providing me friendly yet strict guidance over my thesis work. Working with you was very challenging and fun. I also extend my thanks to my colleagues Eric De Jong, Rob, Fiollett, Steve, Jan, Joan and Philip for providing an extended hand which helped my thesis. My work experience has been to its best during my tenure as a graduate intern in the CB&I. In addition I would like to thanks Romeo, Sharitha and Shanas for boosting positive energy every now and then during difficult times of my thesis.

I would also like to extend my thanks to my friends Tiger, Rajeev, Ram, Bharath, Roopali, Amit and chandralekha for their constant motivation and pep talk. I would also like to thank my best friends Prashanth, Vishnu, Theja, Mathangi, Celin and Shruthi for being the stress busters of my life. I would also thank "The Awesome 10": Flo, Raluca, Sebastian, Bas, Caroline, Eleni, Usman, Ali, Jonekke and Nassir for being my extended family here in Delft. A special thanks to my dearest of friends Nikhil for constantly motivating me throughout the thesis. I also extend my special thanks to my best friend Anjana Udhayakumar for always being there for me. A heart felt thank you to you. Then and most important, I would like to thank my family back in India: Mom, dad, brother and grandparents for showing incredible support at all times. I feel like the luckiest person on earth to have you all by my side. I would like to dedicate this thesis to you.

Dedicated

To my Parents

SUMMARY

Forensic schedule analysis is an analysis method that investigates the events of a CPM Schedule. It is recognized that the forensic schedule analysis may potentially be used in a legal proceeding. This means that the claimant for a delay claim might use the forensic schedule analysis to analyze the events of a CPM schedule to prove his entitlement in a legal proceeding.

When forensic analysis is analyzing a CPM schedule, the quality of the schedule is of high importance. This means, if the quality of the schedule is good, the outcome of the forensic schedule analysis will be accurate & explicit and thus the following entitlement. If the quality of the schedule is poor, the outcome of the forensic schedule analysis will be poor. If this is the case, then there is a higher risk that the claimant has to pay someone else's bill too. Whoever is best prepared for this has the best chance for defending his position successfully and has most chance to pay only for his own risks.

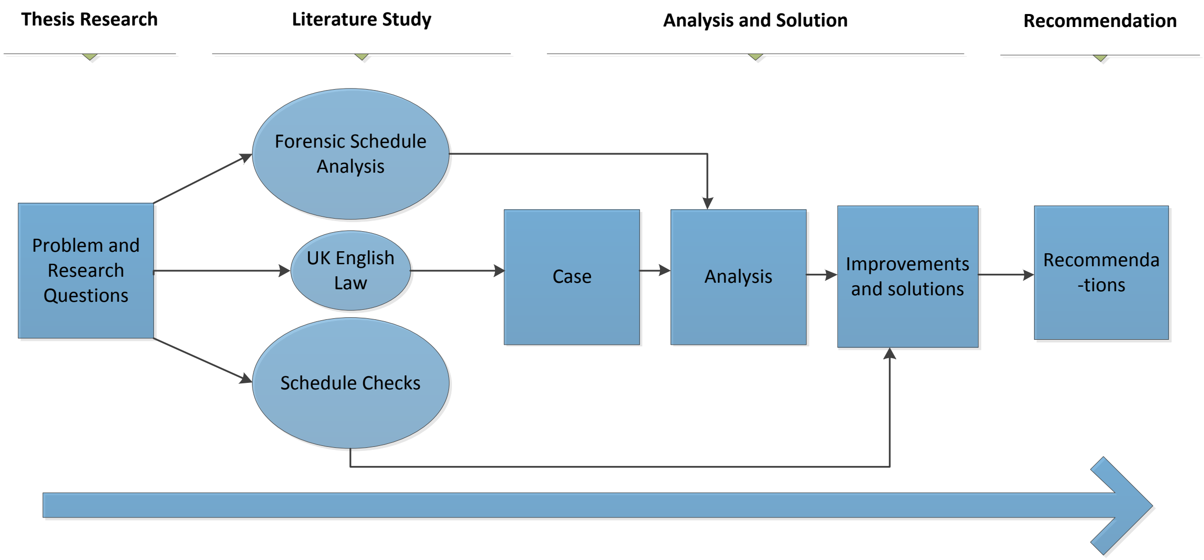
There are already schedule quality checks existing that help to build good quality schedules in a project management perspective. This research would like to explore schedule quality checks that can be introduced from a forensic analysis perspective with legal considerations. This would help to improve the outcome of the forensic analysis which will facilitate the true entitlement during a legal proceeding.

The research focuses on developing technically superior schedules that can stand a forensic schedule to protect ones rights at all times during a legal proceeding for extension of time claims. One has to be best prepared for it to prove their entitlement. This will lead to a set of technical requirements for schedules and an execution methodology to be rolled out on projects. This research is performed at CB&I (EPC contractor), and hence focussed for EPC contractors.

Research Question:

"How can EPC contractors be better prepared to take on a forensic schedule analysis, so as to improve the chances of getting the fair entitlement that is legally just?"

To answer the research question a research methodology is adopted to assist in finding the answer. This is explained further below:



To deal with the research problem an initial literature study is performed on three main topics: legal study, forensic schedule analysis and the quality checks of a schedule. The background study of legal would help in knowing the legal approaches of the UK English Law with respect to extension of time. For eg, according to UK law, a delay has to be shown critical in the schedule before any Extension of time is due. Those approaches will be applied during the forensic schedule analysis and also for identifying schedule quality. The reason to select the UK legal system is because a majority of the contracts for CB&I is based on UK English Law.

Also, there are various methods of forensic schedule analysis. The technical choice of the method depends on available source schedules, purpose of analysis and the level of accuracy needed etc. It has been found that the MIP 3.3/3.4 analysis method is most appropriate to use for extension of time claims by EPC contractor when considering the accuracy, source schedules available, the purpose of analysis and the worst case scenario of an extension of time claim. The worst case scenario is where the non-compensable time extension, compensable delays and acceleration exists altogether in a single extension of time claim. Both MIP 3.3 and 3.4 are identical techniques except for which 3.4 cannot be performed if non-progress revisions are not available. The schedule of the case chosen in this thesis does not have non-progress revisions, hence the MIP 3.3 will be performed and be a basis for the rest of the thesis.

Concurrently, a literature study on the existing schedule checks from a project management perspective is performed. This is because the entitlement of a delay is directly linked to the quality of a schedule. These checks consist of activity checks, logic checks, resource checks, duration checks etc. This study helps in identifying the missed quality gaps of the schedule and to improve them with respect to a forensic analysis.

Next, the analysis stage is performed where a real case from the CB&I is taken into consideration. A thorough study on the delays and the schedule is documented for the case. The forensic analysis initially performed (Impacted As-Planned Technique) for that case is also studied. Now, the MIP 3.3 analysis concluded in the literature study is applied for this case. It is noted that by selecting the apt analysis technique the contractor was able to reduce share of 25% on the case chosen. This difference was observed due to the increased accuracy of apportionment the MIP 3.3 was offering.

Now the schedule quality of the case is studied to identify areas of improvement for fair entitlement from a forensic analysis perspective. This is performed with respect to the schedule quality literature study performed. It has been identified that one can alter the choice of critical path of schedule using the settings in the Primavera P6 scheduling software which in turn can affect the outcome of the forensic analysis. It has been found through this thesis that in order to obtain the true impact of delays of activities on the project end date and to facilitate the burden of proof of criticality of schedule in the UK legal system; it is a good practice that the contractor chooses the Retained logic option to sequence the progressed activities in the schedule. In addition to the schedule improvements, many areas revolving around the forensic analysis have been identified and recommended to the EPC contractor to improve fair entitlement.

This thesis is a start in the field of planning and scheduling from a forensic analysis perspective. I hope that this will create a positive impact on the EPC business, their dispute resolution and also in further research into field of planning and scheduling.

CONTENTS

CHAPTER 1: INTRODUCTION

In the current world wide EPC (Engineering-Procurement-Construction) contracting environment, one can see that economies of scale are becoming more important. Projects are viable only when executed on a larger scale. The projects are getting complex and huge money is at stake. Under these circumstances, one can see clients often referring to lump-sum contracts to execute their projects. This makes the risks to transfer to the contractor and it is impossible for one single contractor to bear all the risks and thus, more contracting parties have to come forward to execute those projects. All these together are giving EPC contractors a hard time.

In case of a delay on the projects, due to the nature of the contracts and the amount of money at stake, one can see that parties need to position themselves in terms of "was the project managed well?" and "who is at fault in case of one or more delays?”. This is done with the help of forensic schedule analysis to find out who is at fault for which delay. All this puts pressure on the quality of project schedules; and the way industries view them has completely changed. Previously, schedules were primarily used to “*Plan the Work, Work the Plan*”. But, they have become so important that they need to be used to protect contractor's own position.

When schedules are used as evidence, their quality is very important without which the true entitlement cannot be obtained. This thesis researches the new schedule quality improvements that can help an EPC contractor to get true entitlement from a forensic schedule analysis point of view. This chapter discusses the scenario explained above, problem statement, research objectives, research question and research methodology. This thesis is performed at CB&I (EPC contractor) and hence this thesis will be focused for CB&I and CB&I like EPC contractors.

1.1 CURRENT SCENARIO

This section is focused on the on-going trends in the global industry and how they affect the EPC (Engineering-Procurement-Construction) contractors of the oil and gas sector in a macroeconomic scale. The reason to focus on oil and gas sector is because EPC projects for CB&I are majorly from this sector.

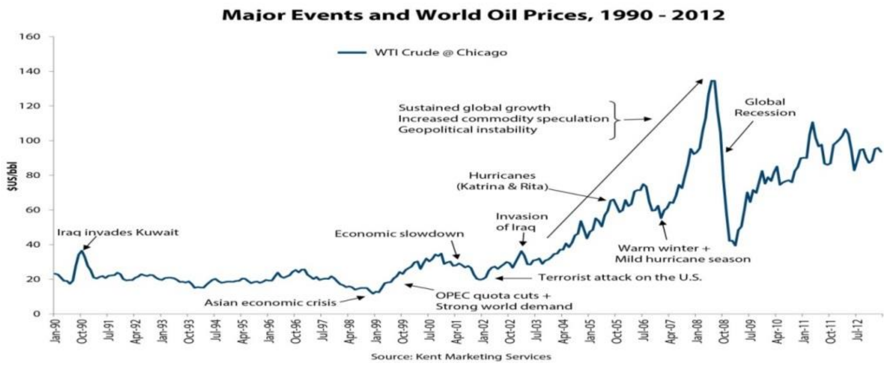


FIGURE 1: WORLD OIL PRICES (CANADIAN FUELS, 2012)

Ever since 2004, the oil prices witnessed a continuous growth and reached a peak of $140/bbl in year 2008 (from graph). However, after the crisis in 2008, the oil prices came down dramatically. The peak price was never reached again. This affected the market prices of the oil and their products. Due to this fluctuation of prices, those involved in the oil and gas industry are unlikely to be the causalities of this effect (Hodges, 2013). Due to the highly fluctuating prices in the world market; the industries shall be less willing to offer long project lifecycle jobs for contractors. This shall drive them to look for contractors who can finish their job in short life cycle. This short life cycle of construction would help the clients of the oil & gas industry predict the uncertainty of prices better, so that they can breakeven their investment faster before any crisis can happen again.

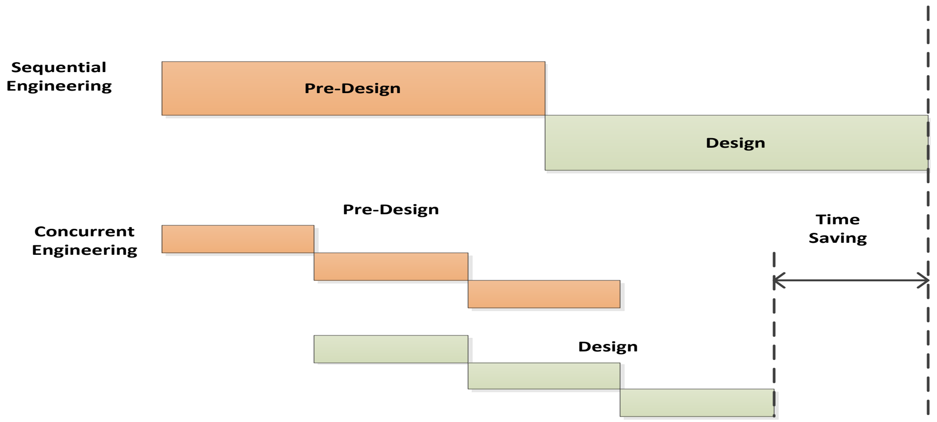


FIGURE 2: CONCURRENT ENGINEERING

In order to achieve shorter life cycles, contractors might have to shift from sequential engineering to concurrent engineering to reduce elapsed time. In addition, major EPC contractors have their bases around the world to offer their services to projects across globe (CB&I.com, Fluor.com, etc.). And also, the talents required for such projects might not be in one place alone. Work force from different countries needs to be used. This is not easy. Effective planning and scheduling of activities is of high priority in such scenarios.

At times where complex planning and scheduling are in necessity, the quality of the schedule makes a huge difference in the output of the project. Poor quality leads to overruns of cost and time. Better quality drives the project to completion with less/no overruns. Thus, a schedule plays a crucial role in the operation of concurrent engineering.

As per the report of Alberta Finance company (Jergeas, O'Toole, & George, 2010), it was shown each mega project in oil and gas sector cost around $8 to $14 Billion and majority of the projects were having cost overrun by 50% to 100%. The report also pointed out that, due to the overruns, clients are more opting for lumpsum contracts than cost reimbursable form of contracts. This is because, in a lumpsum, the contractor bids a price that covers all work, equipment, labour, services etc. required to complete the entire project. This can be very beneficial to the owner as all the risks are now turned towards the contractor. The client can assure a safe completion of the project within the budgeted cost and time. This also can make the contractor more efficient to work on the targeted budget and time.

"Time is money" and when delays happen in lumpsum contract, the contractor does not only lose time but also money. Thus a great importance awaits the schedule of the project. Any delay in the project would reduce the profit margin of the contractor. Especially, if the contractor is dealing with lumpsum in short lifecycle and concurrent engineering, they are even more prone to high risks and it is probable for delays to take place. And if delays are measured with the schedule of the project, a great importance lies in the quality of schedules.

In a presentation given by Deloitte (Oomes, 2012), specialists warns the EPC contractors for challenges and risks to be dealt with the future. They pointed out the shallow oil wells are depleting and deep oil wells are being explored. They also estimated that developing an offshore well costs the company between five to thirteen times more than developing a conventional land well. In addition, deep oil reserves needs innovative technology and it involves a lot of risks (Oomes, 2012).

When the risks and cost of a project is so high, it will be very risky for one contractor to take the whole job of the project. This will tend the contractors to collectively execute the project. When there are many players in a project, there is tendency for many disputes to arise. And the contractor should be prepared to face these disputes.

In summary, the fluctuating world market prices, lump-sum contracts and concurrent engineering shall make the EPC contractor prone to high risks that may lead to delays and a lot depends on the quality of schedule he prepares. In addition to these risks, the contractors shall also be prone to increasing disputes in the future due to the complexity and size of the projects involving many parties and should be prepared to defend their position.

1.2 Delays

Construction delays are defined as the time overrun either beyond completion date specified in the contract, or beyond the date that the parties agreed upon for delivery of a project (Assaf & Al-Hejji, 2006). The following facts show the statistics for occurrence of delays in many projects around the world. These statistics is to make the EPC industry have special focus on delays in their projects and a sign for them to be more prepared to face delays.

In UAE (United Arab Emirates), construction industry alone constitutes 14% of their GDP. A study revealed that half of the construction projects in the country were experiencing delays (Faridi & El-Sayegh, 2006) and this increased about one fifth by the end of 2009 (Motaleb, 2009). In India, a study conducted by Infrastructure & Project Monitoring Division of Ministry of Statistics and Program Implementation reports that out of 646 central sector projects, worth $50 trillion, about 40% are behind schedule and the delays ranges from 1 to 252 months (Lyer & Jha, 2006). Over the last 74 years, the number of claims submitted to the American Arbitration Association (AAA) reached a 25% of 1.7 million claims (Kasab, Hipel, & Hegazy, 2006). In UK, a report in 2001, called “Modernising Construction”, from the National Audit Office revealed that 70% of the projects undertaken by the government were delivered late (PFI: Construction Performance , 2003). By the year 2000, construction industry contributed about 30% to 40% of the non-oil sector in Saudi Arabia. In a recent survey it is reported that 70% of the country’s projects are delayed (Assaf & Al-Hejji, 2006).

1.3 Why Project Slips Schedule?

A project schedule is a tool used to organise and complete projects in a timely, quality and financially responsible manner (Hulett, 2011). The common types of schedules are Bar Charts, Critical Path Method (CPM), Program Evaluation and Review Technique (PERT) and Gantt Charts. This thesis will be focussed on CPM schedules because delay analysis is a tool used for analysing CPM schedules and this thesis is focussed on schedule quality with respect to delay analysis. In a survey conducted among the construction industry (Galloway, 2006), it is shown that about 50% of the respondents (contractors and clients) opt to work with CPM schedules. A CPM is a scheduling technique connecting a set of activities with an algorithm (Hinze, Construction Planning and Scheduling, 2012). A schedule would help the project in the following ways (Hulett, 2011):

- Helps to predict completion dates of project
- Better project management – manage daily activities and resources
- Monitor, control and complete project within time and budget, etc.

According to a survey (Galloway, 2006), It is a gratifying fact that over 80% of the contractor respondents feels that employing CPM schedule provides improved project control after the work starts and over 50% believe that it can reduce delays. A few more believe that it can give time and cost savings too. When the stats are so strong in the belief that a solid CPM schedule can be effective and reduce delays, why is it so evident that a majority of the projects undergo delay?

One of the reasons behind the delays that occur in the project site are associated to project scheduling. Project scheduling forms the base of all the activities that participate in the project. And when the schedule isn’t proper, the project deadlines cannot be reached. Some of the common problems associated with that of scheduling are (Hulett, 2011):

- Project Scheduling is a difficult task. It cannot be mastered by all and can only be made by an experienced scheduler.
- The guidelines/rules (logic, activity durations, resources etc.) to create schedules are not always clear to the scheduler. Poor practice of schedules can sometimes be dangerous too. Debugging the schedules is also equally important before use. And this needs high competence from experienced personal.
- Many times, the owner sets unrealistic deadlines and many other times the contractor is too optimistic in his activities. The scheduler should foresee all these and limit himself from creating unrealistic schedules.
- Project schedules are built using single point (deterministic) estimates. However, this often differ from the CPM scheduling and the scheduling software, as many other critical paths are possible during the project. Thus, the priority of activities and risks change during the course of the project. If unprepared, it can lead to delays and cost overruns.

1.4 Delay Claims – extension of Time

A delay is an event where the project completes later than the one stipulated in contract. A claim is request for time extension, additional compensation etc. from one party to another. Combining both, a claim related to delay is called as delay claim (Abboshi & Yahya, 2013). There can be instances for delays (where contractors are not responsible) during the course of the project like change orders from client, suspension of works, different site conditions etc. that the contractor have their concern to get entitled for the extra time and/or money (Hinze, Construction Planning and Scheduling, 2012).

The need for an appropriate methodology with industry standards to scrutinize tighter and complex project schedules for parties preparing extension of time claims or schedule delay claims gave birth to the Forensic schedule Analysis (Kelly, 2013) (also called as critical path analysis or delay analysis). Forensic schedule analysis is an analysis tool that investigates the events of a CPM Schedule (AACE, 2011). It is also recognized that the forensic schedule analysis may potentially be used in a legal proceeding (AACE, 2011). This means that the claimant for a delay claim can use the forensic schedule analysis to analyze the events of a CPM schedule to prove his entitlement in a legal proceeding. Various delay analysis methods are available to find out the amount of time extension the contractor is entitled for. The book for construction planning and scheduling by Hinze shows a number of court cases where the CPM schedule has been analysed by different delay analysis methods and used to resolve disputes. However, there is no specific schedule analysis methodology recognised universally for quantifying delay and disruption claims (Gorse, 2006).

1.5 EPC Contractor's Concern

When considering the forensic analysis in a legal proceeding, CB&I (EPC contractor) have its concerns with the nature of the common law. The common law has its origin from UK and many of its colonies have strong link legally to the Common Law (USA, Canada, Australia, India, Singapore etc.) (Chalmers, 2012). The common law offers extensive freedom of contract (World Bank, 2006) (Chalmers, 2012). This means that the Common law grants people with the freedom to agree on the content of their deal. In addition to the freedom of contract, the parties are bound by their agreement unless the terms of the contract are for illegal purpose or against public policy (Chalmers, 2012) (Tennant & Mbele, 2013).

This is an important characteristic of the Common law system that the EPC companies should realise while dealing with construction contract drafted in Common law. EPC companies like CB&I are dealing with huge and complex projects. Contracts have to be drafted carefully for those projects. But since the projects are huge and complex drafting every detail would be very difficult. And if the contractor misses/unclear/does not comply his actions with the binding agreement, then he might not win an argument in a legal proceeding.

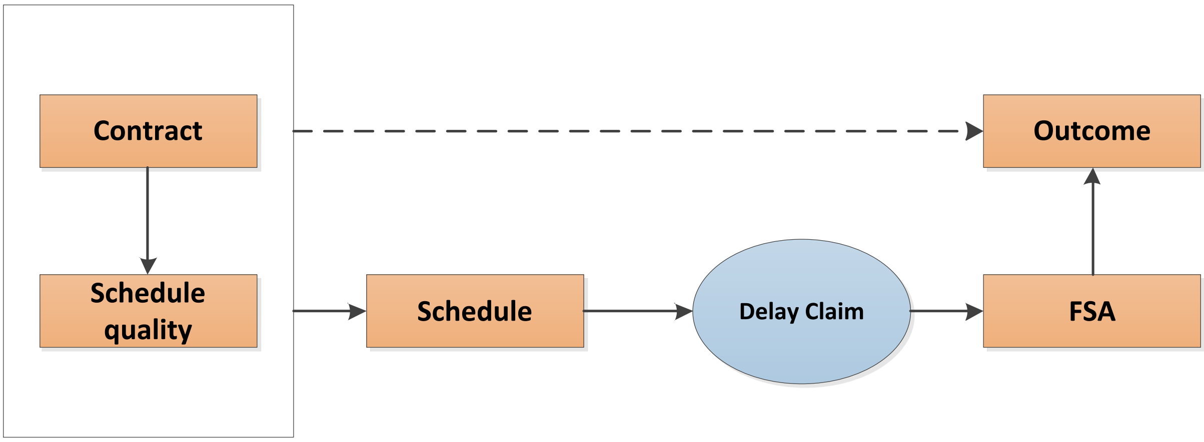


FIGURE 3: EFFECT OF OUTCOME OF FSA DUE TO CONTRACT CONDITIONS

According to CB&I, when they work with EPC projects, scheduling requirements are often a part of contracts. These requirements consist of scheduling quality that should be enforced while creating a schedule for a project. And when schedule is used as evidence in a legal proceeding for a delay claim, these scheduling requirements will be a basis as it is a part of the contract.

The forensic schedule analysis is a technical tool that investigates into the events/activities of a schedule (AACE, 2011). It tells us which activities/events are responsible for the delay in project. When such an analysis is analyzing a CPM schedule, the quality of the schedule is of high importance.

When schedule is analysed to calculate delays with the forensic schedule analysis, the quality of the schedule directly affects the outcome. And thus, the scheduling requirements of a schedule in a contract should be clear without any ambiguity and followed during the project in order to win true entitlement of a delay in case of a legal proceeding. The following example would help in understanding the scenario explained above:

Milestone Example

According to CB&I, majority of their projects are dealt in UK English Law. Hence, consider an example litigation case of a project in the UK. The project is governed by UK English Common Law. Assume that one of the clauses in the contract states ***"Entitlement to EXTENSION OF TIME shall only be granted to the contractor if the float on key milestones on the critical path is consumed".***

Assume the planner of the project prepared the schedule and while doing so he was not made accessible to the contract, hence was not aware of that clause. He prepared the following As-Planned schedule depicted below:

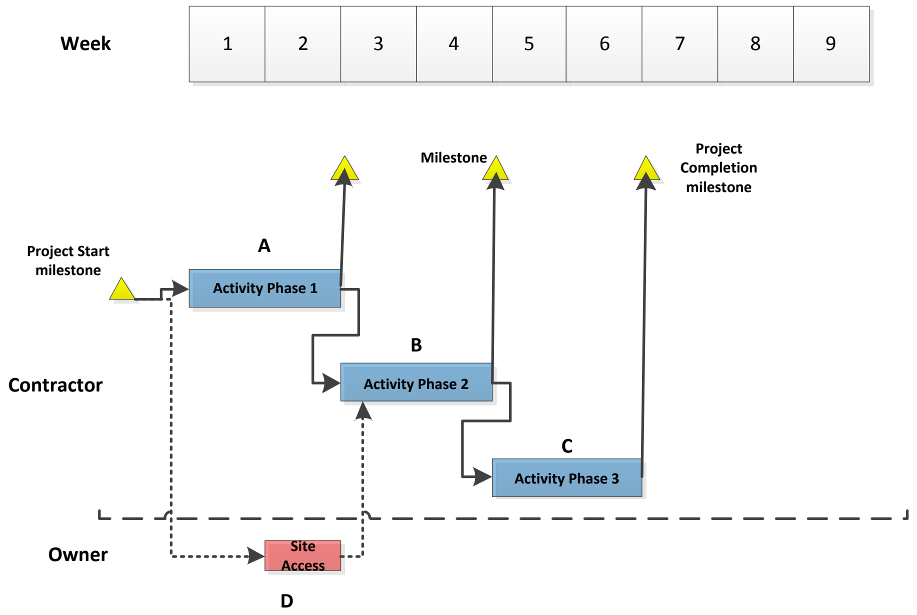


FIGURE 4: AS-PLANNED SCHEDULE

The path A-B-C is the critical path. Each activity has a milestone which represents the end point of each phase of the contractor's activity. Each activity phase is connected to a milestone in finish-start logic. Any delay in a particular phase of activity can delay the milestone date and also the overall date of the project. The initial completion date is end of week 6.

The project started. During the project, the client delayed in granting the site by one week to the contractor. The contractor did manage to issue the notice for that delay to the client. Due to the delay of the client to grant site access, the new critical path is now D-B-C and the project delayed by one week. The as built schedule can be seen below:

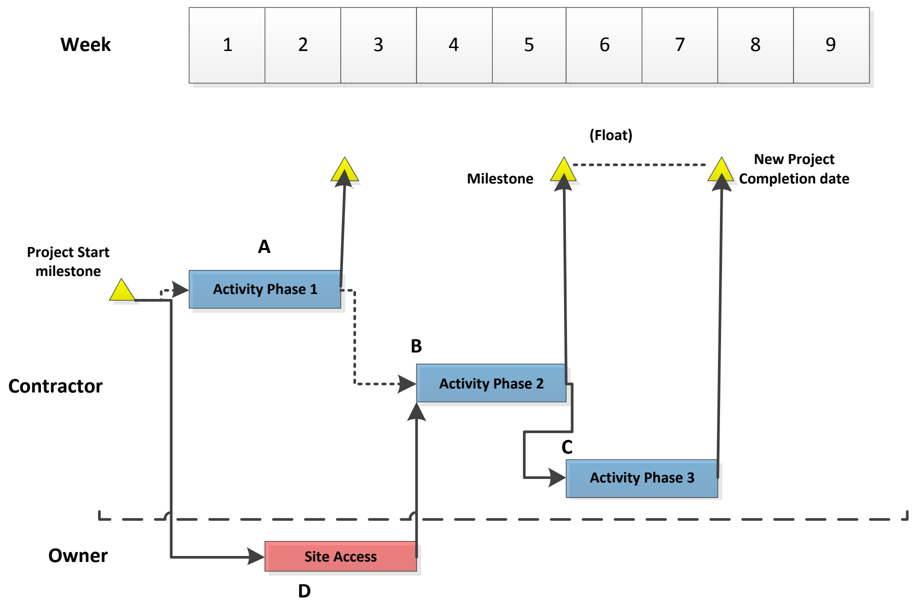


FIGURE 5: AS-BUILT SCHEDULE

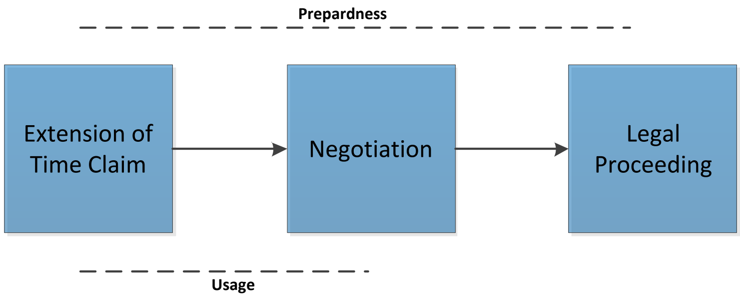
After the project finished, the client of the project imposes liquidated damages for late delivery of the project. But the contractor refuses to pay as the client is responsible for that delay and the client should have given extension of time due to his delay. The contractor now goes to litigation to solve the dispute.

If the current state of the schedules is given as evidence in a legal proceeding, the contractor has fewer chances to win the case. This is because; the schedule might undergo to perform the forensic schedule analysis where the outcome will show that the milestone still has float values and have not yet been consumed (because of no successor). This will not fulfil the contractual clause where the entitlement for extension of time to contractor only happens if the float of the milestones is consumed.

Thus, the English law court shall strike down the appeal of the contractor in this legal proceeding in accordance with the terms of the contract. It is practically true that the client is the cause for the delay. However, the evidence provided by the contractor was not able to overcome the contractual provision (to which the parties were bound) because of the outcome of the forensic analysis. This is due to the insufficient quality of the schedule that is put as evidence in the legal proceeding for the forensic schedule analysis. And this thesis would explore such gaps where in which schedule quality can be developed from a delay analysis perspective taking into account the legal considerations.

1.6 CB&I's Objective

CB&I's objective is to be prepared legally with schedules so that it helps them in obtaining true entitlement for extension of time that is legally just. However, it is their intention to use such legally built schedules so that disputes can be resolved with proper proof during negotiation itself and prevent claims in reaching court that costs unnecessary effort, costs and time.



1.7 Problem Statement

When forensic analysis is analyzing a CPM schedule, the quality of the schedule is of high importance. This means, if the quality of the schedule is good, the outcome of the forensic schedule analysis will be accurate & explicit and thus the following entitlement. If the quality of the schedule is poor, the outcome of the forensic schedule analysis will be poor. If this is the case, then there is a higher risk that the claimant has to pay someone else's bill too. Whoever is best prepared for this has the best chance for defending his position successfully and has most chance to pay only for his own risks.

There is already schedule quality checks existing that help to build good quality schedules in a project management perspective (Ron Winter Consulting LLC , 2002) (GAO Schedule Assessment, 2012). This research would like to explore schedule quality checks that can be introduced from a forensic analysis perspective along with legal considerations. This would help to improve the outcome of the forensic analysis which will facilitate the true entitlement during a legal proceeding.

1.8 Research Objectives

The prime objective of the contractor is to protect its own position in case of claim in the forensic schedule analysis. The research focuses on developing technically superior schedules that can stand a forensic schedule to protect ones rights at all times during a legal proceeding. One has to be best prepared for it to prove their entitlement. This will lead to a set of technical requirements for schedules and an execution methodology to be rolled out on projects.

1.9 Thesis Scope

Many countries around the world follow common law. To limit the scope of the thesis, the UK English law is focussed. This is because, according to CB&I, a majority of projects they dealt with is the UK English Law. Additionally, this thesis has its scope limited to only the time aspect of extension of time claims and not deal with compensation.

1.10 Research Question

To reach the research objective, a main research question is formulated that will be answered throughout the research:

"How can EPC contractors be better prepared to take on a forensic schedule analysis, so as to improve the chances of getting the fair entitlement that is legally just?"

To assist with the solution for the main research question, several sub questions are formulated:

- ***Which analysis method is most appropriate for the EPC contractors?***
- ***What are the guidelines recommended to the scheduler to build good quality schedules?***
- ***Is there a methodology/process that revolves around the forensic analysis? If so, how can the methodology be built?***

1.11 Research Methodology

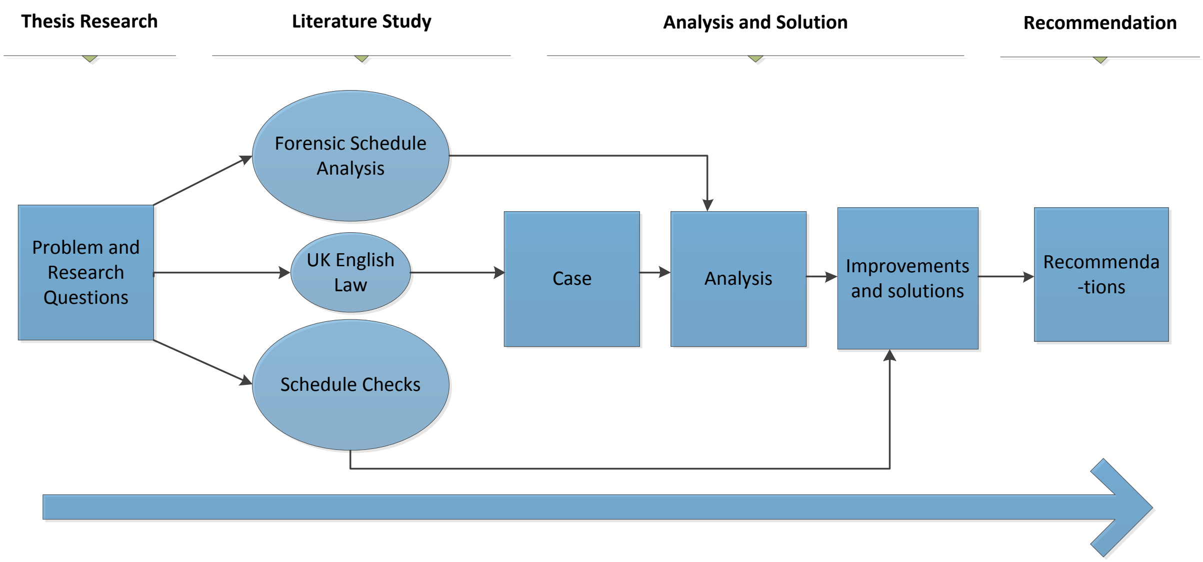


FIGURE 6: RESEARCH FLOW CHART

<u>Step 1: Thesis Research</u>

In this step the background of the problem of the EPC contractor is stated and respective research question is formulated. This thesis will work towards in answering that research question.

Step 2: Literature Study

An initial literature study is performed on three main topics: legal study, forensic schedule analysis and the quality checks of a schedule.

- **Legal Study:** The background study of legal would help in knowing the legal approaches of the UK English Law with respect to extension of time. Those approaches will be applied during the forensic schedule analysis and also when identifying schedule quality with respect to the forensic analysis.
- **Forensic Schedule Analysis Study:** There are various methods of forensic schedule analysis. The choice of the method depends on available source data, purpose of analysis, the level of accuracy needed etc. The most appropriate method for the EPC contractor is discussed in this study. This analysis method will be a basis for the rest of the thesis.
- **Schedule Quality Study:** A literature study on the existing schedule checks is performed. This is because the entitlement of a delay is directly linked to the quality of a schedule. This study helps in identifying the missed quality gaps of the schedule and to improve them with respect to the forensic analysis.

To apply the most appropriate analysis method and to identify new gaps, a real case schedule is taken. This is dealt in the next section.

Step 3: Analysis and Solution

In this section, a real case is taken for analysis of thesis. This case is studied and documented for its schedules, delays and initial schedule analysis performed for the project. Then the most appropriate forensic analysis method, concluded in step 2, will be used to the schedule of the case to study the differences. With the selected delay analysis method, the schedule quality of the real case is studied to identify areas where the contractor could have improved in a forensic analysis point of view. This is done in relation with the schedule checks studied in the literature study of step 2. These improvements are subsequently validated to reach conclusions. The legal system of the case is also considered while framing the conclusion of the schedule quality.

Step 4: Recommendations

In addition to the research findings in step 3, recommendations are suggested to improve the process revolving around the forensic analysis. The limitations of the thesis and the future research suggestions are also enlisted.

CHAPTER 2: INTRODUCTION TO BASIC CONCEPTS

The reader might not understand the schedules, forensic analysis at the first go. To aid the reader, some basic concepts and definitions are explained in this chapter.

2.1 BUILDING A SCHEDULE

An insight on how the schedule network model is developed provides the reader with a strong foundation to the understanding of the forensic schedule analysis. In scheduling, the development of a network model is an important step. As the saying goes "Well begun is half done", a well prepared schedule would help in smooth completion of the project. An ill-prepared schedule loses its useful purpose and compromises construction progress. A schedule consisting of various activities and relationships should be fully understood and clearly conveyed to the user. Only then it serves the purpose to be a project management tool. An explanation of how a schedule is developed is summarised below from a reference of a book called Construction Planning and Scheduling authored by Hinze. It requires 8 steps to build a quality schedule; they are (Hinze, Construction Planning and Scheduling, 2012):

DEFINING ACTIVITIES

Activities are specific actions that need to be performed to achieve project deliverables. It is a notable point that the level of detail of the activities that are included should be of usable scale. Activities like "Nail number 34" are too short in duration that it is not realistic to use them. Moreover, they make the schedule even more complex and the time spent on them would be inappropriate.

One must identify the different types of activities in the construction project. Construction activities are those which are performed physically on-site. These activities are dependent on materials, time and labour. Activities should be carefully defined to suit the resources available at any point of time of the project. Procurement activities are those activities that depend on acquisition of materials, money, labour arrangement etc. Materials that are readily available are not necessary to be defined, however, special materials that have uncertainty with long lead times needs a place in the network model. Also there are management activities that directly affect the schedule and that should be implanted in the network model. However, activities like processing drawing approvals, certification, tracking submittal approvals etc. may not be included.

ORDERING ACTIVITIES

The occurrence of activities relative to others in logical progression forms the basis for the sequencing of activities. It is performed by identifying the immediately preceding activities (IPAs) for every individual activity. When applying IPAs for each activity, each activity's succeeding activities are also defined automatically. Once the IPA list is created, the network model can be created.

Ordering of activities occurs only in a particular order called as "constraints". For e.g., physical constraints means a particular activity can be started only when other activities are completed. For e.g. curing of concrete activity can be started only after concrete has been placed. Resource constraints are those which limit the number of activities to be done at the same time due to the limited number of resources. This is because of the limited number of work equipment or labour etc. Likewise there are safety constraints, financial constraints, environmental constraints, management constraints, contractual constraints and regulatory constraints. At the development stage of the project, only the physical constraint can be entered for preparing the schedule. All other constraints can vary until the actual scheduling of the activities. The following depicts a sample sequencing of activities for laying a pipeline.

TABLE 1: ORDERING OF ACTIVITIES

Activity label	Description	IPAs
A	Excavate	-
B	Fill Sand Layer	A
C	Procure Pipes	-
D	Lay Pipe	B,C
E	Mobilise Welders	-
F	Weld Pipes	D,E
G	Mobilise Testers	-
H	Test Pipeline	F,G
I	Fill Excavation	I

DRAWING THE NETWORK DIAGRAM

The network can be drawn in two methods: precedence diagram and the arrow diagram. In arrow diagram, the activities are represented by arrows. The precedence diagrams use boxes/nodes to represent the activities and are connected by arrows using logic. In the present world, many construction companies and software uses precedence diagrams. Due to many deficiencies, the arrow diagram did not stay long in the construction industry. The precedence diagram is a simple diagram where the activities are linked in a proper sequence and can be easily conveyed and understood. It is read from left to right.

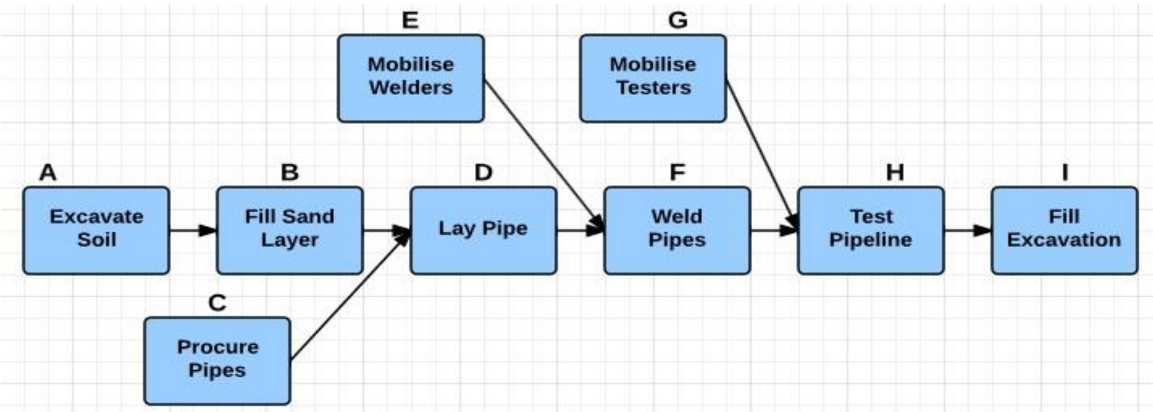


FIGURE 7: EXAMPLE OF PRECEDENCE DIAGRAM

ASSIGNING DURATIONS TO ACTIVITIES

The estimated time that an activity can be completed in called as the duration of the activity. Assigning duration involves adding the start and end date for each individual activity. The duration of the activities can be assigned in days, weeks, months, years etc. In most construction projects, the day scale is used. For more general baseline schedule of mega projects, duration is scaled up to months or years for better representation and easy understanding.

The duration for each activity is filled in three types: standard norms, historical data and guesstimates. Standard norms are used from some standard publish rates (e.g., R.S. Means Publication). The formula for calculating durations is (Hinze, Construction Planning and Scheduling, 2012):

$$\frac{quantity\ of\ work}{quantity/Crew-hour} = Crew-hours \quad or \quad \frac{crew-hour}{hour/day} = days$$

The duration of an activity depends on the resources and their productivity that are directly used for it. The reliability of the factor quantity/crew-hour is an issue which can be obtained from some standard published rates. Historical data is used from data where the company used it previously for similar activities. When no data is available to assign duration, then one can go for durations based on his/her experience called as the guesstimates.

One should note that every activity consumes time. The point of time where the activity is started or is completed is called as an event. Most of the times, the start and finish times are assigned to each activity which enables simple computations to manage a schedule. Some events are identified as milestones. They don't have a start or end date. Instead, they depict an important date of interest and are "topped up" in a schedule.

Assigning resources and costs to activities

A project uses several resources. If there are unlimited resources, the activities in the CPM schedule only deal with the start and finish dates as constraints. However in most practical situations, there are limited number of resources (equipment, labour etc.) and costs. Not all the activities can be performed at the same time. This is limited by the time and money constraints. Resource allocation to the activities permits to examine the amount of each resource required during specific time periods of the project. This in turn will help in managing the project better.

Calculating Early And Late Start/Finish Times

The early start is the earliest time that an activity can begin and the late start is the latest time that an activity can begin. Similarly, the early finish is the earliest time that an activity can be completed and the late finish is the latest time that an activity can be completed. If the late finish date is exceeded by certain number of days then the duration for the activity increases by the same amount. If the early start and late start dates differ, then that activity is said to have "float" (Nicholas & Steyn, 2012). Float is defined as the number of days that the activity can be delayed without causing a delay in the total project network. There are two types of float:

Free Float: It is the amount of time that an activity can be delayed without delaying the early start date of succeeding activity. An activity on the critical path has zero free float.

Total Float: It is the total amount of time that an activity can be delayed from its early start date without causing a delay in the project finish date.

Identify the Critical Path

Any delay in the start/completion dates of an activity such that it affects the completion date of the project, then those activities are said to be "critical". These activities do not have any float. The path connecting the activities which are critical is called as the critical path. Critical path, typically, is the longest path from the start node to the end node of the project and it is expected to be the duration of the project (Nicholas & Steyn, 2012). Identifying the critical path helps the parties to focus on the activities that need prime attention, so that resources can be allocated efficiently.

Start Management Process

Once all the calculations are done in the network activities, the management can start their process. The activities provide them with basic information to execute project requirements. The decision making process of the management largely depends on the flexibility on the activities they have schedule, i.e. float. The key for good management of project is to use the schedule more as a management tool, which largely depends on its accuracy and its quality

In my opinion, the creation of a schedule in an EPC industry is a little different from what is explained in the book of Construction Planning and Scheduling by Hinze. If it is a schedule with limited activities, the procedure explained above can be used. However, an EPC project is vast in size and consists of hundreds of activities. Developing the schedule by the above mentioned procedure will be a hassle. Over my experience in the CB&I, a schedule is created through a process. There are three levels of schedule – Level 1, Level 2 and Level 3, each one differing by the amount of detail mentioned in the schedule. Level 1 is least detailed and Level 3 is most detailed schedule. Initially, a level 2 schedule is made consisting of breakdown of project disciplines, main work packages, major subcontracts, milestones and summary tasks with their respective durations. Keeping the level 2 as a basis, the level 3 schedule is created which is more detailed than the level 2. It enlists all the activities required to complete respective work packages. All the activities are assigned, at this level, with logic relationships and early/late start/ finish dates. Thus a network diagram and critical path of the schedule can be developed at this level. With the help of the detailed Level 3 schedule, a level 1 schedule is created consisting only the summary activities and milestones with their overall durations. This is created for the upper management level to assist them with strategic decision making. All the levels of schedules are created by the contractor and are approved by the client for its use.

2.2 Basic Definitions

The terms listed below are frequently used throughout the thesis. The terms in this section are defined in a context relevant to this thesis.

Employer Delay[1]

It is a delay caused by employer risk event. There are two types. An employer delay causing delay to contractor's progress but not the completion date is called employer delay to progress. An employer delay causing a delay that will affect the contractor's completion date is called employer delay to completion. This thesis deals with employer delay to completion (hereafter called as employer delay).

Contractor Delay[2]

It is a delay caused by the contractor. A Contractor delay causing delay to contractor's progress but not the completion date is called contractor delay to progress. A contractor delay causing a delay that will affect the contractor's completion date is called contractor delay to completion (hereafter called as contractor delay).

Excusable Delay[3]

It is a delay which excuses a party from meeting a contractual deadline. An excusable delay is given when a delay is not caused by a party (Samantha, 2002). Some of those delays where the contractor is excused are force majeure delays.

Inexcusable delay[4]

A delay is not excused when it is due to contractor's mismanagement and thus shall be liable to the cost and consequences of the delay (Samantha, 2002).

Concurrent Delay[5]

True concurrent delay is the occurrence of two or more delay events at the same time. However the term concurrent delay is used when two or more delays occur at different time, but the effect is felt at the same time (Society of construction law, 2002).

Pacing Work[6]

[1] *Delay and Disruption Protocol (2002),* Society of Construction Law, Pg. 56
[2] *Delay and Disruption Protocol (2002),* Society of Construction Law, Pg. 54
[3] A*n overview of construction claims: how they arise and how to avoid them*, Samantha LP, Clark Wilson LLP, 2002, Pg. 3
[4] A*n overview of construction claims: how they arise and how to avoid them*, Samantha LP, Clark Wilson LLP, 2002, Pg. 2
[5] *Delay and Disruption Protocol (2002),* Society of Construction Law, Pg. 53
[6] Analysis of concurrent/pacing delays, Ronald J. Rider, Richard J. Long, Long International Inc., 2013, Pg. 2

Sometimes the contractors received both time extension and recovery of delayed costs when an owner caused a delay on critical path and contractor has a simultaneous delay (Ridder & J.Long, 2013). This is called as "pacing" by the contractor and it utilizes the available float when owner is causing a delay in the critical path. The argument for pacing delays is that contractor does not want to "hurry up and then wait" while the owner cause delay is driving delays for project completion. Pacing delays can be a defense to a potential concurrent delay.

Acceleration[7]

Acceleration is the portion of work or scope of the project that must be completed in a shorter time by the contractor to meet the assigned date/duration (Society of construction law, 2002).

Disruption[8]

Disruption is the disturbance or hindrance to contractor's normal working methods which results in lower efficiency (Society of construction law, 2002).

Liquidated Damages[9]

A fixed sum paid by the contractor, per day or week, if works are not completed within the agreed completion date. This is often mentioned in the contract (Society of construction law, 2002).

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[7] *Delay and Disruption Protocol (2002),* Society of Construction Law, Pg. 52
[8] *Delay and Disruption Protocol (2002),* Society of Construction Law, Pg. 55
[9] *Delay and Disruption Protocol (2002),* Society of Construction Law, Pg. 58

Chapter 3: BACKGROUND STUDY FOR LEGAL

This thesis deals with improving quality of schedules with respect to the delay analysis used for extension of time (EOT). The calculation of extension of time deals with many legal entities. Since the thesis is focused on UK law, this chapter would conduct a literature study on the legality of UK law with respect to extension of time.

For performing the legal study the Delay and Disruption Protocol is chosen. The delay and disruption protocol is prepared by the members of Society of Construction law (SCL), UK (Society of Construction Law, 2002). The first draft was open to consultation and about 400 written submissions were reviewed. Also taking this into account the final draft was published in October 2002 (McCaffrey, 2003). The protocol discusses common issues to resolve matters related to extension of time which arises in construction contracts[10].

The protocol covers the following guidance sections:

- Detailed explanation of 21 core principles and matters relating to delays (Guidance Section 1)

In this section of the protocol, it explains in detail about some core principles regarding delays. It provides guidance on how the owners and contractors resolve a dispute pertaining to delays. Some of the principles include – for eg, extension of time, concurrency, owner ship of float etc.

- Guidelines dealing with preparation and maintenance of records(Guidance Section 2)

The protocol has an approach that disputes can be avoided to a great extent with preparing and maintaining records of the project. It includes guidelines on how the program records should form, the time required for submission of program, how the contract administrator (owner/owner's representative) should accept a program, updating & saving an accepted program and software related practices.

For eg, updating the program is suggested at intervals of no longer than one month. Also, schedule shall be progressed with the actual start and actual finish along with the percentage of finish. It is also suggested that every update shall be assisted with a report of all modifications done with the program.

- Guidelines dealing with extension of time during the course of the project. (Guidance Section 3)

The protocol provides a detailed procedure for extension of time applications in order to set a more accurate and efficient dispute resolution. For eg, simply stating that owner delay have occurred and claiming the whole of that delay apparent to the time of events is not sufficient enough for a proper demonstration of entitlement[11]. A proper procedure suggested by the protocol includes the submitting the full program including the updates, determining the cause and effect of that delay through a proper delay analysis methodology, following the approaches suggested for different issues in the 21 core principles and finally resulting the EOT in a fair and reasonable manner.

- Guidelines dealing with retrospective assessment of delays. (Guidance Section 4)

The protocol discusses the various delay analysis that can be adopted to show the nature of proof of a particular delay. It also enlists the minimum records and works that are necessary for proper apportionment of delays – this includes, the conditions of contract, nature of causative events, value of dispute, time available, records available, program information available and programmer's skill and familiarity with the project.

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[10] SCL Delay and Disruption Protocol (2002), Section A, page 3
[11] SCL Delay and Disruption Protocol (2002), Section 3.2.2, page42

3.1 Approaches to delay issues

The delay and disruption protocol provides some key legal issues to deal with the extension of time between the owner and the contractor. This will be the basis of apportioning delays and also to deal with improvements in schedule quality.

Extension of Time

According to the protocol, the legal requirements in claiming an extension of time needs the contractor to prove that the employer delay is critical to meeting the contractual completion date[12]. This means if the contractor fails to show that the employer delay is critical in his schedule, the nature of proof will be lost and the contractor shall not be able to get the extension of time.[13]

Concurrent Delays

According to the protocol, true concurrent delay is the delays that occurs at the same time and felt at the same time. In that situation, the contractor should nevertheless be granted an EOT. However, true concurrent delays are of rare occurrence. Again according to the protocol, concurrent delays refer where two or more delays occur at different time but the effect is felt at the same time. In such circumstances, where the contractor's delay to completion occurs concurrently with the employer's delay to completion, the contractor's concurrent delay should not reduce any EOT due[14]. This legal approach is derived from the Henry Boot Construction v Malmaison hotel (Technology and construction court,1999) and followed by a number of English Cases[15]. While apportioning the delays in this thesis in the later chapters, this will be considered.

Records for evidence

According to the protocol, though the schedules are used to guide in determination of EOT, it should be accompanied by proper records and documentation as evidence to make it fair and reasonable[16]. Thus while apportioning delays in the further chapters, proper documentation will be screened to make the resultant EOT as fair as possible.

3.2 Personal Reflection on the Protocol

Delay analysis

The nature of proof required for the demonstrating delays is explained less in the delay and disruption protocol. It only describes 4 techniques and prioritizes the time impact analysis technique[17]. In addition, it does not tell how these techniques should be applied. Firstly, the delay analysis is not merely limited to four techniques and every technique has its own pros and cons. The choice of technique also depends on but not limited to the complexity of the project, the records available and the purpose of analysis. The delay analysis plays a crucial role in this thesis. Thus a separate literature study is performed for the delay analysis.

Ownership of float

The protocol discussed the ownership of float[18] narrowly. It more refers to the terminal float where it corresponds to the time available between the contractual completion date and the contractor's early

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[12] Delay and Disruption Protocol, Society of Construction Law (2002), section 1.3.6

[13] Also the book of Delay Analysis in construction contracts (P.J. Kaene, 2008) states that the UK courts recognizes that a delay must be shown critical for providing relevant award of time or time related damages.

[14] Delay and Disruption Protocol, Society of Construction Law (2002), section 1.4.1

[15] International Approaches to the legal analysis of concurrent delay: is there a solution to the English Law?, Mathew Cocklin, 2012, pg 2.

[16] Delay and Disruption Protocol, Society of Construction Law (2002), section 3.2.13

[17] Delay and Disruption Protocol, Society of Construction Law (2002), page 47

[18] Delay and Disruption Protocol, Society of Construction Law (2002), section 1.3

completion date. However, there are many kinds of float existing within the schedule technically and this distinction has to be made clear in the protocol. For eg, pacing delays[19] is also associated with float (referring to activity float) and the ownership of float can also be witnessed in this scenario.

Administrative Burden

Contractors shall verify whether the modal clauses given by the protocol would help them run the project effectively, otherwise it can lead to another unjustified administrative burden. For example clause 2.5 of appendix C of protocol insists in reporting each day of work. In my opinion everyday reporting to the Contract administrator takes in a lot of effort and time giving rise to administrative burden. This can be optimised by reporting every month/week.

Liability of the contract Administrator

The protocol makes the contract administrator to take on more liability. The model clause 4.3[20] presented by the protocol requires the contract administrator to accept the contractor's intended program. In such circumstances, upon acceptance, the contract administrator can partly find himself liable of the contractor's program of intended works. This could give rise to joint liability and could mean that he is also liable if the project program is not achievable, this might make the contractor insolvent. More clarity is required on the acceptance of program, otherwise can lead to new disputes.

Schedule Quality

The protocol more concentrates on the submission of the program. However, when speaking of the Extension of time, the protocol stated the need for the employer delay to be critical (critical is a quality of CPM schedule) and this involves schedules[21]. As seen in the introduction chapter, the complexity of the schedule and its quality sometimes fail to show explicitly a delay that corresponds to real time activities. This will rise disputes between the parties and dispute resolution is very tough at such complexities. The protocol failed to concentrate on the schedule quality that hinders in explicitly portraying the proof of a delay.

3.3 Summary

The protocol more concentrated on the submission of contractor's program, dealing disputes and procedures for extension of time. However, it concentrated less on the delay analysis and the complexity of the schedule used as a proof. The delay analysis itself has its own pros and cons in explicitly and accurately showing a delay. Also the quality of schedule is highly important to resolve a dispute in a smooth manner. This is because, the proof lies on the quality of schedule and if that schedule does not manage to explicitly show a delay, then disputes are unlikely to solve in the negotiation level. Thus making the parties seek courts to resolve their disputes. This thesis would help the legal community bridge the gap about the complexity of delay analysis and the quality of schedules with that of the legal requirements. Thus providing more clarity linking the schedules with the legal requirements which would help in smooth dispute resolution and avoiding unnecessary judicial seeking.

[19] Construction Delay Analysis Techniques—A Review of Application Issues and Improvement Needs, Nuhu braimah (2013), pg. 527 – Pacing Delays: Delays caused by deceleration of one's works due to the delay of other party to the project end date. Pacing delays often tends to minimize compensable delay.

[20] Delay and Disruption Protocol, Society of Construction Law (2002), Page 66

[21] Delay and Disruption Protocol, Society of Construction Law (2002), section 1.3.6

Chapter 4: Theoretical background on Forensic Schedule Analysis

This chapter conducts a literature study on the various schedule analysis methods available. Based on the study, a conclusion is arrived on the most appropriate method suitable for the EPC contractors. This method will be used in a real case in the successive chapters.

4.1 Forensic Schedule Analysis

Forensic schedule analysis is a technical tool that helps in investigating the events of a CPM schedule, so that delays can be apportioned between the players involved in a project. It is a tool that may be potentially be used in a legal proceeding, i.e. in order to prove a delay in a legal proceeding using a schedule (as evidence), this tool can be used to analyze and prove that particular delay. This thesis is going to build the quality of the schedules with respect to the forensic schedule analysis. In order to do so, one needs to know the technicality of the various schedule analysis methods. To perform the literature study, I chose the AACE international Recommended Practice No. 29R-03 "Forensic Schedule Analysis" (hereafter will be mentioned as RP) as a reference. The reason to choose this reference is because, it is the first and only guide that deals with the forensic schedule analysis methods and offers a reference at a technical level. In addition, the guide is prepared by a team of certified forensic analyst experts from various industries which makes it more reliable. Also, this reference is used as basis for other publications by consultancies (WPL Publishing, 2014) (DeMotte, 2014), universities (Braimah, 2013), books (Leon, 2010) (Keane & Caletka) and construction industry (Kelly, 2013). Thus RP is a reliable reference for my research.

All the schedule analysis methods discussed in this chapter is based on this reference. At the end of the chapter, a suitable method is chosen that would suit the characteristics of the EPC contractor's job.

4.2 Types of Techniques

In the recommended practice No. 29R-03, based on the classification, a list of 9 analysis methods is present ranging from MIP 3.1to MIP 3.9 (MIP – Method Implementation Protocol). These MIPs describe each forensic schedule analysis method and provide guidelines in implementing these methods. Each MIP is an unique method and each MIP shows the procedure to perform those methods. Before dealing with the methods, let us go through some hierarchical classification which makes each of the 9 methods unique. An overall family tree diagram of this classification is provided in the appendix. We shall now summarize the various levels of classification:

Level 1:

Prospective Analysis: The analysis is performed prior to the occurrence of delay event, in other words, the analysis estimates for future events. This is not the focus of our thesis.

Retrospective Analysis: The analysis is performed after the occurrence of the delay event. Thus for this analysis, the delays, its impacts and the outcome is known. The scope of this thesis is limited to the retrospective analysis.

Level 2:

Under the retrospective analysis, there are two subsets: observational method and the modeled method.

Observational Method: The analysis is performed only by observation of the events. A comparison of schedules is made with one another. For example, the as-planned and the as-built schedule are compared to find out how long the delay is (As planned vs As-Built Analysis method). Here, no change is done to the schedule. This method has two subsets.

i. **Static Logic Method:** it compares the plan of one network to the as-built schedule of the same network.

ii. **Dynamic Logic Method:** This is different from the static one. This uses the schedule updates of the baseline schedule to compare with the as-built schedule. During the process, there can be changes in logic that are incorporated in the project. A baseline schedule created during the initiation of the contract may not be executed the same throughout the project. Some activities need a change according to changing scenarios. Thus, the schedule is updated every time period to suit the project. This is called as schedule updates.

Modeled Method: The analysis is performed by the intervention of activities that represents delays into the CPM network. This is followed by comparison of the 'after' and 'before' states of schedules. This again has two subsets.

i. **Additive Modeling:** it involves the adding of schedule elements (delays) to the as-planned schedule and comparing it with as-built schedule. "Impacted As-planned" method is one of those kinds.

ii. **Subtractive Modeling:** it involves the subtracting of schedule elements (delays) from the As-Built schedule and comparing with the As-planned schedule. "Collapsed As-built" is an example for this type.

Now let us go through each type of schedule analysis method. The core principles are shown with examples and the variants of the methods are explained below.

As-Planned vs. As-Built

This method does not involve explicit use of CPM logic. Hence, they are called observational static methods. This covers the MIP 3.1 (observational-static-gross) and MIP 3.2 (observational-static-periodic) based on the AACE recommended protocol 29R-03. The MIP 3.1 considers the schedule as a whole and analyzed and MIP 3.2 divides the schedules into segments and performs the same analysis as 3.1, however does not consider the critical path shift of the schedule. In this As-planned vs As-built method, there is a comparison made between the as-built schedule and the as-planned schedule. All the delay events are present in the as-built schedule. The difference between the as-planned and the as-built completion dates gives the delayed time. The claimant can ask for compensation in time and monetary terms for this delayed time.

Methodology

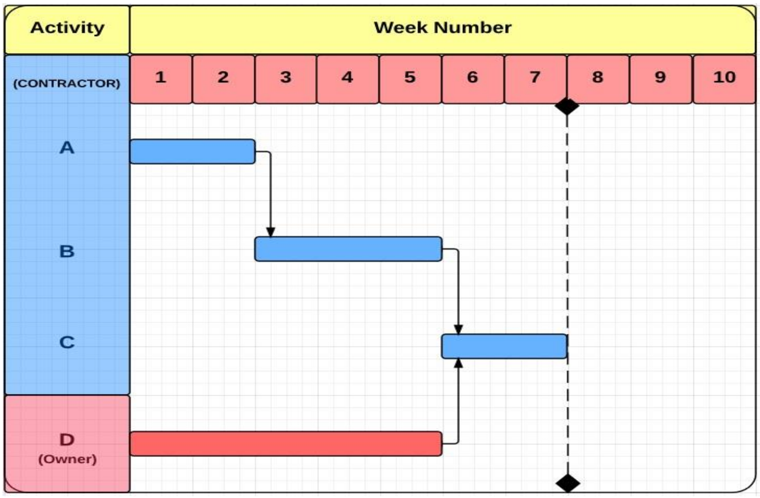


FIGURE 8: AS-PLANNED SCHEDULE

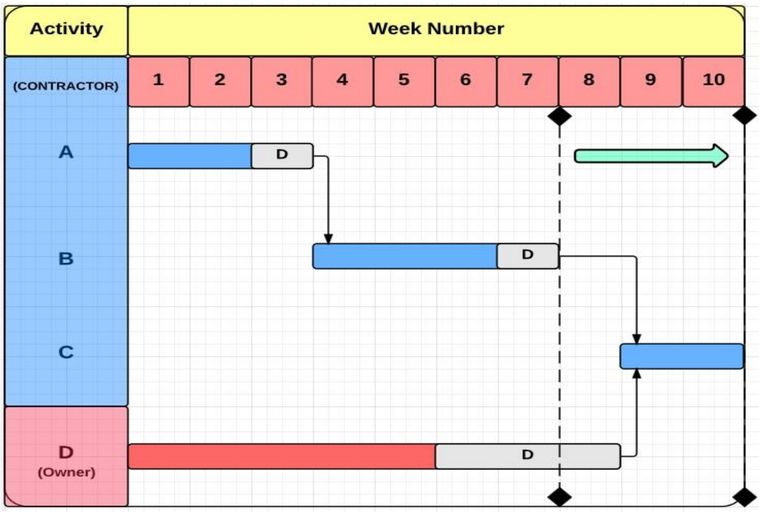


FIGURE 9: AS-BUILT SCHEDULE

Consider an as-planned and as-built schedule as shown in figures. An as-planned schedule is a schedule by which the contractor intends to work. The as-built schedule is a schedule by which the contractor actually performed on site. The following illustrates the methodology of a sample project:

Sum of contractor caused delays = 1+1 = 2 weeks

Sum of Owner Caused Delays = 3 weeks

Therefore the concurrent delay for both parties is 2 weeks.

The net project delay the owner is responsible is = 3 – 2 = 1 week delay.

The total project delay is 10 – 7 = 3 weeks.

The balance after owner's delay is the contractor's responsibility which is = 3 – 1 = 2 weeks delay.

Thus, the result of the as-planned vs as-built schedule analysis is that **owner** is responsible for **1 week delay** and **contractor** is responsible for **2 weeks delay**.

PROS

- Suitable for small projects with minimal logic changes
- Technically simple to perform.
- Easy to understand and simple to present

CONS

- Not suitable for projects having numerous schedule updates
- Not suitable for projects with multiple critical paths
- Does not account critical path shift
- Does not consider pacing and concurrency issues
- Does not consider the changes in the baseline schedule which might be the actual cause of the delay.
- Ignores the dynamic nature of the critical path and any changes in schedule logic

IMPACTED AS-PLANNED

This covers the MIP 3.6 [observational-additive-single base] based on the AACE recommended protocol 29R-03. This method uses the As-Planned CPM schedule to measure the delays. Each delay is considered an activity and added to the as-planned network in a chronological order. Hence, it is called as an additive model. With each added delay activity the effect of delay in the whole schedule is observed and indicates how the project is being delayed. The difference between the completion dates before and after the impacts shows the delayed time.

METHODOLOGY

In this method, each delay in inserted one by one in chronological order and the impact on the finish date is observed. The delay on the total project each of contractor and owner is segregated according to their respective impacts on the finish date. The impact of each delay is shown in the figures below in a chronological order.

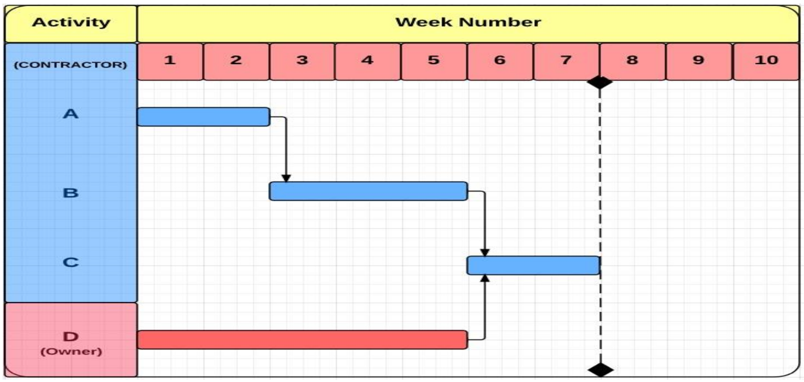


FIGURE 10: AS-PLANNED SCHEDULE

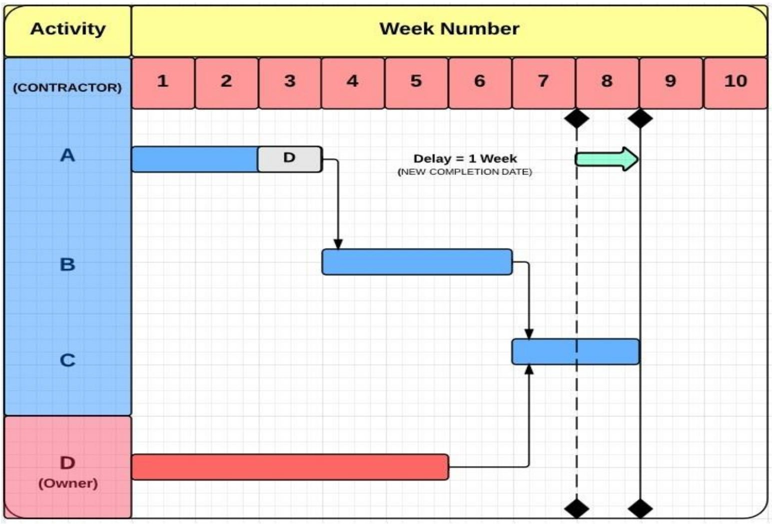


FIGURE 11: IMPACT OF DELAY 1

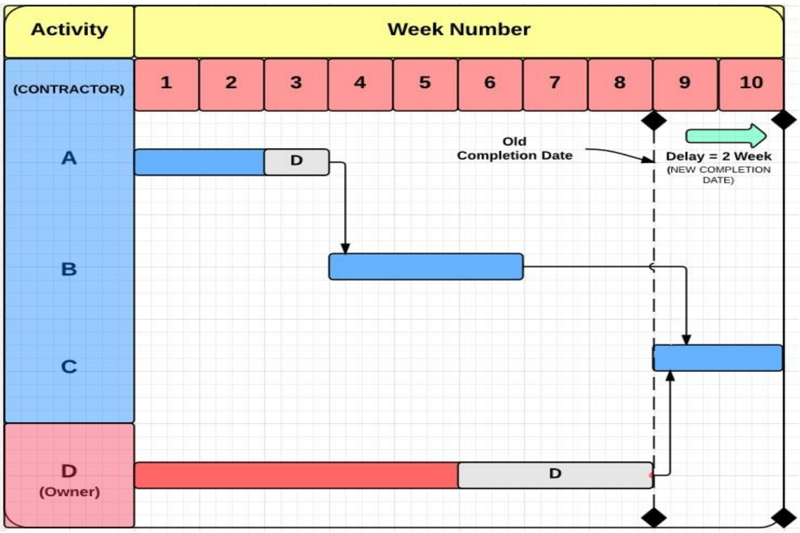


FIGURE 12: IMPACT OF DELAY 2

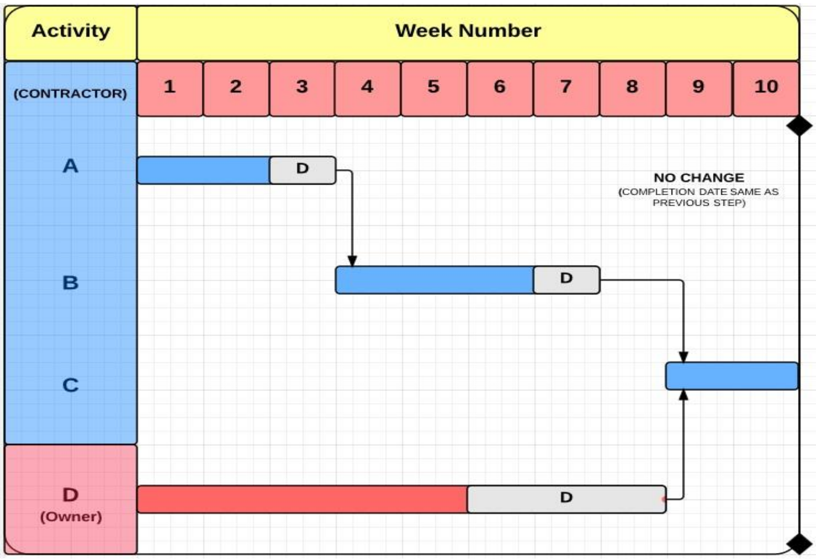


FIGURE 13: IMPACT OF DELAY 3

The first delay (1 week) was on the critical path of A-B-C causing a delay of 1 week to the finish date of the project. According to the chronological order, the second delay is the delay caused by the owner (3 weeks) making D-C as critical path and causing a delay of 2 weeks in the finish date of the project. The third delay has no impact on the completion date. Thus, the results are tabulated below:

TABLE 2: COMPARISON OF DELAYS

Chronology of Delays	Activity	DELAYS		
		Type	Duration (Weeks)	Impact (Weeks)
1	A	Contractor	1	1
2	D	Owner	3	2
3	B	Contractor	1	0

From the table, it is clear that the owner is responsible for two weeks delay and the contractor is responsible for one week delay. The results turned out much differently than the as-planned vs. the as-built method explained previously. To find the individual delays of contractor and owner, this method can also be performed by separately inserting the owner and contractor delays individually for calculating project end.

PROS

- Can be used to quantify non compensable time extensions
- Can be implemented easily compared with other methods
- Can identify acceleration in the schedule
- Can isolate owner and contractor delays

CONS

- Cannot quantify compensable delays as it does not take into account the issues of concurrent or pacing delays
- It does not rely on as-built schedule. Many times, the construction activities on site are much different than the baseline schedule logic.
- Does not necessarily consider chronological order of delays
- Has the potential of failing to consider delays of all parties and especially of the claimant.
- Accuracy of duration of critical path impact degrades in proportion to the chronological distance of the delay event in the data date of the schedule.

COLLAPSED AS-BUILT

This covers the MIP 3.8 (Modeled-Subtractive-Single base) based on the AACE recommended protocol 29R-03. This model is a subtractive model as this method involves removing of delays of each party (contractor and client) from the as-built schedule so that the resulting schedule will give the completion date of the project but for the delays of the other party.

METHODOLOGY

The as-built schedule is taken as a basis. The respective owner and contractor delays are removed individually to observe the impact of the finish date each caused. The methodology is done on contractor's point of view as well as the owner's point of view:

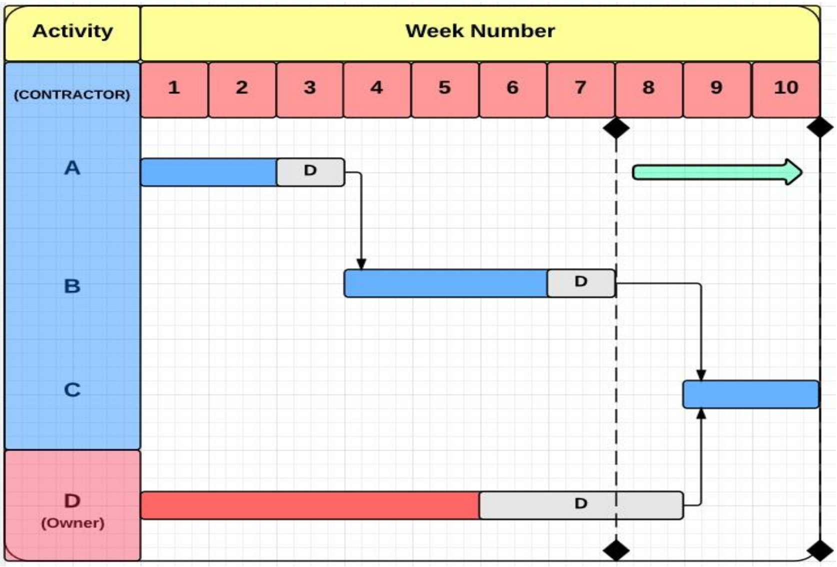


FIGURE 14: AS-BUILT SCHEDULE

CONTRACTOR POINT OF VIEW:

Here, the owner caused delays are removed from the as-built schedule and the finish date is observed as week 9. The path A-B-C is the critical path. The actual completion date of project is week 10. Thus, the contractor caused 2 weeks delay in the project and owner caused the remaining one week delay.

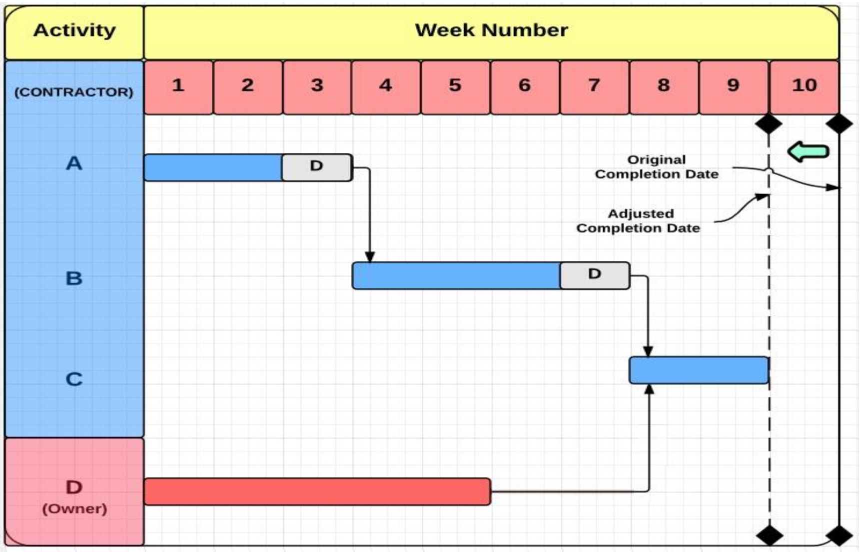


FIGURE 15: SCHEDULE WITH OWNERS DELAY SUBTRACTED

OWNER POINT OF VIEW:

Here, the contractor caused delays are removed from the as-built schedule. The finish date is observed as week 10 which is same as the actual completion date. Thus all the delays are attributed to the owner and the contractor is free from delays.

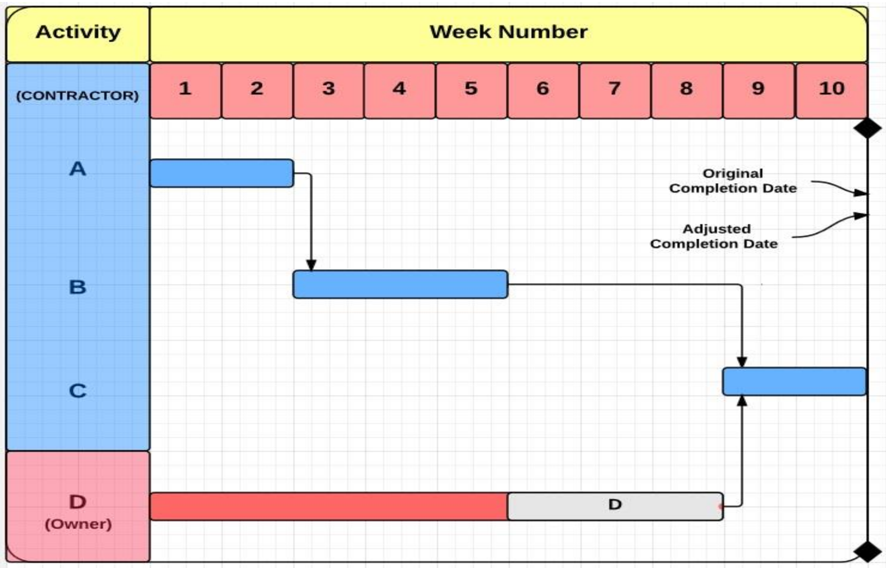


FIGURE 16: SCHEDULE WITH CONTRACTOR'S DELAY SUBTRACTED

PROS

- This technique is of high credibility as it takes into account the history of actual events that occurred in the project (as-built schedule).
- Can isolate owner and contractor caused delays
- Can be implemented without any baseline schedule updates

Cons

- Analyst forced to add after-the-fact logic ties that does not refer to the schedule updates used during the project.
- Reconstructing the as-built schedule is laborious in nature.
- Ignores the dynamic nature of the critical path
- The critical path of the as-built schedule does not necessarily coincide with the critical path of the contemporaneous schedule updates.
- Not suitable for identification or quantification of acceleration

Window Analysis

This analysis involves interim assessment of delay on updated schedules at specific periods of the project. It is also called as the “snapshot technique” or “contemporaneous period analysis”. Initially, the total project duration is divided into a number of short periods (windows). The duration of these windows depends on the schedule updates of the project. Within each window, the schedule is updated to reflect the actual durations and sequence at the time of delay. The remaining schedule beyond the window is maintained. Analysis within the window is performed to determine any changes in the critical path and new completion date. This new completion date is compared with that of the as-planned schedule to give the amount of delay period.

This covers the MIP 3.3(observational-dynamic-contemporaneous As-is), 3.4(observational-dynamic-contemporaneous Split), 3.5(observational-dynamic-Modified), 3.7(Modeled-Additive-Multibase) and 3.9(Modeled-Subtractive-Multibase) based on the AACE recommended protocol 29R-03.

In MIP 3.3 method, the schedules are used as it is and observed for any delays. The schedules are also not intervened. It considers changes in logic and hence a dynamic logic method.

MIP 3.4 is identical to MIP 3.3 in all aspects except that this technique will assist in easy identification of schedule slippage during non-progress revisions made to the schedule. If there are no non-progress revisions, this method cannot be used and MIP 3.3 can be used instead. This is also an observational technique.

MIP 3.5 is used when there is missing information in the schedule. This is done by recreating the schedule updates and calculating the loss or gain of time in a windows manner.

MIP 3.7 is a mix of Impacted As-planned (MIP 3.6) and window analysis (MIP 3.3).

MIP 3.9 is a mix of As-built schedule (MIP 3.8) and the window analysis (MIP 3.3).

Methodology

The window analysis technique is demonstrated in a step by step manner for easy understanding. Consider an As- planned schedule and an As-built schedule shown in figure 17 and 18 below. According to the diagram one can see that there are a total of 4 activities where the activities B and C follow activity A and precede activity D. the as-planned schedule took 7 weeks whereas the as-built schedule took 9 weeks. If one looks keen in the as-built schedule, there was 2 weeks owner caused delays and one week contractor caused delay. However, there was a total project delay of only 2 weeks. Let us observe how the window analysis works with the windows. As said earlier, the windows analysis can be split into many windows. To give a deeper understanding, this example is going to demonstrate various window sizes and the results of the apportionment of the delays between the contractor and owner.

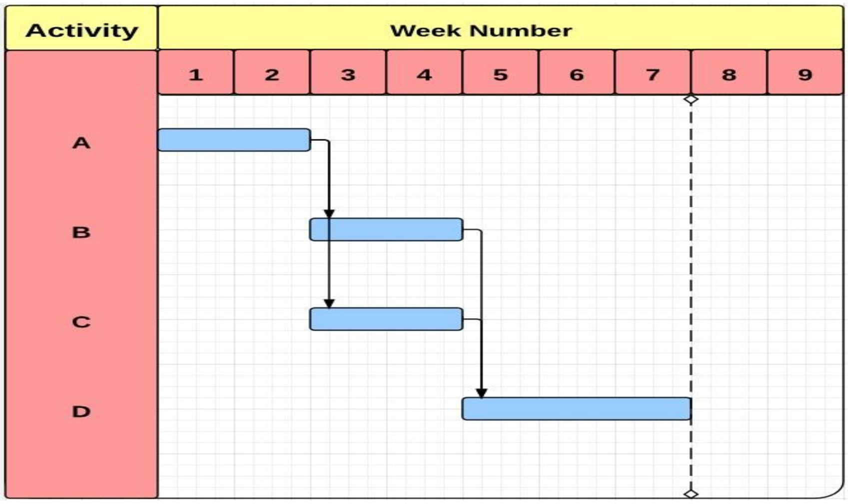


FIGURE 17: AS-PLANNED SCHEDULE

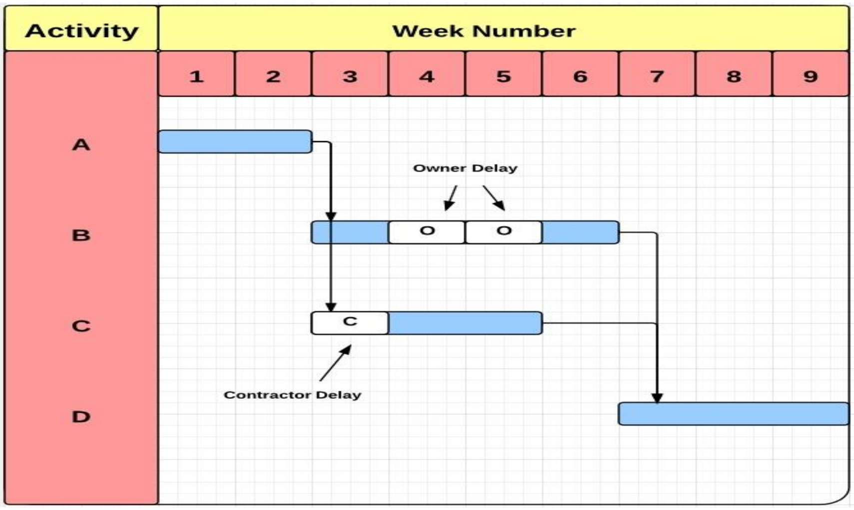


FIGURE 18: AS-BUILT SCHEDULE

Windows Analysis with one window (full project as one window)

When one takes the whole project as one window, the time period of the window is 9 weeks (refer As-built schedule diagram). One can observe that there are 2 weeks of owner delays that occurred in the critical path. Hence, the two week project delay is apportioned to owner.

Windows Analysis with two windows (ending at week 3 and week 9)

Consider the below figures 19 and 20 for working with windows ending at week 3 and week 9 respectively. Window analysis is done window by window. First, let us consider the first window ending at week 3. There is one contractor delay in path A-C-D leading to the delay of the project by one week. Now let us consider the second window ending at 9. Now the critical path is shifted to A-B-D making one more extra delay to the project. Thus, the owner and contractor each contributes one delay to the project.

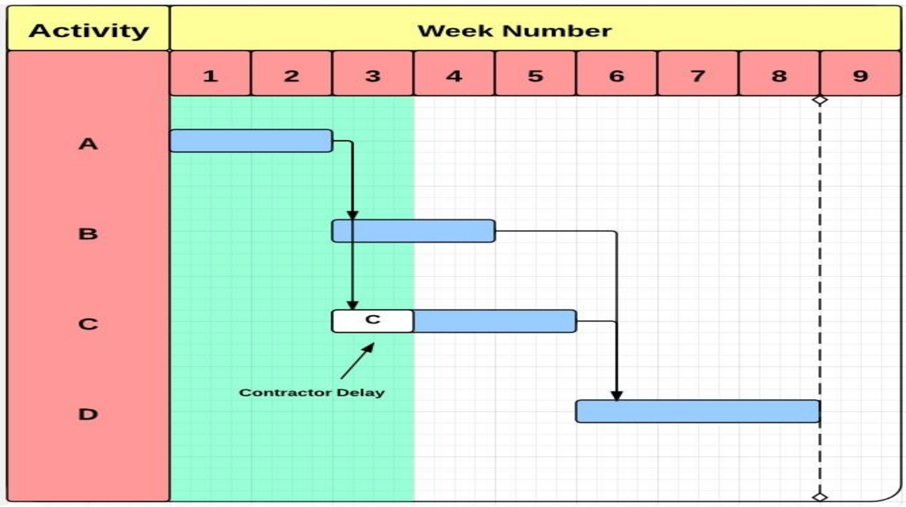


FIGURE 19: WINDOW ENDING AT 3RD DAY

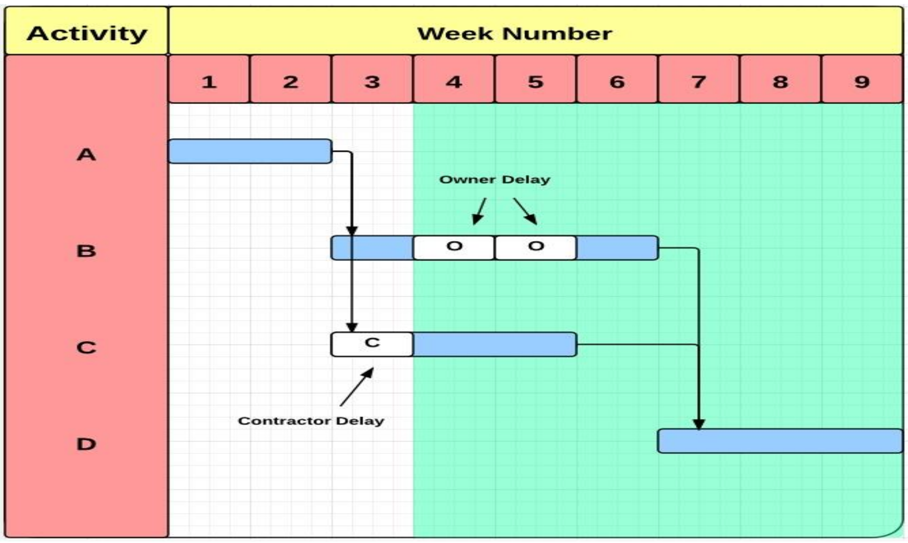


FIGURE 20: WINDOW ENDING AT DAY 9

WINDOWS ANALYSIS WITH TWO WINDOWS (ENDING AT WEEK 4 AND WEEK 9)

Consider the first window ending at week 4. Both the paths A-B-D and A-C-D are critical with both owner and contractor contributing one week delay resulting in one week delay of the overall project. Consider the second window ending at 9. Now the path A-B-D becomes critical path where owner caused delay causes the project to delay one more week. Thus one week delay of the project is shared by the contractor and the owner and other week is contributed completely by the owner.

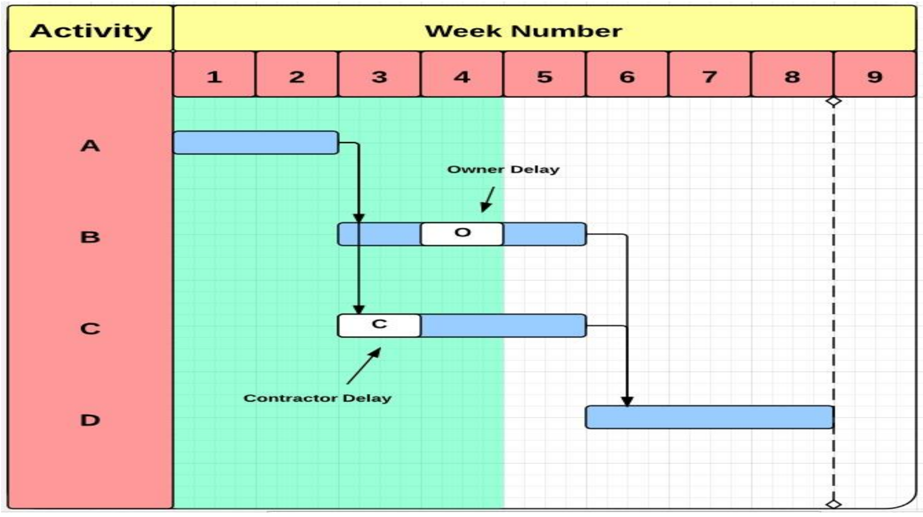


FIGURE 21: WINDOW ENDING AT WEEK 4

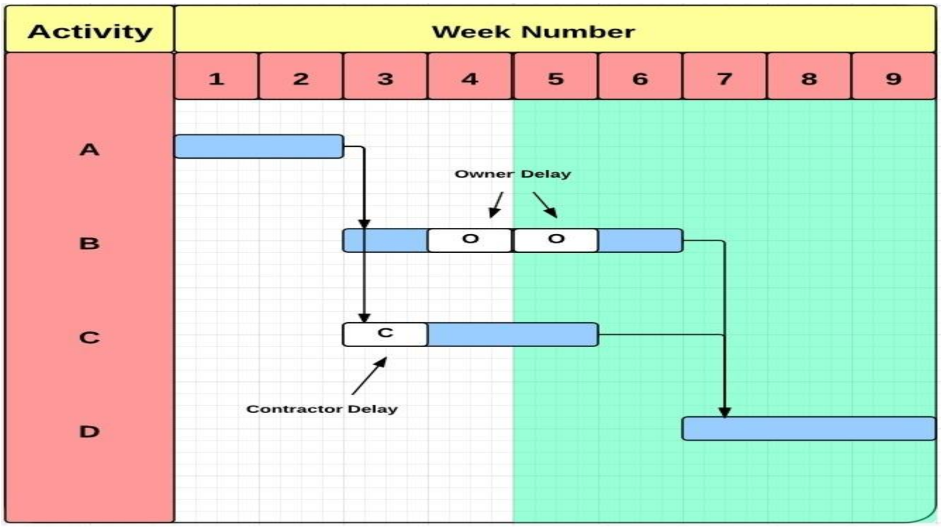


FIGURE 22: WINDOW ENDING AT DAY 9

Let us summarize the delays based on the different window sizes worked out.

TABLE 3: COMPARISON OF DIFFERENT WINDOWS

Window Sizes	Delay Responsibility	
	Owner (O)	Contractor (C)
One window ending at 9th week	2	0
Two windows ending at 3rd and 9th week	1	1
Two windows ending at 4th week and 9th week	1.5	0.5

This simple example shows the basic working of the windows analysis technique based on the selection of different windows. However, real time schedules aren't this simple and they are laborious to work with. Hence, sufficient expertise is required to operate this kind of schedules.

PROS

- Takes into account the dynamic nature of the critical path

- divides the complicated network in to small windows which are easily manageable
- Results are more accurate than other methods.

Cons

- As worked out before, different window sizes can give different results. The parties might have problems choosing the window period. This can be avoided by prior discussion before starting the analysis.
- This method needs a lot of contemporaneous data, especially from updates. Without which performing this method is difficult.
- The windows method is complex and time consuming.
- A lot of costs might be incurred to perform this technique.
- Only people with expertise can perform this technique.

4.3 Choosing a Method

All analysis methods explained above are unique in its own way. The choice of choosing the right technique to suit the dispute depends on a lot of factors. These factors would be considered to discuss the best method for an EPC contractor in the next section. A list of factors from the AACE recommended protocol 29R-03 is summarized below. Each factor is categorized by legal, practical and technical considerations which are mentioned in the brackets below. The factors are:

Contractual Requirements (Legal)

Contractual language highly determines the type of analysis to be used. If the analysis method/protocol is mentioned in the contract, the analyst has no option and has to work with that particular protocol. Sometimes, the mentioned analysis can be generic, for e.g. Time impact analysis. This is a generic term that falls under a range of protocols, for e.g. In case of time impact analysis, protocols referring to MIP 3.6 and MIP 3.7 can be used based on the advantage of the analyst.

On the other hand, if the contract is silent on the terms of the analysis method used, the analyst is free to choose his own method. However, certain clauses, like "…..Impacted the critical path of the schedule" or "…cause or will cause the end date of the schedule later than the current contract completion date", can affect the choice of the analyst, not by the analysis method, but by choosing one of the observational dynamic, additive modeling or subtractive modeling techniques.

More often, it is not uncommon to have unclear or ambiguous contracts. However, forensic schedule analysts should perform adhering to the requirements of the contract, applicable codes and laws governing the contract with high priority.

Purpose of Analysis (Technical)

Some analysis techniques are better suited for some purposes than others. A detailed table is enlisted below showing the ones applicable for their respective purposes.

TABLE 4: PURPOSE OF ANALYSISINVALID SOURCE SPECIFIED.

Forensic Use of Analysis	Method								
	3.1	**3.2**	**3.3**	**3.4**	**3.5**	**3.6**	**3.7**	**3.8**	**3.9**
Non-Compensable time Extension	OK	OK	OK	OK	OK	OK	OK	OK	OK
Compensable Delay	OK	OK	OK	OK	OK			OK	OK
Right to finish early compensable delay								OK	OK

Entitlement to early completion bonus	OK	OK	OK	OK	OK	OK	OK	OK	OK
Disruption without project delay	OK	OK	OK	OK	OK	OK	OK		
Constructive Acceleration			OK	OK		OK	OK		

SOURCE DATA VALIDITY AND RELIABILITY (TECHNICAL)

The method of analysis is highly based on the source validation protocols (SVP) mentioned for each MIP in the Recommended Practice 29R-03. This means that to perform an analysis method, certain sources should be made available and validated. For e.g., if the projects records only have data regarding baseline schedule and As-built schedule, but no update schedules, then only the MIPs 3.1 and 3.2 can be used. Likewise, minimum required protocols/source data for all other MIPs it is tabulated below.

TABLE 5: SOURCE OF SCHEDULE DATAINVALID SOURCE SPECIFIED.

Source of Schedule Data	**METHOD**								
	3.1	**3.2**	**3.3**	**3.4**	**3.5**	**3.6**	**3.7**	**3.8**	**3.9**
Baseline Schedule	Min.	Min.				Min.	Min.		
Schedule Updates			Min.	Min.			Min.		Min.
As-Built Record	Min.	Min.			Min.			Min.	Min.

SIZE OF DISPUTE (PRACTICAL)

The size of the dispute highly influences the selection of the technique. For dealing with claims of low value, it is recommended to use inexpensive techniques. If the claim is of high value then it is up to the analyst to select a suitable method that is both cost effective and suitable for the dispute.

COMPLEXITY OF THE DISPUTE (TECHNICAL)

The complexity of the schedule is also a factor for selecting the type of schedule. If it is a small schedule having few delays, then a simple comparison with the as-built schedule would suffice. If, however, the schedule is complex with hundreds of activities and a lot of delays, then scheduler can use one of the window analysis techniques that divide the whole schedule into smaller periods to isolate and analyze delays.

BUDGET FOR FORENSIC SCHEDULE ANALYSIS (PRACTICAL)

If the project is dealing with claims of low value, it is beneficial to go with less expensive analysis methods and vice versa. If the spending on the dispute is more than what the party gets, it is not wise to invest so much of money in a analysis technique.

TIME ALLOWED FOR FORENSIC SCHEDULE ANALYSIS (PRACTICAL)

Some techniques are complex, where some are simple to use. Complex techniques take a lot of time, especially, when dealing with schedules having hundreds of activities. Depending upon the money at stake and the time allowed for the dispute to take, it is wise to go for the appropriate analysis technique.

EXPERTISE OF THE FORENSIC SCHEDULE ANALYST AND RESOURCES AVAILABLE (PRACTICAL)

Complex techniques, like window analysis technique, need expertise to perform efficiently. Sometimes he might need assistance too. If the analyst is left with no assistance to perform the analysis, then he may be compelled to use simpler methods.

Forum for resolution and Audience (Legal)

As long as the parties are on the negotiating table, the range of options to select a forensic schedule method is open as audience is the only people around. To resolve a dispute, they may be motivated, persuaded or willing to make decisions other than it is mentioned in the contract. If however, they move to court, this freedom might be arrested as many courts and boards have their own rules and regulations to follow. And some techniques may be too technical for courts to understand and fair judgment might be lost.

Legal or procedural requirements (Legal)

When selecting the type of analysis method, the analyst has to take into consideration about the contractual, legal, or procedural rules that may impact its selection. Consultation with the client's legal counsel on these issues is necessary.

Custom and usage of methods on the project or the case (Practical)

The final factor is to consider the past methods/techniques used between parties for dispute resolution. The forensic schedule analyst will not come until preliminary negotiations failed. The analyst should know about the methods used in the preliminary negotiations and why it has failed. He should not recommend the same method to be used as it already caused a failure.

In my opinion, in addition to all the above mentioned factors, collaboration between the players is also a factor to be considered while choosing the analysis technique. Methodologies like windows analysis need a lot of records (schedules, updates, notices etc.). This also includes noticing delays between the parties. Pointing of delays (Delay Notice) in the start of the project itself may harm relations and make it tough to work together. If noticing delays are so vigorous in the start of the project, then more focus of the players would be on the blame game rather than finishing the project together. This would consume more time on dealing disputes and less time for project completion. However if methodologies like MIP 3.1 is used, the schedule as a whole is taken into consideration. No updates are used and delays can be categorized at the end of the project. Thus, disputes wait till the end of the project and more focus of the players would be for completing the project.

4.4 Summary of Literature Study

This section summarises all the literature study performed for the forensic schedule analysis. The tabular column will assist in clear understanding of the different analysis methods

ASPECTS	**METHOD**								
	3.1	**3.2**	**3.3**	**3.4**	**3.5**	**3.6**	**3.7**	**3.8**	**3.9**
	CRITICAL PATH SHIFT								
Critical path Shift	No	No	Yes	Yes	Yes	No	Yes	No	Yes
	INTERVENTION								
Intervention	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Manipulation	No	No	No	No	Yes	Yes	Yes	Yes	Yes
	SOURCES REQUIRED								
Baseline Schedule	Yes	Yes				Yes	Yes		
Schedule Updates			Yes	Yes			Yes		Yes
As-Built Record	Yes	Yes			Yes			Yes	Yes
Special requirement				Non-	Recrea				

				progress -ive revision	-ted schedu -le				
	PURPOSE OF ANALYSIS								
Non-Compensable time Extension for EOT	YES	YES	YES	YES	YES	YES	YES	YES	YES
Compensable Delay for EOT	YES	YES	YES	YES	YES			YES	YES
Right to finish early compensable delay not for EOT								YES	YES
Entitlement to early completion bonus Not for EOT	YES	YES	YES	YES	YES	YES	YES	YES	YES
Disruption without project delay Not for EOT	YES	YES	YES	YES	YES	YES	YES		
Constructive Acceleration for EOT			YES	YES		YES	YES		
	Practical Considerations								
Time	Less	Less	More	More	More	More	More	More	More
Money	Less	Less	More	More	More	More	More	More	More
Expertise	Less	Less	More	More	More	More	More	More	More

The critical path set in the as planned schedule might not be the same during the project and at the end of the project. This is because the project might undergo a lot of changing circumstances and depending on those circumstances, the critical shapes through the schedule. This is one of the important aspects that should be noted for reliability of accurate apportioning of delays. For eg, if one considers the as-planned vs as-built schedule (MIP 3.1), it only considers the critical path of the as-planned schedule and calculate schedule variances .However practically, due to the changes that occurred in site, the critical path could have shifted. Hence the apportioning of delays using this model is less accurate and reliable. However, if one considers any of the window analysis – MIP 3.3, 3.4, 3.5, 3.7 and 3.9, these models consider critical path shift. This means these models calculate schedule variances on the critical path activities that are close to reality of the project. Hence the techniques considering windows provide a higher level of accuracy than the ones that don't consider windows.

Some techniques calculate just by observation, where as some models calculate by modelling manually. The modelling of the schedule causes intervention and thus possible to manipulate the results of apportioning. Thus there is a risk of loss of reliability and possible arguments over delay apportioning when these methods are used. However, this is not possible for the techniques performed by observation.

For performing a technique, one must need source schedules. For eg, to perform the MIP 3.1 one must need a minimum of the as planned and the as built schedules. Some techniques like MIP 3.4 need special requirements such as non-progressive revision of schedules. Hence the choice of analysis method is dependent on that.

The purpose of analysis is an important criteria to deal with apportioning of delays. There are various delays possible in a project, and no one technique is capable of performing all those purposes. For eg, MIP 3.3 is not capable of Right to finish early compensable delays. And MIP 3.1 cannot account for acceleration. This purpose depends on the issue at stake. This thesis focuses on extension of time claims. Delays such as Right to finish early compensable delay, Entitlement to early completion bonus, disruption without project delay do not create a delay to the project that account for liquidated damages. Thus not in the scope of Extension of time claims. However, non -compensable time extension, compensable delay and acceleration attribute delay to the project and hence these form the scope for extension of time claims. Since my thesis is limited to the scope of extension of time, only these three purposes will be a platform for discussion while choosing the most appropriate method for the EPC contractor.

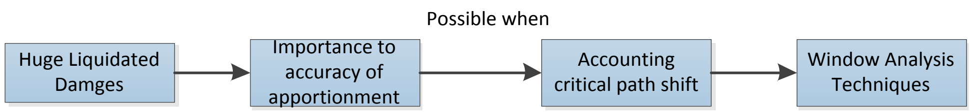
In addition to the various other aspects, there are some practical considerations that deal with the choice of analysis. These are cost, time and expertise. While the MIP 3.1 and 3.2 are simple methods, the rest are complicated and hence, there is a direct relation to the cost, time and expertise.

Above all these aspects, the legal nature of the claim comes above. For example, in the Anglo-Saxon law, the contract is the basis for a legal proceeding and the contract language can hinder the choice of a particular methodology. For eg, "…impacted the critical path of the project schedule" or "…caused or will cause the end date of the project schedule to be later than the current contract completion date" will force the analyst to only choose MIP 3.3, 3.4, 3.5, 3.6, 3.7, 3.8 or 3.9.

4.5 Most Appropriate Method for EPC Contractor

This thesis limits to the EPC contractors of the Oil and Gas Sector (like CB&I) performing projects with huge liquidated damages. And since I am performing my graduation thesis in the CB&I, the choice concluded will be for CB&I and CB&I like companies (hereafter will be represented as EPC contractor). Before starting the deduction of the most appropriate technique, the practical considerations of time, cost and expertise are assumed to be available.

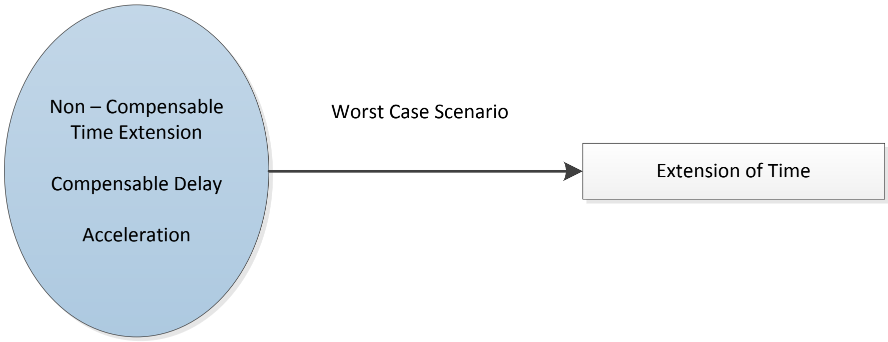
According to CB&I, they deal with projects ranging from a few millions to a few billions and even a single day of delay can make the contractors liable for huge liquidated damages. Thus the precision for apportioning the number of delays caused by each party is of high priority; otherwise the respective party might lose their share. This is possible when a method takes into account the critical path shift where maximum accuracy can be obtained. It has been observed from the table that only the techniques using window analysis can account critical path shift. These analyses include MIP 3.3, 3.4, 3.5, 3.7 and 3.9. A further discussion on these analysis will be made to choose the most appropriate one.



Next to account for the purpose of analysis for choosing the most appropriate technique. The purpose of analysis is as equally important as accuracy of apportionment.

ASPECTS	METHOD								
	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9
	PURPOSE OF ANALYSIS								
Non-Compensable time Extension for EOT	YES	YES	YES	YES	YES	YES	YES	YES	YES
Compensable Delay for EOT	YES	YES	YES	YES	YES			YES	YES
Constructive Acceleration for EOT			YES	YES		YES	YES		

An EOT claim can contain one or more of the following types of delay – Non Compensable time Extension, compensable delays and acceleration. An EPC contractor should be prepared all the purposes and thus this thesis would take the worst case scenario – i.e. all the three purposes can occur and will be accounted. When this is the case, MIP 3.3 and MIP 3.4 are the only ones that can satisfy all the purposes. Rest of the techniques are deficient in form or the other.



Both the MIP 3.3 and 3.4 solves all the purposes of analysis related to EOT. To perform these techniques one needs the schedule updates and according to CB&I, they perform schedule updates to their projects. Hence the source data to perform the technique is available. Both are identical methods and the difference is if MIP 3.4 is used one can easily identify the schedule slippage caused by non-progress revisions. If there are no non-progress revisions, MIP 3.4 cannot be performed and it is suggested to use MIP 3.3. The presence of non-progressive revisions depends from schedule to schedule. Hence the choice is to be made for the type of schedule present in the case. In this thesis, the schedule used in case study does not have any logic changes, hence MIP 3.4 cannot be performed and thus MIP 3.3 will be used.

Note: Even if the purpose of analysis is only non-compensable time extension where in which all the analysis techniques are capable of identifying, in my opinion, the MIP 3.3/3.4 is still the most appropriate technique to use. This is because, MIP 3.1 and 3.2 cannot account for the critical path shift and MIP 3.5, 3.6, 3.7, 3.8 and 3.9 are techniques that involve intervention and hence can be manipulated leading to unfair apportionment. Hence the reliability of the results in the other techniques is low compared to the MIP 3.3/3.4 technique.

4.6 Reliability of using the MIP 3.3/3.4

According to the Recommended Protocol, the reliability of the MIP 3.3/3.4 relies on two things:

Contemporaneous records

The schedules used for delay analysis is only for a reference to calculate the time, however the activities should be supported by contemporaneous records without which the reliability falls down dramatically. According to CB&I, they maintain a good record keeping. However, all the records should be validated before performing the analysis. If there are any missing records of any particular activities, it becomes void for delay analysis and any effects/impacts of that particular activity will be attributed to the contractor.

Date Constraints

According to the RP, if date constraints are used liberally analysis may be difficult. This is true as constraints tend to hinder schedule logic and disrupt the analysis and hence constraints should be avoided as far as possible. If in case constraints are present in the schedule, special attention is necessary to analyse at such events. This might need a separate analysis with the date constraints which might be time consuming and difficult to analyse.

4.7 Summary

Considering the accuracy, the availability source schedules and the worst case scenario of an EOT claim it is seen that the MIP 3.3 and MIP 3.4 are the most appropriate techniques for use by the EPC contractor.

However, due to the nature of schedule without non-progressive revisions in the case in chapter 6 MIP 3.4 cannot be performed and hence the MIP 3.3 will be used for this thesis. This is again limited to the legal requirements that should be foreseen before taking a decision on the possible technique. In the case I chose for this thesis (chapter 7), the contract does not have any contractual provisions that influences the choice of technique. Hence this thesis will be performed on the MIP 3.3 analysis technique and possible schedule quality improvements are discussed.

CHAPTER 5: THEORETICAL BACKGROUND ON BEST SCHEDULING PRACTICES

This chapter deals with the literature study of already existing schedule checks required for a quality and reliable scheduling practice.

This study will help in searching for new criteria for this thesis where one could build schedule with enough quality to increase the accuracy of the outcome of the forensic schedule analysis. Those new criteria will be identified and validated by considering a real schedule case in the successive chapters.

To conduct a literature study on existing schedule checks I considered a reference “GAO Schedule Assessment guide” published by Government Accountability Office (GAO). The GAO has identified that a well-planned schedule is a basic management tool that will help the government’s programs/facilities to use public funds in an effective way. And they made this guide to help them measure schedule variances in various programs in their governmental functions (Government Accountability Office, 2012). In addition, there is software called acumen where it uses the GAO checks to measure the quality of the schedule. And this software is used by many construction industries around the world (Acumen, 2013). Due to its widespread use around the world, I use this as a reliable reference for this thesis work. To increase the credibility of this research, the literature study of another well-structured schedule assessments checks called “Checks and Balances: Baseline Schedule Review” is considered (Ron Winter Consulting LLC , 2002). According to CB&I, they use Primavera as a scheduling tool. Thus this paper would add more value for this research. The following summarises the schedule quality checks from both the literatures and will be used as a reference for finding schedule quality from a forensic analysis perspective.

A high quality and reliable schedule has four characteristics – comprehensive, well-constructed, credible and controlled.

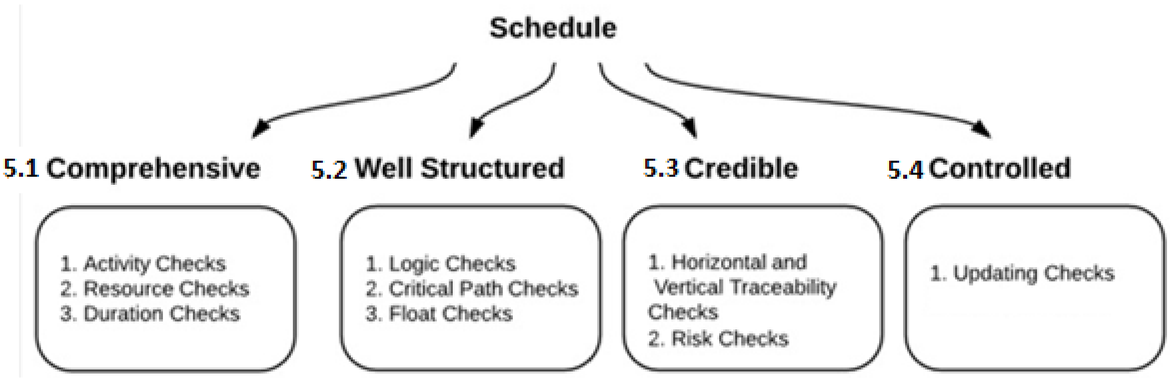


FIGURE 23: CHARACTERISTICS AND CHECKS FOR A SCHEDULE

Now each of these checks is summarised below. The checks from GAO are referred as ① and checks from Primavera conference paper are referred as ②.

5.1 COMPREHENSIVE SCHEDULE

As the name suggests, a comprehensive schedule covers all or nearly all the aspects of a schedule. It includes all the activities needed to fulfil the objectives of the project or the Work Breakdown Structure (WBS). It includes activities of both the owner and the contractor. The schedule is also resource allocated and depicts the needed labour, materials, overheads etc. Durations of each activity is also depicted to each activity that will allow one to measure progress of the activity. The following checks to be done to ensure a reliable and quality comprehensive schedule:

ACTIVITY CHECKS

- Check for activities with missing early and actual start dates (bogus dates). ②
- Review proper use of activity type. For e.g., task, independent activity, start milestone, finish milestone etc. ②①
- Check for total number of activities. Many contract documents specify the minimum and the maximum number of activities in a schedule to control the complexity of the schedule. ②
- Eliminate and correct any activities that have negative float. ②
- Check for early completion date. This means that the contractor is intended to complete before the actual date itself and it might incur costs for the owner. All negotiations should be done regarding this before the start of the project. ②
- Check for the percentage of critical and non-critical activities in the schedule. Typically, upper limit are 30% critical and 50% non-critical activities. ②
- Check for activity IDs. Only numeric Ids are often difficult to recognize. Professional schedulers normally tend to use alpha numeric activity IDs starting with an alphabet. ②
- Look for activity duration checks. Many contracts specific maximum or minimum limit for each individual activity. If the activity is very long, break down into smaller activities with short durations that can be measurable and qualifiable. ②
- Look out for suspicious remaining duration. Any unstarted activity will have original duration same as the remaining duration. In any case, the remaining duration should never be greater than the original duration. ②
- Look out for use of actual dates in the schedule (except for notice to proceed). Using actual dates obligates the contractor to perform within that date and can easily fall for poor performance. Look for missing activity description. This serves as the scope of work for that particular activity. ②
- Look out for Notice to proceed in the schedule. Most of the contracts run in concept of "time is the essence" that require a formal declaration of the start of the project. ②
- Look out for substantial completion. It should always be a milestone and should not bear any duration. Any confusion in this date will lead to legal proceedings for liquidated damages. ②
- Look out for beneficial occupancy date. It is the date where in which the owner can occupy a portion of the project even when the project is not completed. ②
- Check for activities with work percentages as title. This is poor scheduling method. Measuring by percentage is difficult. Instead the use of physical lengths is recommended. For e.g., "POUR FOUNDATION, 1-3 GRID LINE" is recommended than "POUR FOUNDATION, 30% GRIDLINE". ②
- Look for "REVIEW" or "APPROVE" activities. Both the review and approve activities are distinct activities and take time. Thus, can influence a schedule. Every review activity should be followed by an approve activity. Sometimes, there might be in need of submittal activity as well. ②
- Look out for Inspect activities. These activities also incur time and affect a schedule. ②
- Look for Utility activities. They are not under the control of neither the owner nor the contractor. They are done by third party persons. Any delay from such parties to the contractor must be compensable to the owner. ②
- Look for major material purchase and delivery. These have long-lead times and there is a lot uncertainty in such activities which can influence the schedule and such activities should be accounted in the schedule. ②
- Check on Temporary activities. Sometimes contractors propose temporary measures which are not allowable. ②
- Look for possible exceptional activities. Acceptance of the schedule with description of delays by an owner will make him accountable for those delays. There should be no room profanity in the schedules. ②
- Look for duplicate activity descriptions. They are confusing to track and many times unclear, thus should be eliminated. ②

- Look for milestones coded as activities (zero duration activities). These activities should either have duration or be coded as a milestone. ②
- Identify all the contractual milestones. Check for their presence in the contract document as well. ②
- Creating an activity histogram is recommended to create a layout of the number of activities in a period of time. 50% float activities is normally recommended. ②
- It is strongly recommended to use activity IDs that help in manage a schedule database. They are normally represented in alpha numerical with the first two letters defining the phase or work space of the project. ②
- Code definitions should be provided to check out legends and as reference in future. If one is not using this field, it is recommended to delete that portion to make the files smaller and less complex. ②
- Look out for activity IDs with blank descriptions. This occurs when codes are created in auto mode and sometimes the user gets a wrong code inserted for an activity. Identify such codes and put in the correct codes. ②
- Look out for activity IDs with duplicated descriptions. The duplicated description should be deleted and those respective codes should be updated. ②
- Look out for reserved words for Activity ID codes. Some softwares have reserved words which cannot be identified if those words are put in use. For eg, 1EF, BLNK, T1LF etc. might be reserved words for some particular software and when using such software these words shouldn't be used as activity IDs. ②
- Look out for unregistered activity IDs. Identify and validate all those unregistered IDs. ②
- Look for blank activity IDs. If no activity ID is used, then mention something like a 'N/A' so that one does not have gaps or empty spaces. ②
- Create an expanded activity ID field layout. This helps in listing all the codes, with descriptions and number of activities in each subcategory (grouping). This enables a user to identify any missing activities in the group. ②
- Identify all the activities in the WBS and check them with the baseline schedule for completeness. ②①
- Confirm that all WBS levels are fully defined and are not blank. Missing WBS definitions will lead to ambiguity and confusion. ②
- Check out whether all WBS acts are assisted with a WBS code. This helps to summarize all the activities with a similar WBS code. ②①
- It is recommended to have an expanded WBS field layout enlisting all the WBS fields, this descriptions and number of activities that fall into each category. This will help identifying any missing activities in a particular category. ②

RESOURCES CHECKS

- The amount of resources available at a point of time affects the work and its duration in the schedule. The resources include labour, equipment, machines, material, overhead etc. ①
- The schedule should realistically reflect the available resources that are needed to work. ①
- Once the resource is loaded in the schedule, check the total resources in the schedule is in accordance with the allocated budget and contractual cost constraints. ①
- Look for resource peaks as it may influence the project budget, availability of resource and the timeliness of each peak. Resource peaks are those points in the schedule where the demand for resources is abnormally inconsistent with respect to the points nearby. For eg, gathering 50 labourers one day and then gathering 120 labourers the other and 20 labourers the next day is erratic. Mobilizing incurs costs for each and every day. Thus use of resources should be consistent. The resources allocation should be levelled properly with minimum peaks. ①
- Check out for resource levelling and adjust corresponding resources①
- The activities that are levelled for resources levelling are the ones with greatest free float and least amount of resources are assigned for such activities①

- Sometimes, the resources in the critical path might delay causing conflicts and they should be thoroughly documented for later dispute resolution. Planners and managers should sit together to adjust resources between the critical path activities (high priority) and the float activities (low priority). ①
- During resource levelling, thorough documentation should be supported with the use of historical data.
- Check for resources specified and assigned to the activities and at what level these are performed (e.g. labour categories, individual names etc.) ①
- Check for significant material and equipment that are captured in the schedule. ①
- Look for potential difficulties in obtaining scarce resources①
- Develop a plan for resource deficiencies in critical situations. ①

Duration Checks

- Activity duration directly influence the resources and the estimated work required. ①
- Detailed activity durations are less than 2 months or 44 working days. ①
- Long duration constitutes months or even years. Long duration should be broken down to smaller durations for better workability with the schedule. If not practical to work with smaller durations, it should be supported by documentation. The maximum or minimum length of each activity is sometime mentioned in the contract. ①
- Very short duration such as one day scale make the schedule complex and make updating harder. However, this is the most recommended and used schedule in the construction industry. ①
- Level of Effort (LOE) activities are clearly marked in the schedule. Care should be taken that such activities do not appear in the critical path. They are scheduled as hammock or summary activities so that their durations are derived from other discrete activities. ①
- Consistency of unit should be maintained throughout the schedule. The same unit should be used throughout the schedule (for eg, days, months, weeks etc.). Days unit are normally recommended. ①
- Main assumptions for the duration of activities should be documented. ①
- All estimates of the duration should be supported by "normal conditions", not optimal or "successful" conditions, i.e the durations do not contain any buffer for risk. ①
- All durations of WBS elements should correspond to the cost estimates of the same WBS elements.
- Calendars are used to specify valid working times for resources and activities. ①
- Durations are also affected by constraints. List all the constraints and ensure only the constraints mentioned in the contract are used. Otherwise, the contractor can use constraints for reserving float which is typically not allowed. ②
- Identify and zero total float constraints. If there is special concern, verify the reasonableness of durations. ②
- Identify and zero free float constraints. If there is special concern, verify the reasonableness of durations. ②
- Identify active expected finish constraints. They compute remaining duration necessary to complete a certain activity. Review the durations for this criterion for reasonableness. ②
- Look for unstarted activities with expected finish constraints. This may attempt to artificially inflate the duration of an activity to use all available time. Expected finishes should not be left in the schedule without justification. ②
- Check for active mandatory constraints. Mandatory start or finish constraints completely override network logic and do not allow float calculations. Instead it is recommended to use START ON or START NOT EARLIER THAN (SNET) or START NO LATER THAN (SNLT) constraints. Mandatory start and finish constraints don't obey CPM rules. However, the use of START ON constraint not only works the same way as mandatory constraint but also obey CPM rules. SNET helps in float calculation in delay direction and SNLT allows float calculation in accelerate direction. ②①

- Look for active START ON constraints. They control the activity in both the forward and backward direction. Such constraints don't give flexibility in operations in changing conditions. Instead it is recommended to use SNET or SNLT constraints. ②

5.2 Well-constructed Schedule

A schedule is well-constructed when all of its activities are logically sequenced supported by the validity of the critical path and ensuring reasonable float. Complicated logic techniques are difficult to execute and its use should be minimum. Any such logic usage should be mentioned in the project documentation. The validity of the critical path helps in better allocation of resources and drives the project's early completion date. The identification of float helps the schedule to be flexible to work with. The following checks to be done to ensure a reliable and quality well-constructed schedule:

Logic Checks

- Check for non-overlapping lag relationships, i.e. check for lags or leads that are greater in duration than that of the activity duration. If the lag is too great, the activities will never overlap in time and the reason to use SS or FF relationship disappears. Investigate in converting such relationships to FS relationships. ②
- Look out for activities that have multiple logical relationships. Normally, SS, SF, FF, FS relationships are possible between activities. If one is using multiple relationships it is recommended only to use the pair of SS and FF. any other relationship combinations are unusual. ②
- Look out for start-finish relationships and confirm its intentional use and not as an entry error. Such kind of relationships is highly unusual. ②
- Check for logic open ends. Atleast one FS or SS predecessor and one FS or FF successor is required for each activity. This prevents logic open ends in the schedule network. ②①
- Look for activities logically after substantial completion. This might include activities like maintenance or punch list activities. These are important to satisfy the completion of the contract. Normally, a contractor is free from penalties after substantial completion. ②
- Look out for late activities not logically tied to substantial completion. These are activities that occur after substantial completion milestone. Care should be taken as large float in these activities might extend the completion of the project. ②
- Look out for activities prior to mobilization. If the contractor fails to mobilize resources on the agreed date, then the project experiences a bad start. ②
- Look out for activities before notice to proceed(NTP). No activity should be started by the contractor without the notice to proceed. Any such activities should be reviewed and postponed after the notice to proceed. ②
- Look out for early activities not logically tied to notice to proceed. Some activities might have missing predecessors and contractor might perform these activities before the NTP. Care should be taken not to start anything before the NTP. ②
- Look out for submittal activities without review activities. Every submittal activity should be followed by a review activity. Both take time and influence the schedule. The review activity should also be linked to a successor activity. ②
- Look out for multiple simultaneous near critical path activities. This induces owner caused delay to be the causal delay for the project. Owner should look out for such usage and justification should be done for usage of any such activities. ②
- Review any relationship that uses a lag other than zero and provide proper reasoning. ②
- Avoid the use of lags and leads by breaking into smaller tasks. ①
- If lags and leads are used judiciously by compelling reasons then it should be supported by schedule documentation. ①

- Verify except for the start and finish milestones every other activity has atleast one predecessor or atleast one successor. ②
- Any missing predecessor or successor is properly justified by documentation. ②①
- Verify that no activity in the schedule has dangling logic. Each activity (except start milestone) should have a FS or SS predecessor that drives the start date. Each activity(except finish milestone and deliverables) should have an FS or FF successor that it drives. ②
- Verify summary activities do not have logic relationships②
- SNET constraints are replaced by activities of third party vendor as actual activities if existed. ②

Critical path checks

Critical path is the most important segment of scheduling. All the important resources are given high priority to the critical path activities as they directly influence the finishing date of the project. Performing checks on the critical path is highly recommended for a good quality schedule. The foremost check of a schedule is to validate the critical path. This can be done by:

- Does not have LOE activities, summary activities or other unusually long activities. ①
- Verify the continuity of the path from status date till major completion milestone. ①
- Check that the activities of the critical path do not have any constraints so that other activities are unimportant in driving the schedule. ①
- Verify whether any lag or lead is not influencing the critical path. ①
- Verify the derivation of summary schedules by vertical integration of lower level detailed schedules. ①
- Management shall justify and validate the current critical path calculated by the software①
- Validate the influence of critical path on key milestones and deliverables. ①
- Examine and mitigate any risks in the activities that can delay the key milestones or deliverables. ①
- Review and analyse near critical path activities as this might overtake the existing critical path and influence the schedule. ①
- Recognize not only the lowest float activities but also those that are truly driving the finish date of key milestones. ①
- Evaluate the critical path before the schedule is baselined and validate it after every schedule update. ①

Float checks

Total float of the schedule influences its flexibility. Thus it is an important criteria that drive the quality of the schedule. The following are a series of float checks:

- The remaining activities other than the ones in the critical path are sorted by total float and assessed for reasonableness. Look for missing logic and rectify for activities that are sorted by total float. ①
- Excessive total float value activities are documented. ①
- Calculate total float values for main deliverables or milestones including the project finish milestone①
- If schedule slips, verify and validate any reassigning of resources for free or total float activities①
- Balance the use of float keeping in mind that the total float is shared among a path of activities. ①
- Constantly verify the amount of float left for critical and near critical activities in periodic reports. ①
- Justify negative floats caused by date constraints. Evaluate and implement any mitigations taken for a delay that is significant. ①

5.3 Credible Schedule

A schedule is said to be credible when it is convincing and reliable. A credible schedule is one which is horizontally traceable, vertically traceable and risk analysis is performed. Horizontal traceability reflects the order of required activities to achieve the outcomes. Vertical traceability reflects the activities in various levels of the schedule map. This includes the summary and the detailed activities. The risk analysis predicts the risks and opportunities that induce the level of confidence of the project schedule. The following checks to be done to ensure a reliable and quality credible schedule:

HORIZONTAL AND VERTICAL TRACEABILITY CHECKS

- The horizontal traceability ensures proper logical relationships between program elements and clearly shows major deliverables. The following checks have to be made for horizontal traceability: ①
    - Check for complete logic from program start to finish
    - Check for the integrity of the schedule with the entire scope of work
    - Check for key milestones for deliverables.
    - Validate each milestone with a traceable predecessor to ensure the completing milestone.
    - Clearly identify and logically link 'giver/receiver' milestones between schedules. Support them with documentation
    - Check for dynamical reforecast of milestone for delayed activities.
- Vertical traceability demonstrates that data are consistent between summary, intermediate and detailed levels of schedule, including dates. The following checks have to be made for vertical traceability: ①
    - Check the schedule to allow activity owner to trace activities to higher level milestones wih intermediate and summary schedules.
    - Check the schedule for lower level schedules to be rolled up into overall program schedule that includes the owner's, contractor's activities and the interfaces with external parties.

RISK ANALYSIS CHECKS

- A schedule Risk Analysis (SRA) is conducted to determine the likelihood of project completion. In addition it is also helpful to identify risks that are likely to delay a project and their respective contingency. ①
- Asses the schedules against the best practices and then depending on the situation, conduct SRA. ①
- Account for correlation and uncertainty of activity durations. ①
- Prioritise risks by probability and impact. ①
- Identify risk factors through risk register①
- Document SRA data and methodology①
- Identify activities in critical and near critical activities to closely monitor them①
- Validate risk inputs①
- Periodically perform SRA on the schedule to increase the confidence level of the user. ①

5.4 CONTROLLED SCHEDULE

A schedule is said to be controlled if it is periodically updated by professional schedulers using actual progress and logic to realistically forecast dates for program activities. It helps in measuring, monitoring and reporting project progress in correspondence to the actual baseline schedule. The baseline schedule is assisted by documentation which mentions the overall approach of the project, ground rules, assumptions and unique features of the schedule. The following checks to be done to ensure a reliable and quality controlled schedule:

UPDATING CHECKS

- Schedule progress is recorded and monitored using constant updates of the progress of the project. schedule status is updated with the actual and the remaining progress①
- All the updates are dependent on progress records for a time period which includes name, unique ID, original and remaining duration, planned and actual start and finish dates and float. A series of checks are necessary for quality updating of schedules. ①
- The status date is recorded or the latest update. ①
- No activities precede the status date without actual start or finish dates and actual effort up to the status date. ①

- Asses the activities that are behind the status date for any delay that is significant and review resources that may be reassigned depending on the schedule progress①
- Document changes made to the schedule during an update①
- Review new activities for completeness of predecessor and successor logic. ①
- Review schedule updates and verify and assess effects on plan. Significant changes are documented and understood. ①
- Examine schedule structure after each update to ensure that logic is not missing, all data constraints are necessary and no artifacts impede the ability of the schedule to dynamically forecast dates. ①
- Assign a version number for the schedule update for better documentation①
- Include the status of the key milestone dates including the project finish date①
- Include the status of key hand-offs or giver/receiver dates①
- Include explanations for any changes in key dates①
- Include changes in network logic with lags, date constraints, relationship logic and their effect on schedule. ①
- Include a description of critical paths, near critical paths, longest paths with the comparison of the previous paths①
- Include any software options that have changed from the previous update①

5.5 Summary

The schedule quality checks summarised above will the basis of reference to find improvements in schedule quality from a forensic analysis perspective in the later stages of this thesis.

CHAPTER 6: REAL CASE PRESENTATION

This chapter would present a real case of a project. The reason for selecting this case is because it is a typical case in the company where it has undergone a schedule analysis. A real case is chosen because the recommendations concluded can be used in the practical EPC industry. This case will be used in successive chapters to perform the forensic schedule analysis concluded in literature study. This case is also used to identify improvements for any new scheduling checks that are necessary in the forensic analysis point of view.

Since EPC projects are vast in size, and normally with hundreds of activities, only a particular section is taken out from the original schedule to perform the case study evaluation. This small schedule is qualified for validation of this thesis as one can still measure the statistical variance using the forensic analysis and the schedule quality criteria. Due to the confidentiality of the data, all the components are renamed and suited for academic purpose of this thesis. The validation of schedule quality is performed only on one case due to limited time.

This chapter explains about the plot plan of the project, the schedule narrative about the initial planning, the scope of work and their respective records in a week wise manner.

6.1 PROJECT DOCUMENTATION

The figure 24, gives an overview of the plot plan of a chemical plant. The plot consists of two structures-1 and 2, 6 columns – C21, C41, C45, C22, C31 and C34, one compressor house and a pipe rack that runs through the middle of the plot which is subdivided into the north and the south Pipe Rack.

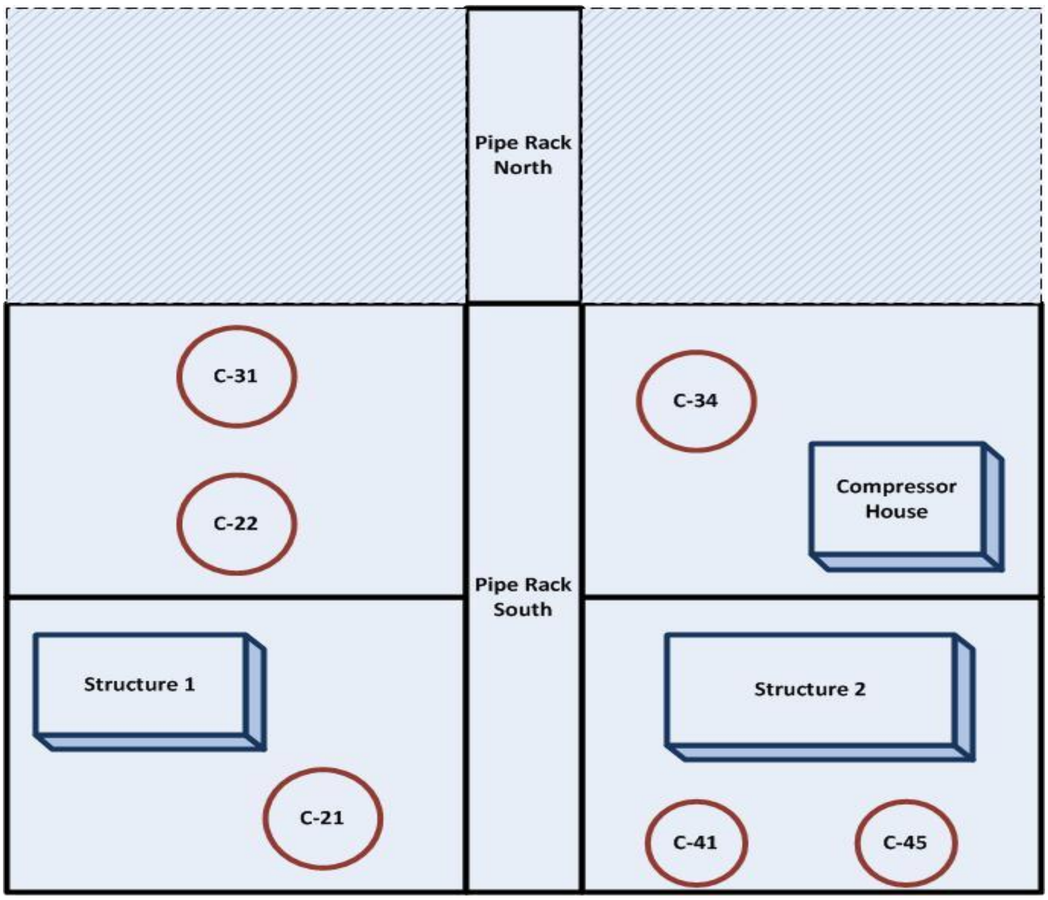


FIGURE 24: PLOT PLAN

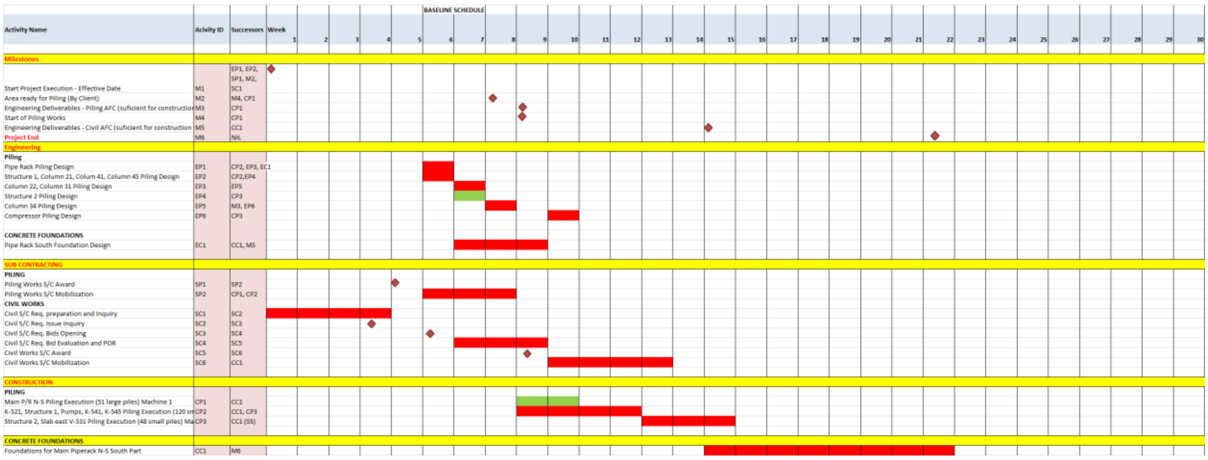


FIGURE 25: BASELINE SCHEDULE

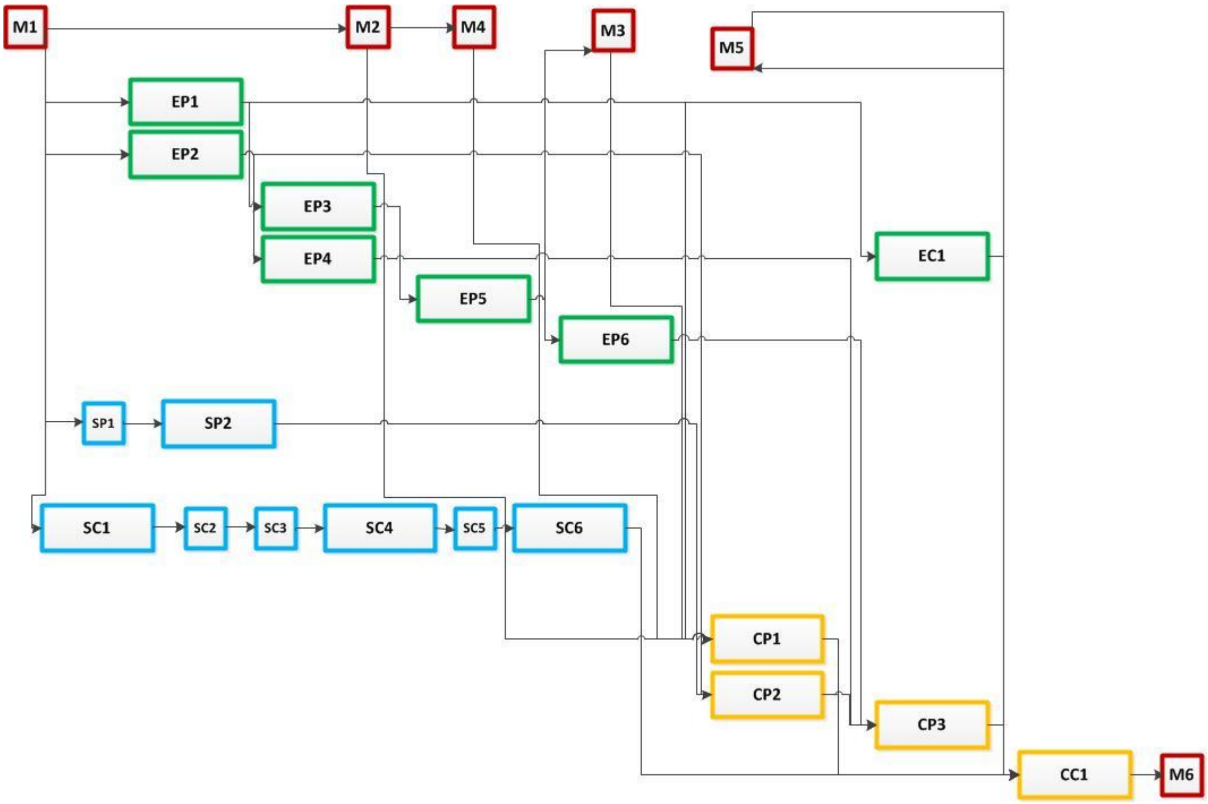


FIGURE 26: RELATIONSHIP DIAGRAM

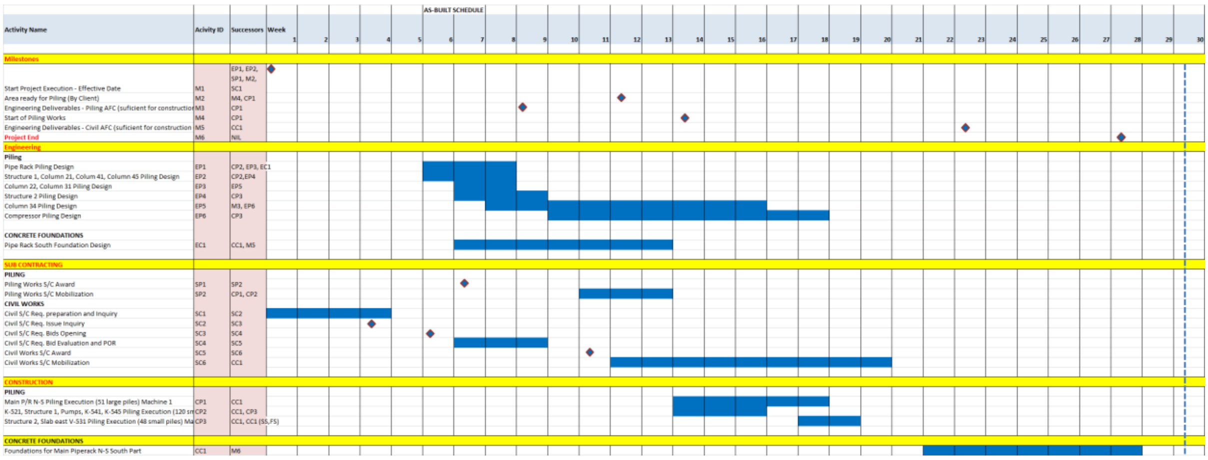


FIGURE 27: AS-BUILT SCHEDULE

The figure 25 shows the baseline schedule of how the original schedule was planned for the project. All critical activities are represented in red blocks and all non -critical activities are represented in green. The diamond shaped ones are milestones. The figure 27 shows the as-built schedule.

And the Figure 26 shows the relationship between different activities. The maroon color blocks represent milestones, green blocks represent engineering activities, blue blocks represent sub-contracting activities and yellow blocks represent construction activities. A reference of the successors of each activity is also provided in the baseline schedule for better understanding. The use of so many relationships and increasing complexity is to suit the projects goals at the shortest time possible using concurrent activities. All the schedules are obtained as it is from the project files of CB&I. According to CB&I, these schedules are created using Primavera P6.

6.2 Schedule Narrative

Scope of Work Definition:

Contractor is responsible for EPC (Engineering-Procurement-Construction) activities of a chemical unit. The project shall kick off on week 1.

The contractor is responsible for all designs of the chemical unit (piling and foundation engineering designs). The contractor will also provide the owner construction management services and support the owner to place bids, prepare enquiries, evaluating bids, select the best subcontractor etc. on the site. The owner will award the construction sub-contracts (S/C), i.e. all the responsibility of the sub-contract award will be for the owner and the contractor will only assist.

Schedule Strategies:

In the initial phase of the project, the contractor will assist the owner in awarding the piling and civil sub-contracts (S/C). Piling subcontract shall be awarded by the client on week 5, after which the contractors shall need 3 weeks' time to mobilise. The civil subcontract preparation shall start on week 1, aiming to award the civil subcontract (by the client) on week 9, after which the contractor shall need 4 weeks to mobilise at site. Construction works are supposed to start after the completion of the site preparation & underground (U/G) works (to be executed by Client), i.e. the area should be made ready (by owner) on week 8 for construction.

Concurrently the contractor will start its engineering phase (piling designs) in week 6. After the release of the first piling design AFC (Approved for Construction) documents, the contractor shall hand over them to the piling subcontractor to start construction activities for piling.

The foundation design activities shall start on week 7 after the piling design activities. After the release of the first foundation design AFC (Approved for Construction) documents, the contractor will hand over them to the civil subcontractor to start civil construction activities.

For both the piling and civil works, priority is given to the pipe rack in the middle of the plot plan and then to the structures surrounding it. The constructability of the project focuses on south to north approach to the execution of the work.

The start of construction activities on site is mainly dependent on the date when the owner makes the area ready for construction, on availability of sufficient engineering deliverables and on the piling and the civil sub-contractors' effective mobilization. Any delay in any of these related activities/milestones can cause a delay in the completion of the project.

The schedule ends with the activity of the completion of pipe rack foundation in week 22. The reason to choose this activity as end point for schedule is for two reasons. One is because the main pipe rack foundation is crucial for any further work in the area of the plot plan. The other is to make the evaluation of the forensic analysis feasible. As such, this portion of work will constitute the basis of this case study.

The completion of this portion of the project is scheduled in the baseline to be completed in week 22.

6.3 Project Records

The table below summarizes all the relevant information of the project records, outlining the events that occurred during the project.

TABLE 6: PROJECT RECORDS

Week	Contractor's records	Owner's Records
1	The project has started with the effective date in week 1. Civil S/C Inquiry has also started in the same week. No Piling Preparation or enquiry is performed by contractor as owner has already performed it and did not seek assistance.	Contractor has started the project in week 1 by starting preparations to assist us in selection of Civil S/C Self-performed Piling S/C enquiry.
2	Civil S/C preparation inquiry in progress	Civil S/C preparation inquiry in progress
3	Civil S/C preparation inquiry in progress	Civil S/C preparation inquiry in progress
4	Preparation for civil S/C inquiry has been completed. An inquiry has been issued to various civil S/C	inquiry to various civil sub-contractors issued
5	Piling S/C was not awarded yet and can cause delay in the construction activities.	Piling S/C selected. But not awarded officially still.
6	EP1 and EP2 piling design started as planned and also issued. However, drawings required revision for changes in reinforcement from request of Piling S/C. Thus piling drawings have to be reissued. Start of piling construction might get affected. Bids have been opened for Civil S/C to apply	Contractor did not give good piling designs. Revisions requested by piling S/C. Bids for Civil S/C opened by contractor.
7	EP3 and EP4 piling design started as planned and also issued. However, drawings required revision for changes in reinforcement from the request of Piling S/C. EC1 foundation design started as planned. Civil S/C Bids started evaluation.	Officially awarded Piling S/C to start piling in week 12. Many designs needed revisions from contractor.

	Piling S/C award done by client with 2 weeks delay without contractor involvement. Contract with Piling S/C was signed such a way that the first pile construction will start in week 12.	
8	EP1, EP2 and EP3 piling design completed revision. EP4 piling design still on revision. EP5 piling design started as planned. A change order was given by client for the compressor house. Need more time for feasibility study and then implement. This affects EP6 piling design and also has impact on EP5 and cannot be issued on time for Engineering deliverables milestone next week. Civil S/C evaluation in progress. Piling S/C not started mobilisation No information received regarding area ready by client.	Piling S/C got EP1, EP2 and EP3 piling design. EP4 still is pending. Change Order given for contractor on time. Thus activities shouldn't be affected. However contractor asked for extra time to conduct feasibility study first and then go for design. This will affect the engineering deliverables and start for construction. Contractor didn't ask for area to be ready. Hence no information given.
9	EP4 piling design completed revision. EP1, EP2, EP3 and EP4 are submitted as engineering deliverables sufficient for construction for piling S/C to start. EP5 was not submitted due to change order. EC1 foundation design not finished as planned, undergoing delays due insufficient manpower of contractor. Civil S/C evaluation completed. However, client has not issued Civil S/C Award. Construction activities which should have started delayed as first pile from Piling S/C is on week 12. However, Piling S/C not started Mobilisation	Contractor did not give all the piling design deliverables promised. Foundation design also delayed, noticed as insufficient manpower.
10	EP5 piling design still running on delays due to the impact of change order. EP6 piling design started as planned but not completed due change order for compressor from client. EC1 foundation design running on delays. No information received regarding area ready by client. Construction cannot start without it. Civil S/C still not awarded by client causing delay in their mobilisation.	EP5 and EP6 piling design on delays. Notice is referred to change order. EC1 foundation design still on delays.
11	EP5 and EP6 piling designs on delays due to change order. EC1 foundation design still on delays. Piling S/C started mobilisation with 5 week delay. LOI issued by client mentioning Civil S/C will start first construction on week 15. Civil S/C awarded by client without contractor involvement with 2 weeks delay. Civil S/C was informed about Piling S/C delay.	Civil S/C officially awarded. Letter of Intent given to contractor regarding civil S/C. EP5, EP6 and EC1 on delays.
12	EP5, EP6 piling designs and EC1 foundation designs still on delays. Civil S/C started mobilisation.	Notice given to contractor for area ready for piling. However, Piling S/C mobilisation is causing a delay.

	Area ready by client with 4 weeks delay. First pile construction should have started, but Piling S/C has not mobilised yet.	
13	EP5 and EP6 piling design on delays. EC1 foundation design completed with 4 weeks delay. Civil S/C mobilization did not complete as planned, having delays due to Piling S/C.	EC1 foundation design completed having high impact on project completion. Piling Designs EP5 and EP6 still not complete.
14	EP5 and EP6 piling design still with delays. Piling S/C mobilization complete. Started first piling activity with 5 weeks delay. Thus, CP1 and CP2 piling construction started with 5 weeks delay. Civil S/C mobilization not complete.	Piling S/C completed mobilization and started CP1 and CP2 piling construction.
15	EP5 and EP6 piling design having delays. Engineering deliverables got delayed due to insufficient man power. Civil S/C mobilization not complete and did not start the first foundation construction as promised. This is due to the late start of piling construction activity. CP1 And CP2 piling construction progressing.	Civil S/C creating delays in mobilisation. Noticed because of Piling construction works going on. Piling Designs EP5 and EP6 on delays.
16	EP5 piling design completed with 8 weeks delay. Civil S/C mobilization not complete CP1 piling construction completed with 6 week delay. CP2 piling construction progressing.	Ep5 completed with 8 weeks delay. Engineering deliverables supplied after 7 weeks.
17	Civil S/C mobilization not complete CP2 piling construction having delays. Engineering Deliverables – foundation further delayed due to manpower insufficiency.	Foundation engineering deliverables still not supplied, causing more delays in project. However, EC1 foundation design was supplied as sufficient for construction.
18	EP6 piling design completed with 6 weeks delay. CP2 piling construction completed with 7 weeks delay. CP3 piling construction started. CC1 foundation construction could have been started. However, Civil S/C mobilization not complete	Civil S/C making delays and did not start first foundation construction; inspite the piling construction is complete.
19	Civil S/C mobilization not complete CP3 piling construction completed.	Piling S/C finished his piling construction activities.
20	Civil S/C mobilization completed with 7 weeks delay from baseline. However CC1 foundation construction still didn't start for construction though sufficient designs were issued for construction to start.	Civil S/C finally mobilised in site after 5 weeks delay from award.
21	CC1 foundation construction started with 7 week delay.	CC1 foundation construction started
22	CC1 foundation construction progressing	CC1 foundation construction progressing
23	CC1 foundation construction progressing Complete foundation Engineering deliverables given with 3 weeks delay.	All engineering deliverables for foundation design given after 8 weeks delay.
24	CC1 foundation construction progressing	CC1 foundation construction progressing
25	CC1 foundation construction progressing	CC1 foundation construction progressing

26	CC1 foundation construction progressing	CC1 foundation construction progressing
27	CC1 foundation construction progressing	CC1 foundation construction progressing
28	CC1 foundation construction completed with 6 weeks delay.	CC1 foundation construction completed with 6 weeks delay

6.4 SUMMARY OF THE CASE

The project was baselined to be completed on week 22. But ultimately it was completed on week 28 with 6 weeks delay. The following are individual delays that are collectively responsible for the whole project delay of 6 weeks.

- Piling S/C award was delayed by 2 weeks.
- Piling S/C first started their construction with 5 weeks delay.
- Civil S/C award was delayed by 2 weeks.
- Civil S/C first started their construction with 7 weeks delay.
- Client made the area available for construction with 4 weeks delay.
- Foundation Engineering Deliverables delayed by 8 weeks by contractor insufficient manpower.
- Though sufficient piling engineering deliverables are given (due to revisions and change orders), the actual deliverables were delayed by 8 weeks.

Observing all the records of events and corresponding delays by respective parties, it is of great ambiguity to decide who caused the project delay of 6 weeks. This is where the forensic analysis would come into play to evaluate and apportion delays between parties, to find out the responsible party for those delays. The next chapter would deal with the step by step apportioning of delays.

CHAPTER 7: APPORTIONING DELAYS

This chapter will go through the forensic analysis of the case model presented in the previous section.

Before performing the forensic analysis, first we need to validate a delay according to causal of delay and notices issued. For that, one needs to know the scenarios before and during the project. And only then we progress to the forensic analysis. The scenarios presented are factual data of the project obtained from the CB&I. At the end of the section, the number of delays each party is responsible is obtained. The schedules, records and forensic analysis are studied and new scheduling checks are identified in the next chapter. These checks are analysed and recommendations are concluded in the successive chapters to improve the entitlement of an EPC contractor.

This chapter goes through two sections of analysis. The first analysis is performed with impacted as planned analysis. This analysis method is chosen because; the EPC contractor chose this method in real time to deal the dispute with the owner. After that, the MIP 3.3 analysis technique is performed, as this is the technique concluded as the EPC contractors' most appropriate technique. The validation is performed by analysing difference between the two analyses techniques and is concluded at the end of chapter.

7.1 DELAY VALIDATION:

A validation of a delay in a construction project is a process. It involves the contractual conditions and notices issued and are explaied below.

CONTRACTUAL CONDITIONS OF DELAYS AND SCHEDULE:

The following contractual conditions of contract are taken from the original contract of the case study project. Only the relevant clauses for the thesis are explained below:

Law:

- The validity, interpretation and implementation of the Contract shall be governed by and construed in all respects in accordance with the UK English Law.

Delays:

- The contractor is obligated to notify the client for the delays occurring in the project without which the contractor will be responsible for those delays.
- Any delay in the completion date of the project shall make the contractor liable for liquidated damages.
- For qualifying for a delay claim, the contactor is obligated to notify a delay at the latest but not more than 28 days with the cause and impact of the delay. And then within 42 days the contractor is qualified for filing a claim for that delay.

Schedule:

- The baseline schedule is obligated to be done in Critical Path Method(CPM). The baseline level 3 schedule is created by the contractor and approved by the client/owner. Both the hardcopy and the soft copy should be handed over to the client. The baseline is allowed to be submitted at week 12 with works starting from week 1. This means the client will sign the baseline at week 12, but approving the events from week 1. This is because, the creation of baseline schedule takes time and work should not be affected till the baseline is created. However, the calculation of Liquidated damages (LD) will be from week1, as the client will approve and validate the baseline from week1.

- The baseline shall show the critical path. This consists of the critical path activities and the near critical path activities, both categorized as critical path activities for the project. The condition for calculation of critical path in the primavera software is by total float calculation with a value equal or less than 5 days(~1 week). This means all the paths having a total float equal or less than 5 will be critical. This is because, the project runs over a period of 2 years and an approximation of 5 days is taken to highlight the critical activities.
- The use of constraints such as “early start dates” to be kept absolutely minimum. Constraints like “Must Finish/ Must start” shall never be used, unless and until agreed with the owner. The use of lags, start to start, finish to finish shall be minimum as much as possible. Finish to start relationships shall be used preferably. The durations shall be expressed in working days.
- Schedule shall be built with sufficient detailing with activity duration not longer than 1 to 2 months.
- Along with the baseline, the contractor is obligated to create updates to show the progress schedule and the happenings of the project to the client. The first update was issued to the client in week 13 with the first 3 months together as first update. Thereafter, updates are created and approved on a monthly basis.

LIABILITIES OF DELAY:

The events happened during the project are summarized in the previous section. This section deals only with the events w.r.t to the validation of the delay. First, the liability of delay is categorized by the causal of the delay and the notices provided to the client. With the help of the project records, the data below are collected. Please note that the subcontractor events are also regarded to the owner. Hence for both the owner and subcontractor events, it is labelled as owner in the following part of the thesis. Only a few activities are shown below for the understanding of the reader. The detailed table is referred in the appendix.

Validity of Delay matrix:

TABLE 7: LIABILITY MATRIX

Activity Delayed by	Notice Given	Delay Liability
Contractor Activity	YES	CONTRACTOR
Contractor Activity	NO	CONTRACTOR
Owner Activity	YES	OWNER
Owner Activity	NO	CONTRACTOR

With the help of the matrix, the liability of a delay event is formulated below:

TABLE 8: DELAY LIABILITY BASED ON LIABILITY MATRIX

Activities	Activity ID	Delay	Cause	Notice	Liability
Pipe Rack Piling Design	EP1	YES	Contractor	NO	Contractor
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	YES	Contractor	NO	Contractor
Column 22, Column 31 Piling Design	EP3	YES	Contractor	NO	Contractor
Structure 2 Piling Design	EP4	YES	Contractor	NO	Contractor
Column 34 Piling Design	EP5	YES	OWNER	YES	OWNER
Compressor Piling Design	EP6	YES	OWNER	YES	OWNER

7.2 Analysis 1: impacted As-Planned

As summarized in the last chapter, many delays were caused by many parties. But the project was only delayed by 6 weeks. Below is the negotiation process that led to the choice of analysis.

Negotiation Process:

- When there are delays (created both by client and the contractor) identified in the project, CB&I (contractor) notified it to the client. This process took place with the exchange of letters and formal notices.
- Then, the impact of these delays with the project finish date is studied.
- As soon as the impact was noted on the project completion date, it was notified it to the client.
- Then the client ordered the contractor for any acceleration that is possible to meet the finish date.
- However, the contractor did not find any possibilities of mitigating those delays and notified that the delay of the project was evident.
- Since the delay of the project would impose liquidated damages on the contractor, they filed a claim with the client for extension of time to remove liquidated damages. This was supported with a report show casing all the delays, its impact on project completion date and corresponding notices issued.
- This report was considered by the client and decided to negotiate on the Extension of time that can be granted to the contractor. These negotiations were conducted on the basis of contract by the upper management of both parties.
- During the negotiation process, there was blame game witnessed by both the parties and the exact number of delays responsible by each party was the focus of negotiation.
- At this time, the contractor proposed the impacted as planned technique where the contractor and owner caused delays on the project can be explicitly analyzed and then the Extension of time can be granted. The contractor managed to convince the owner on the method.
- Considering the claim in to consideration, the EOT is considered for events occurred till the end of week 28 of the as-planned schedule.

Analysis:

The impacted as-planned analysis is performed by entering the contractor and owner's delays separately in the as-planned schedule and seeing the impact of project delay. The detailed analysis on how it is performed can be referred in the appendix.

As a result of this analysis, both the owner and contractor are responsible for 6 weeks of concurrent delay. According to the UK English law, when the contractor's delay to completion occurs concurrently with the employer's delay to completion, the contractor's concurrent delay should not reduce any EOT due. Thus, the EOT due by the owner is 6 weeks. In this analysis method, the share of delay is 50:50 share between the client and owner.

In my opinion, the dispute was not resolved in an accurate manner. The main flaw in this dispute resolution is the use of impacted as planned analysis. The use of impacted as planned analysis is not recommended in literature study of forensic schedule analysis as it is not accurate. From literature study, it is suggested for the EPC contractor to use the MIP 3.3 observational window analysis method to get an accurate apportion of the delays. The next section will perform the MIP 3.3 method of schedule analysis.

7.3 Analysis 2: MIP 3.3 Analysis Technique

The following is the MIP 3.3 analysis method performed for the same dispute claim. The monthly updates are used as discrete windows and net delays are calculated at the end of each window. This would help in fair apportioning of delays by considering the dynamic nature of the critical path. An example of how it is performed is shown below for one window. The detailed analysis can be referred in the appendix.

The schedule observed 5 updates being created. Thus each of these updates is treated as separate window. The following is a table representing the windows and their corresponding weeks:

TABLE 9: WINDOWS TABLE

Window	Window Period	Schedule at Window Start	Schedule at Window End
1	Weeks 1 to 13	Baseline (As-Planned Schedule)	Update 1
2	Weeks 14 to 18	Update 1	Update 2
3	Weeks 19 to 22	Update 2	Update 3
4	Weeks 23 to 26	Update 3	Update 4
5	Weeks 27 to 31	Update 4	As-Built Schedule (Update 5)

WINDOW 1

Let us start the analysis with window 1. Here we observe two schedules – as planned schedule and the update 1 schedule.

BASELINE SCHEDULE

Activity Name	Acivity ID	Original Duration	Remaining Duration	Total Float	Successors
Milestones					
Start Project Execution - Effective Date	M1	0	0	0	EP1, EP2, SP1, M2, SC1
Area ready for Piling (By Client)	M2	0	0	0	M4, CP1
Engineering Deliverables - Piling AFC (suficient for construction Constractors to Start)	M3	0	0	0	CP1
Start of Piling Works	M4	0	0	0	CP1
Engineering Deliverables - Civil AFC (suficient for construction Constractors to Start)	M5	0	0	0	CC1
Project End	M6	0	0	0	NIL
Engineering					
Piling					
Pipe Rack Piling Design	EP1	1	1	0	CP2, EP3, EC1
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	1	1	0	CP2,EP4
Column 22, Column 31 Piling Design	EP3	1	1	0	EP5
Structure 2 Piling Design	EP4	1	1	3	CP3
Column 34 Piling Design	EP5	1	1	0	M3, EP6
Compressor Piling Design	EP6	1	1	0	CP3
CONCRETE FOUNDATIONS					
Pipe Rack South Foundation Design	EC1	3	3	0	CC1, M5
SUB CONTRACTING					
PILING					
Piling Works S/C Award	SP1	0	0	0	SP2
Piling Works S/C Mobilization	SP2	3	3	0	CP1, CP2
CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	4	4	0	SC2
Civil S/C Req. Issue Inquiry	SC2	0	0	0	SC3
Civil S/C Req. Bids Opening	SC3	0	0	0	SC4
Civil S/C Req. Bid Evaluation and POR	SC4	3	3	0	SC5
Civil Works S/C Award	SC5	0	0	0	SC6
Civil Works S/C Mobilization	SC6	4	4	0	CC1
CONSTRUCTION					
PILING					
Main P/R N-S Piling Execution (51 large piles) Machine 1	CP1	2	2	4	CC1
K-521, Structure 1, Pumps, K-541, K-545 Piling Execution (120 small piles) Machine 2	CP2	4	4	0	CC1, CP3
Structure 2, Slab east V-531 Piling Execution (48 small piles) Machine 2	CP3	3	3	0	CC1 (SS)
CONCRETE FOUNDATIONS					
Foundations for Main Piperack N-S South Part	CC1	8	8	0	M6

Week 1–30

FIGURE 28: AS PLANNED SCHEDULE

Activity Name	Acivity ID	Original Duration	Remaining Duration	Total Float	Successors
Milestones					
Start Project Execution - Effective Date	M1	0	0		EP1, EP2, SP1, M2, SC1
Area ready for Piling (By Client)	M2	0	0		M4, CP1
Engineering Deliverables - Piling AFC (suficient for construction Constractors to Start)	M3	0	0		CP1
Start of Piling Works	M4	0	0	0	CP1
Engineering Deliverables - Civil AFC (suficient for construction Constractors to Start)	M5	0	0	0	CC1
Project End	M6	0	0		NIL
Engineering					
Piling					
Pipe Rack Piling Design	EP1	1	0		CP2, EP3, EC1
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	1	0		CP2,EP4
Column 22, Column 31 Piling Design	EP3	1	0		EP5
Structure 2 Piling Design	EP4	1	0		CP3
Column 34 Piling Design	EP5	1	1	0	M3, EP6
Compressor Piling Design	EP6	1	4	0	CP3
CONCRETE FOUNDATIONS					
Pipe Rack South Foundation Design	EC1				CC1, M5
SUB CONTRACTING					
PILING					
Piling Works S/C Award	SP1	0	0		SP2
Piling Works S/C Mobilization	SP2	3	0		CP1, CP2
CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	4	0		SC2
Civil S/C Req. Issue Inquiry	SC2	0	0		SC3
Civil S/C Req. Bids Opening	SC3	0	0		SC4
Civil S/C Req. Bid Evaluation and POR	SC4	3	0		SC5
Civil Works S/C Award	SC5	0	0		SC6
Civil Works S/C Mobilization	SC6	4	6	0	CC1
CONSTRUCTION					
PILING					
Main P/R N-S Piling Execution (51 large piles) Machine 1	CP1	2	3	4	CC1
K-521, Structure 1, Pumps, K-541, K-545 Piling Execution (120 small piles) Machine 2	CP2	4	5	0	CC1, CP3
Structure 2, Slab east V-531 Piling Execution (48 small piles) Machine 2	CP3	3	3	0	CC1
CONCRETE FOUNDATIONS					
Foundations for Main Piperack N-S South Part	CC1	8	8	0	M6

FIGURE 29: UPDATE 1

For apportioning the delays, the two windows are compared. All the activities are tabulated and the corresponding activity variance (activity delay) and the project delay are calculated. This will enable us to see the progress of the project delay with each activity delay occurring in the project. At the end of the table, the net delay is noted.

The numbers ending with 'a' are denoted as actual data dates. The activities where delays are occurring at the same time are concurrent delays and those delays are represented by ending activity variance number with "(c)". These concurrent delays have a combined effect on the total project delay.

The notes column in the table defines whether a activity has delays (or savings) experienced by a critical activity. The following are used: STE (Slower than Expected) and BTE (Better than Expected)

For each activity, the activity variance (activity delay) is calculated in one column, to which if there is an impact of the project complete, the delay of project is calculated in the next column. Likewise, all the activities are tabulated below:

TABLE 10: WINDOW 1 FORENSIC ANALYSIS

ID	Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
		Planned Start	Planned Finish	Revised Start	Revised Finish				
Window 1 (Baseline and Update 1)									
M1	Project Start	1		1a		0	0	22	As-Planned
SC1	Civil S/C Prep	1	4	1a	4a	0	0	22	As-Planned
SC2	Civil S/C Issue	4		4a		0	0	22	As-Planned
SP1	Piling S/C Award	5		7a		2	2	24	STE
EP1	p/r Pil Design	6	6	6a	8a	2	0	24	STE
EP2	Struc-1 Piling Design	6	6	6a	8a	2	0	24	STE
SC3	Civil S/C open bid	6		6a		0	0	24	As-Planned
SP2	Pil. S/C Mob.	6	8	11a	13	3(5-2)	3(c)	27	STE, sequential delay
EP3	C-22 Pil Design	7	7	7a	8a	1	0	27	STE
EC1	P/R Found Design	7	9	7	13	4	4(c)	27	STE
SC4	Civil S/C Eval	7	9	7a	9a	0	0	27	STE
M2	Area by client	8		12a		4	4(c)	27	STE
EP5	C-34 Pil	8	8	8a	14	6	0	27	STE

	Design								
M3	Piling AFC	9		9a		0	0	27	STE
M4	Stat Pil	9		14		5	0	27	STE
SC5	Civ S/C award	9		11a		2	2(c)	27	STE
CP2	Struc-1 Pil const	9	12	14	18	5	0	27	STE
EP6	Comp pil design	10	10	10a	17	5(7-2)	5(c)	27	STE, sequential delay
SC6	Civil s/c mob	10	13	12	19	6	5(c), 1	28	STE
CP3	Comp. piling	13	15	18	20	5	0	28	STE
						Window 1 Net Delays	6	28	

Piling Design EP4 was not considered in the analysis, as it has float and not impacting the project finish. The piling designs EP1, EP2, EP3 and EP5 has not caused any impact on the project delay as the milestone Piling Engineering Deliverables AFC has become a hard constraint (by giving actual data date) on the promised date and hence did not create an impact for the end of foundation construction activity CC1. This means the relationship given in the as planned schedule is not respected, but practically, the sufficient deliverables (EP1, EP2 and EP3) were submitted. In the activities of SP2 and EP6 one can see that the activity variance is derived from a difference of delays represented in the brackets. This is because the sequential delay is deducted from the total activity delay. And milestone M4 do not have any impact on the project finish as the milestone is just a representation of the start of piling works and hence not considered for the impact of the delay. SP2, EC1, M2, SC5, EP6 and SC6 are causing concurrent delays as they are having delays in different critical paths. Thus, the effective delay calculated for window 1 is 6 weeks and the project completion shifted from week 22 to week 28.

RESULT OF THE ANALYSIS

As a result of this analysis performed for this schedule, it has been observed that the EOT due by the owner is 6 weeks. And share of delays between the contractor and owner is 25:75.

7.4 PERSONAL REFLECTION ON THE IMPACTED AS-PLANNED AND MIP 3.3

Based on the study and analysis of the two methods performed in this chapter, the following describes my personal opinion on the observation of the two methods.

<u>Accuracy</u>

The impacted as planned technique took the whole schedule into consideration whereas the MIP 3.3 was able to analyze each and every activity on a unit basis. This particular characteristic of the MIP 3.3 was able to bring in more accurate apportioning of delays. The difference between the first analysis (impacted as planned) and the second analysis (MIP 3.3. observational technique) where the contractor share reduced by a percentage of = 50% - 25% = 25 %. This is because of the improved accuracy that the MIP 3.3 technique was offering.

Usage of Windows

In the Impacted as-planned technique, the usage of windows was not seen, whereas the MIP 3.3 was able to use that. The use of windows not only increases the accuracy but will be able to also note the critical path shift in the schedule. Thus the usage of windows in MIP 3.3 is an added benefit.

Time Consumption

Because of the usage of windows and the indepth analysis of each activity of schedule made the MIP 3.3 really time consuming. Whereas, the Impacted as planned is comparatively simple and easy to perform because of the least amount of variables involved in this method and can save a lot of time. This is a plus point of the Impacted as-planned if project is on hold because of the dispute/decisions of the dispute has to be made fast.

Negotiation Process

During the negotiation process of the dispute, the contractor was the one who suggested and convinced the client regarding the use of Impacted As-planned. Through this research it has been noted that the MIP 3.3 offers even more accuracy. If a situation like this dispute arises again, I would recommend the contractor to also consider the MIP 3.3 and act accordingly in the blame game of the negotiation process. The contractor was able to convince the use of impacted as planned to the client and since the advantages of MIP 3.3 is more than the impacted as-planned technique; it should not be hard to convince this technique to the client.

Convincing the Judge

There are two methods presented in this chapter with varying results of apportionment. When a delay claim goes to litigation, and these differences are being learnt during the hearing, there might be a chance that there can be arguments of choosing a particular method. Also, it should be noted that the judge might not have the required competency regarding scheduling/forensic analysis. At this stage, the plaintiff has to shift focus in making the judge understand why a particular method was chosen with suitable arguments. If there was a contractual obligation of choosing a particular method, the plaintiff can point out to that. However, the contract of this case did not have any such obligations. Hence the parties are free to choose their own methods. If this is the case, the plaintiff should be ready with arguments for choosing a particular method. In the above case of the two analysis, the plaintiff can visually show the judge the differences in the analysis and make the judge aware of the added benefits of MIP 3.3 analysis. In this way, the right analysis technique can be won in a legal proceeding. Winning the right analysis technique is half way to winning the true entitlement.

7.5 Summary

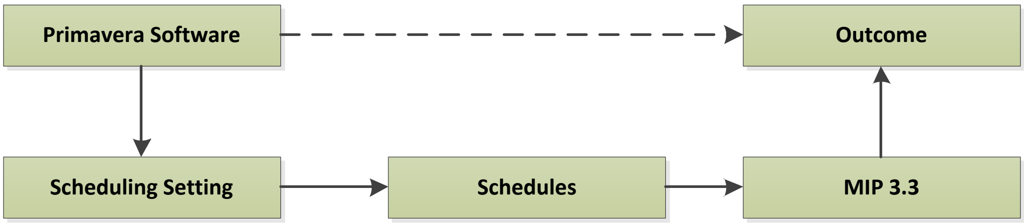
Only through the choice of the right analysis method, the contractor has witnessed a reduction of 25% of his share of delays. However, this gain depends from case to case. There can be instances where the owner also can gain. The difference is due to the increased accuracy of the critical path shift the MIP 3.3 was offering. In my opinion, the contractor still has space to improve his entitlement by improving the quality of scheduling and various scenarios revolving around the forensic analysis. These gaps are identified in the next chapters.

CHAPTER 8: SCHEDULE QUALITY IMPROVEMENTS

This chapter will identify the areas of improvement for good scheduling practice where in which the EPC contractor can be proactively prepared keeping in mind the forensic schedule analysis.

Since MIP 3.3 method is selected as the most appropriate method for the EPC contractor, the improvements concluded in the chapter is based on the MIP 3.3 method and limited to MIP 3.3 method.

The schedules presented for the case in chapter 5 are created by CB&I using the Primavera software. There are scheduling settings in the primavera software that affect the choice of critical path of a schedule according to user's desirability – Progress override, Retained Logic Option and Actual Dates.



If one can observe the MIP 3.3 analysis performed in chapter 6, the outcome is highly dependent on the critical path activities. If one has the ability to change the choice of critical path by various settings in software, then the outcome of the forensic analysis will also change. However, according to my literature study of scheduling checks in chapter 4 there was no check mentioned regarding the choice of settings above. Thus this chapter will go through these settings and suggest a scheduling good practice that would help the EPC contractor in a forensic analysis point of view.

8.1 DESCRIPTION

While scheduling in Primavera software, there are three options available in the software – retained logic, progress override and actual dates. The difference between the three can be felt when out of sequence activities occur.

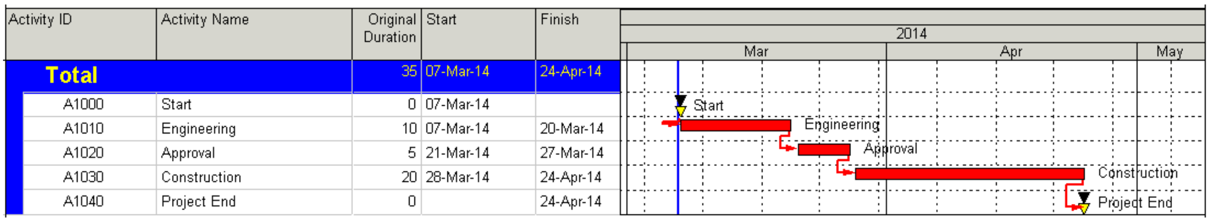
The paper presented by Ron Winter "Much Ado about dates" explains how the software calculates these schedules (Winter, 2009).

The paper explains that if the retained logic is chosen, the importance is given to the logic between the activities and sequencing is done. If the progress override is chosen, the logic is not followed and sequencing is done. For instance, when two activities are connected with a finish to start relationship and an update is created across these activities, progress override allows the succeeding activity to finish without the finish of the predecessor activity. Whereas, retained logic won't allow doing so. In simple words, the impact of the predecessor activity is felt in the schedule for the retained logic option and not felt in the progress override option.

If the actual dates option is chosen, the predecessor activity's late finish date is set to the time unit before the actual start date of the out-of-sequence predecessor. In simple words, the actual dates option behaves like retained logic when the out of sequence activity is not completed and behaves like Progress override when the out of sequence activity is completed. This means the impact of the predecessor activity is felt in the schedule depends on the completion of the out of sequence activity.

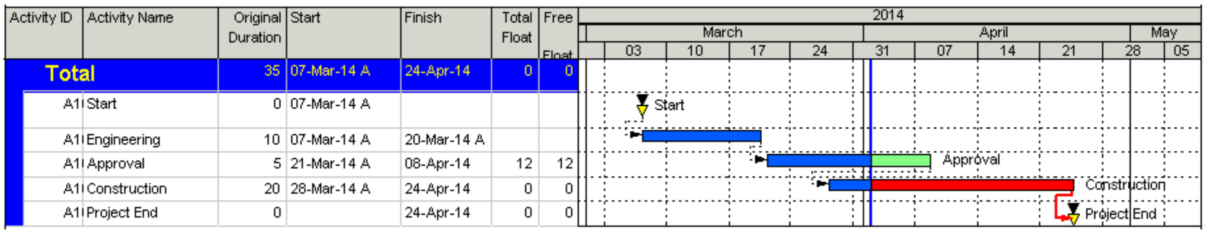
If one observes carefully, the actual dates option follows the principles of retained logic and progress override depending on the completion of the out of sequence activity. Thus, we will first discuss about the retained logic and progress override option from a delay analysis perspective and then discuss about the effect actual dates option.

To observe the difference of retained logic and progress override, consider an example project. The project has to perform engineering and construction by the contractor. Before the construction is started, approval for the engineering drawings must be done by the owner. The project is scheduled as depicted below:

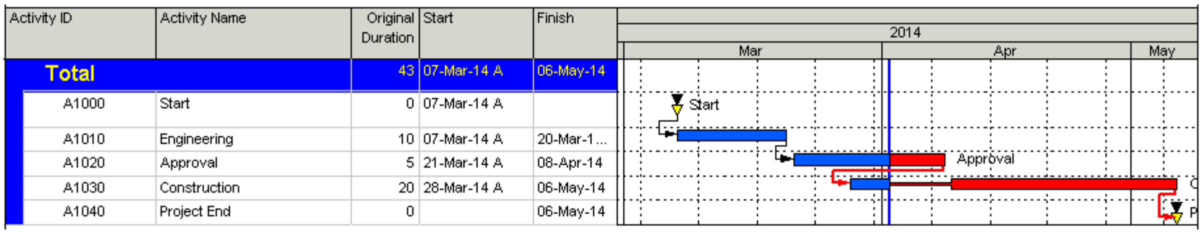


Activity ID	Activity Name	Original Duration	Start	Finish
Total		35	07-Mar-14	24-Apr-14
A1000	Start	0	07-Mar-14	
A1010	Engineering	10	07-Mar-14	20-Mar-14
A1020	Approval	5	21-Mar-14	27-Mar-14
A1030	Construction	20	28-Mar-14	24-Apr-14
A1040	Project End	0		24-Apr-14

Consider that an out of sequence activity occurs as follows. The engineering is finished and sent for approval. However, during the approval stage, the engineer needs to check on a few minor things before he can formally approve. However, the contractor decided to start the construction and make those minor amendments after the final approval is received in order to finish the project on time. Thus, the construction activity has started before the approval was fully completed. Thus an out of sequence activity was experienced. The two different settings in Primavera would give the results as below:



Activity ID	Activity Name	Original Duration	Start	Finish	Total Float	Free Float
Total		35	07-Mar-14 A	24-Apr-14	0	0
A1	Start	0	07-Mar-14 A			
A1	Engineering	10	07-Mar-14 A	20-Mar-14 A		
A1	Approval	5	21-Mar-14 A	08-Apr-14	12	12
A1	Construction	20	28-Mar-14 A	24-Apr-14	0	0
A1	Project End	0		24-Apr-14	0	0



Activity ID	Activity Name	Original Duration	Start	Finish
Total		43	07-Mar-14 A	06-May-14
A1000	Start	0	07-Mar-14 A	
A1010	Engineering	10	07-Mar-14 A	20-Mar-1...
A1020	Approval	5	21-Mar-14 A	08-Apr-14
A1030	Construction	20	28-Mar-14 A	06-May-14
A1040	Project End	0		06-May-14

8.2 IDENTIFICATION IN THE CASE

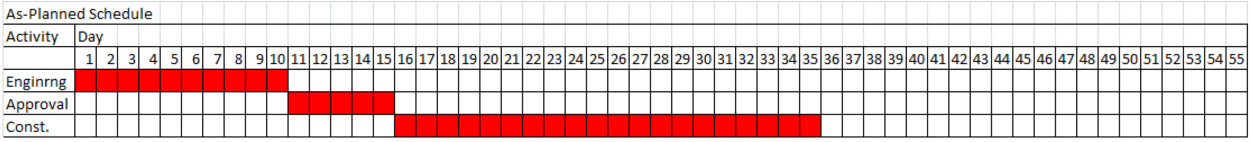
In this real case we dealt with, the contractor was given the freedom to choose his scheduling technique and took retained logic as his choice of scheduling. This thesis will substantiate the use of proper scheduling options in the next sections.

An out of sequence activity occurred when M3 milestone was marked as completed but still the EP5 design was not completed. Thus, the EP5 design was shown as critical in update 1 due to retained logic option.

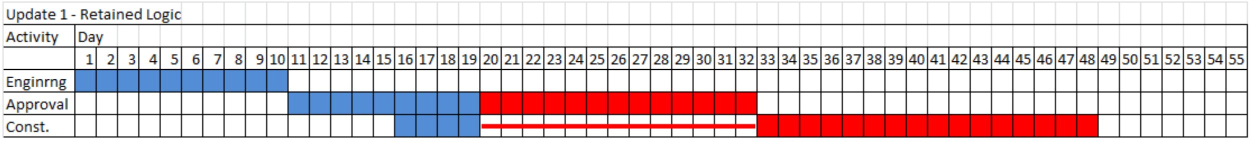
<u>Analysis:</u>

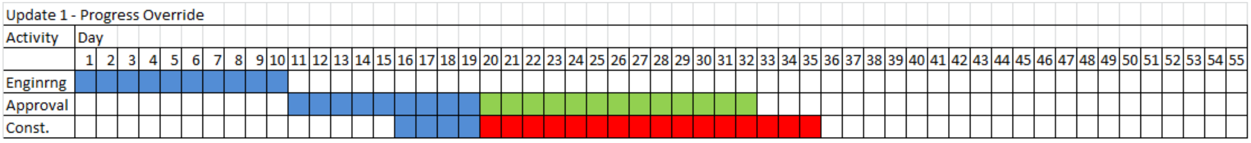
An analysis will be performed for the same example above. The primavera schedules are translated using excel sheets for easy representation.

The following is the as –planned schedule made before the start of the project.

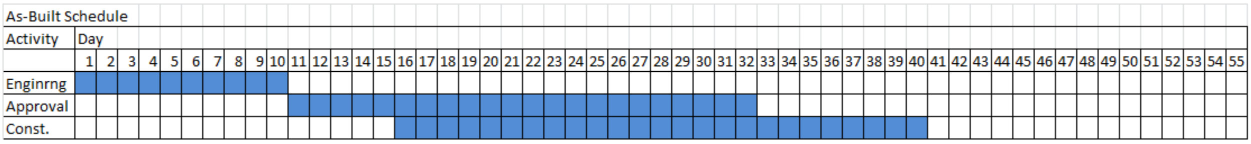


A schedule update is created at day 20. The difference of retained logic and progress override is shown below.



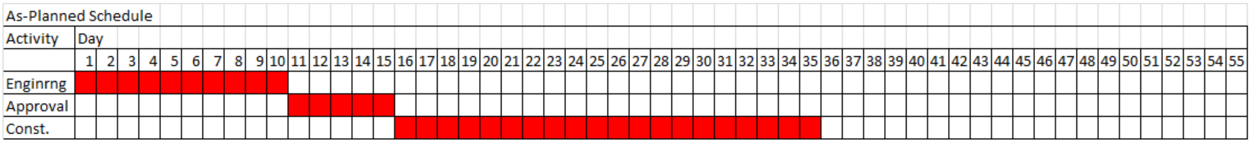


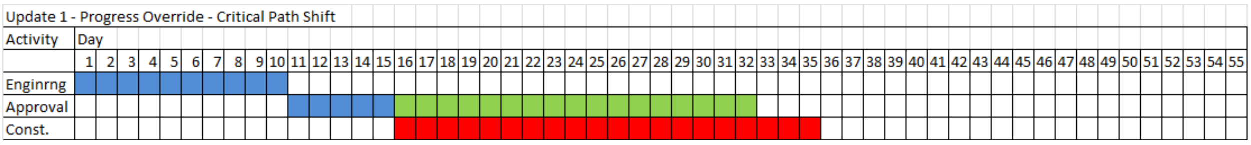
The following is the as-built schedule. The construction activity is delayed by 5 days because of the late approval of the owner. The project is assumed to have sufficient contemporaneous records for the owner delay.

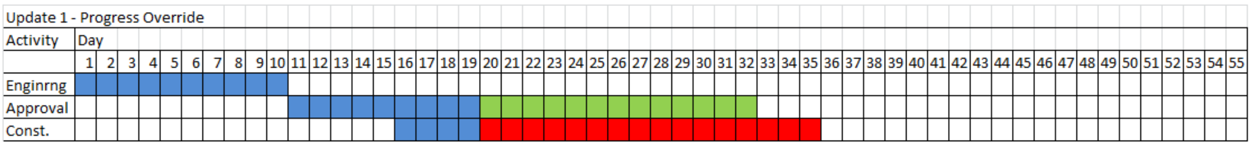


8.3 Analysis Using Progress Override option

<u>For Window 1:</u>



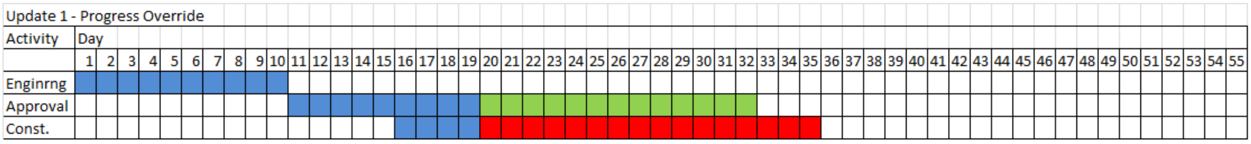


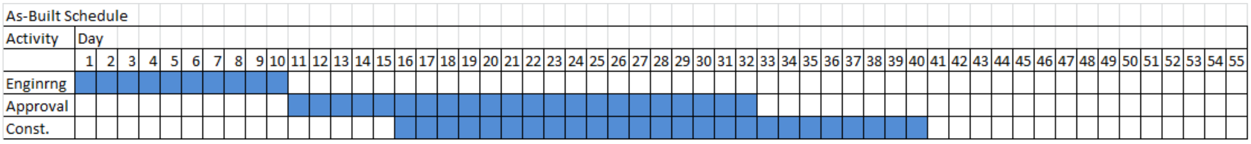


Window1: As-planned and Update 1

Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
	Planned Start	Planned Finish	Revised Start	Revised Finish				
Window 1 (As-planned and Update 1)								
Engineering	1	10	1	10	0	0	35	As-planned
Approval (owner)	11	15	11	15	0	0	35	As-planned
Critical Path Shift								
Construction	16	35	16	35	0	0	35	As-Planned
Net Delays for window 1						0	35	

For Window 2:





Window2: Update 1 and As-Built

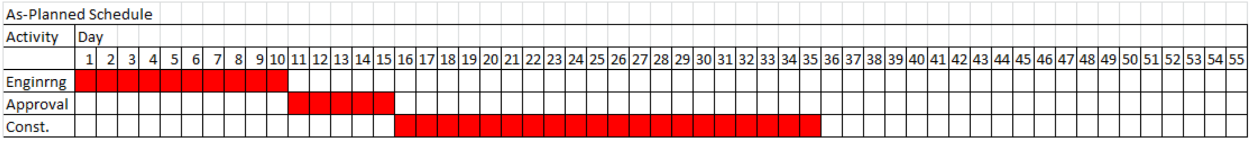
Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
	Planned Start	Planned Finish	Revised Start	Revised Finish				
Net Delay from Window 1						0	35	
Window 2 (Update 1 and As-Built)								
Construction	20	35	20	40	5	5	40	Late, owner caused delay in approval
Net Delays for window 2						5	40	

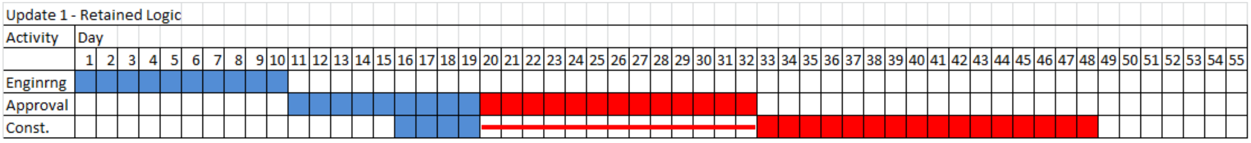
Inference:

Using the progress override option, the owner activity did not cause an effect on the project completion date during the analysis. This is because the progress override option disrespects the logic and calculates the schedule. However in reality, he was the cause of the delay. Thus the progress override option was not capable of showing the evidence in the schedule for the cause and effect of the owner delay. This can make the owner insolvent and contractor can be vulnerable to pay liquidated damages for late completion.

8.4 Analysis Using Retained Logic Option

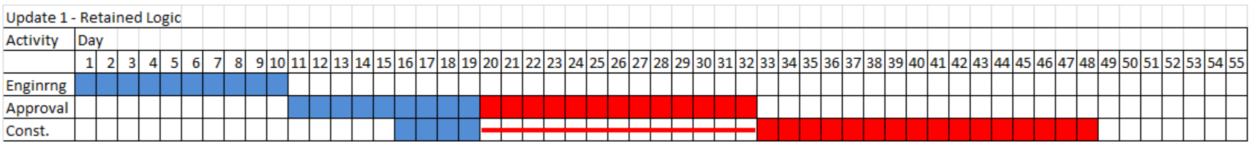
For Window 1:

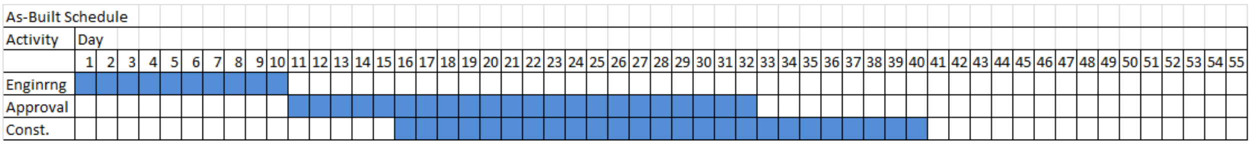




Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
	Planned Start	Planned Finish	Revised Start	Revised Finish				
Window 1 (As-planned and Update 1)								
Engineering	1	10	1	10	0	0	35	As-planned
Approval (owner)	11	15	11	32	17	13	48	Late, out of sequence
Construction	16	35	16	48	13	0	48	As-Planned, Out of sequence
Net Delays for window 1						13	48	

For Window 2:





Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
	Planned Start	Planned Finish	Revised Start	Revised Finish				
Net Delay from Window 1						13	48	
Window 2 (Update 1 and As-Built)								
Approval	20	32	20	32	0	0	48	As-Planned
Construction	33	48	20	40	(8)	(8)	40	Savings, out of sequence
Net Delays for window 2						(8)	40	
				Summary:	Owner caused an impact of 13 days and construction activity caused an savings of 8 days as out of sequence. The remaining impact 5 days will be attributed to the owner.			

Inference:

From the above analysis, the cause and effect of the owner delay is clearly seen. Thus, the retained logic option helps in providing a strong proof of delay and hence the contractor can defend himself for fair entitlement.

Coming to the Actual dates option, as discussed before, it behaves like progress override or like retained logic depending on the completion of the out of sequence activity. This means that the Actual dates behaves like progress override at certain instances. Which again, the schedule will not be able to portray the cause and effect of the out of sequence activity. Hence the actual dates will also fail to the delay analysis.

In summary, the retained logic option shows to be promising in portraying the cause and effect of the delays. Whereas, the other two options are not capable. Hence it is recommended to the contactor to use the Retained logic option for the schedules.

8.5 Influence of the UK English Law

The UK courts have an approach that the delay must be shown critical in order to be awarded for time and compensation[22]. In addition, the courts also specifically follow the approach that owner delay should be critical in meeting the contractual completion date before any Extension of Time can be due to the contractor[23]. From the example analysis shown, this is possible only through the Retained Logic Option. The other two options fail to show the criticality of the out of sequence predecessor activity. Thus will make the contractor vulnerable to bear those delays in the above case. Thus it is recommended for the EPC contractor to use the Retained Logic option. This is also valid for the owners to ensure that the EPC contractors use retained logic by making it a part of contract; otherwise the contractors might take an advantage of making their delays insolvent and can give rise to compensable delays.

8.6 Conclusion

To project the cause and effect of a delay in the delay analysis and also to provide a strong evidence for an Extension of Time claim, it is recommended for the contractor to use Retained Logic Option for scheduling progressed activities. Due to the time constraint of this thesis, it has been limited to only one schedule quality. However, more schedule quality might be identified through prolonged research.

8.7 Recommendation

For owners and contractors:

Since different settings give different results, it is recommended to make the retained logic setting clear in the contract. This will help to prevent manipulation of activities using different settings and obtain the true impact of delays for an extension of time claim.

For legal community:

Sometimes, the parties might take an advantage using the progress override or actual dates to lose the criticality of their activities and their respective delays. Such manipulation shall be overseen and measures shall be taken to make the CPM calculation through retained logic. If the schedule gives erratic results of the retained logic, then measures has to be taken to rectify the CPM calculation and perform the analysis.

[22] Delay Analysis in Construction Contracts, P. John Keane, Anthony F. Caletka, Page 119
[23] Delay and Disruption Protocol, Society of Construction Law, Section 1.3.6, Page 15;

CHAPTER 9: RECOMMENDATIONS TO CB&I

The third sub research question formulated in this thesis deals with the identification of methodology/processes that revolves around the forensic analysis. To answer this question, this thesis has identified areas where the EPC contractor could have done some actions, during the project phase of the case, proactively for a better outcome of fair entitlement during the forensic analysis. These improvements are arrived by logical reasoning and suggested as recommendations to the EPC contractor. The recommendations are arrived for the case used for this thesis; however, these recommendations will also be generalized to make them usable to wide areas in the construction industry.

9.1 QUALITY ASPECTS

This aspect deals with the quality of the schedule of the case presented in chapter 6 with respect to the contractual conditions of the project of the case and the quality checks mentioned in chapter 7 and chapter 5 respectively.

1. <u>Measuring schedule Quality</u>

<u>Observation:</u>

The first step to a fair entitlement of delays is meeting the schedule quality requirements of the contract. The result for the As-planned schedule of the case presented in chapter 6 is uploaded and the quality score can be obtained by the use of Acumen Software that uses the GAO schedule quality checks.

Missing Logic	Logic Density™	Critical	Hard Constra...	Negative Float	Insufficient Deta...	Number of Lags	Number of Leads	Merge Hotspot	Score
2 (8%)	2.96	23 (92%)	1 (4%)	0 (0%)	6 (40%)	10 (40%)	0 (0%)	4 (16%)	32%

FIGURE 30: ACUMEN SOFTWARE SCHEDULE QUALITY RESULT

In the result diagram above, the quality of the schedule is measured with 10 metrics – missing logic, logic density, critical, hard constraints, negative float, insufficient detail, number of lags, number of leads, merge hotspot and score. The overall score of the schedule is based on these metrics.

In the result above, the score of the schedule quality has been highly influenced by the ones marked in red colour. Those are highly responsible for degrading the quality of the schedule. Special focus should be done in those areas. The main causal was the insufficient detailing metric contributing to 40% of the activities in the schedule. Insufficient detailing is done by measuring the length of the activity with respect to the length of the full schedule. It should be cautioned that the schedule used was separated from the original schedule that was lasting over a couple of years. This means that the insufficient detailing can be ignored from the consideration in this case. On removing, the new score of the schedule was observed as 48%. This is still rated as poor schedule.

The other factors that are responsible are critical, logic density, number of lags and merge hotspot (the one in the green are ignored as it is safe). According to the contract, focus should be on lags & hard constraints and it can be observed that these are deteriorating the schedule. The activities influencing these metrics should be identified and repaired.

Assuming that it is repaired, the new score of the quality is calculated. To measure the new score the lags and hard constraint metrics were disabled in addition to the insufficient detailing metric.

Missing Logic	Logic Density™	Critical	Negative Float	Number of Leads	Merge Hotspot	Score
2 (8%)	2.96	23 (92%)	0 (0%)	0 (0%)	4 (16%)	76%

FIGURE 31: SCHEDULE QUALITY RESULT WITH EXEMPTIONS

Thus, the new score is 76% (which is safe) and it can be observed that the quality checks that are in correspondence with the contract are highly deteriorating the schedule. However, there was a problem. In discussion with the planner of the case, he mentioned that these metrics that are affecting the score is necessary to prevent the complexity of the schedule which might hinder its purpose for project management and quality was traded off.

Recommendation:

In such situations it is to suggest the scheduler to include substantiation report for the schedule he creates that explains the exceptions to be regarded while calculating the schedule score. Such exemptions can be set in the software and the new score can be calculated. This will give a satisfactory score and validate the quality of the schedule. Thus, the use of schedule as a proof can be used in the dispute resolution with confidence. Referring to chapter 5, this was also recommended by the GAO schedule quality checks. This boosts and validates the quality of the schedule and can be a strong proof in dispute to use it in case of any claims.

Generalization:

Schedules are used not only in the EPC industry, but also in wide area of construction projects. To maintain the complexity of the schedule to a usable level there can be trade-offs in the quality of the schedule as seen in this case. Thus a substantiation report for the traded off quality is necessary for a better delay analysis to protect one's entitlement. Hence, all the parties in the construction industry who use a schedule for purpose of project management, this shall be an important recommendation.

9.2 Scenarios Aspect

This aspect deals with identification of strategies where in which the contractor could have performed to gain fair entitlement during the forensic analysis. This is performed from the insights of project records (chapter 6), delay liability table (chapter 7) and MIP 3.3 analysis (chapter 7).

1. Notice for delays

Observation:

One can observe that in chapter 7, though some delays are caused by owner, the delay is attributed to the contractor, because the contractor failed to notify the client for that delay. In the discussion with the project manager of this project, he conveyed that they were fully aware that the owner was causing a delay in the project concurrently to theirs. However, they gave priority to their relationship with the client for better collaboration and thus in full consciousness did not report that delay. According to the contract, they were supposed to notify the delay to the client if in case they want an EOT (Extension of Time). Since it was the start of the project, and since the contractor did not want to have bad relationship for the rest of the project, he did not notify it. If in case he notified the client regarding his delay, that delay would be validated in the client's account and the contractor would have less share of his part of delays.

Recommendation:

If the contractor is requesting for an EOT, according to the conditions of contract, he is obligated to notify the delay to the client, without which it will be waived off as owner caused delay. Even the SCL protocol recommends the contractor to notify the client when delays occur irrespective of who the causal of the delay [24]is. I strongly suggest the contractor to do so to protect his entitlement. The total number of contractor caused activity delays is 19 weeks. By giving proper notice for milestone "area ready by client", the contractor would have saved 4 days. This will reduce his share for the project delay by 20% (refer to window 1 table of MIP 3.3).

At instances, where relationship becomes the top priority, I would suggest the contractor to atleast make the client aware of the delay through informal correspondence. This might include the minutes of the meeting, visiting site along with the owner, penning down verbal communication, notifying by e-mail etc. Through these informal correspondences, the contractor will atleast try to make the client aware of his delay.

It is true that these informal correspondences do not hold as a formal notification. Submission of an informal correspondence as a proof will be a misrepresentation of material fact and thus cannot be taken as a proof for materiality. But the chances of regarding such informal correspondence are higher than sitting silently and loose the contractor entitlement. This suggestion is recommended by the proceedings of the following case:

In the Sharbern case, Sharbern Holding Inc. v. Vancouver Airport centre Ltd., the supreme court of Canada (SCC) ruled that the developer was entitled for his share, even though the developer failed to disclose a delay in a formal statement (Smyte, 2012). The purchaser did argue that the informal notice given by the developer was not according to the contract and it is misrepresentation of material fact. But his argument did not help him for two reasons:

- The informal notice was absorbed by the purchaser without any complaint and that he was aware of the delay
- The word misrepresentation was taken as "false or misleading" according to the REDMA Act. Here, the developer's informal notice was not misleading as it portrayed actual impact of delays.

Thus in this case, the common law has accepted the informal notice. It is true that my thesis deals with English Common Law and the above case was from Canada. However, Canada also follows common law and just like the English common law it also gives freedom of contract where in which the parties are bound by their agreement. If similar conditions of the sharbern case are faced by a EPC contractor within the UK English law, he might have a chance of arguing the materiality of the notice and gaining entitlement.

As a result, I would also recommend the contractor to also perform informal correspondences to notify delays. This recommendation should not be taken for granted and not to be used at all places. It should be used only when the contractor has a potential to loose entitlement and relations with the client are of top priority. This suggestion only improves the chances of gaining true entitlement and does not guarantee that the English court would consider this material fact. The risk of performing this recommendation is with the contractor and Legal advice should be taken before performing these tasks. However, this kind of approach might help to keep relationship in place and help in resolving the dispute at the negotiation level.

Generalisation:

The approach of informal notices for delay claims can be made a little confidently in the Canada region. However, for projects in other countries performing such an approach can hinder their entitlement in a legal proceeding. Hence care shall be taken to apply thorough legal knowledge before performing it.

[24] Delay and Disruption Protocol (2002), society of construction law, Section 1.2.7

2. Consensus in selection of delay analysis method

Observation:

In chapter 7, during negotiation, the contractor and the owner did not have written consensus regarding the choice of the analysis technique. The contractor was lucky in this case that the owner allowed the contractor to solely perform the analysis. However, there can be times where in which arguments over the delay can occur with different analysis techniques. The contractor has to be prepared for this scenario.

Recommendation:

The difference in opinion of the choice of methodology shall be done before the start of performing the analysis method. This would help in reaching consensus and avoid arguments later on. Consensus in writing can be done in two ways- in the contract or agree in writing at the stage of negotiation of claim.

When the delay analysis is used in the contract, there are high chances that the parties see the project from the delay point of view. This may hinder project progress and damages trust where everything has to be proved. It also has a disadvantage that the drawbacks of a particular method have to be accepted while using the technique. This may reduce the reliability of the technique when used. Ofcourse there have been instances where the delay analysis has been a part of contract before (Bara, 2002). However, it is my recommendation not to choose this type of approach, but instead choose the analysis technique in writing at the stage of negotiation. This would help the parties not to concentrate the project based on delays and also help the selection of the technique based on the purpose of delay (which is not possible to oversee at the stage of setting the contract).

If a technique has to be chosen in the contract, I recommend the parties to choose the MIP 3.3/MIP 3.4 technique since it provides reliable results without any possible manipulation like the other techniques. Also it covers a majority of drawbacks faced by other techniques. However, the drawbacks of this technique shall be taken into account and accepted before reaching consensus.

Generalization:

Delay disputes can occur generally over all areas of the construction industry. Any party who is involved in a dispute resolution for extension of time claim shall adopt to reach consensus before making the delay analysis.

3. Schedule updates

Observation:

The baseline was originally signed in week 12. The first update was also signed for week 1 to week 13 together. Thereafter updates were created and approved on a monthly basis (~4 weeks). This affected the choice of windows during the MIP 3.3 analysis in chapter 6. The first window was taken as first 13 weeks and the next succeeding windows are taken as between 4 to 5 weeks (~1 month). The first window itself witnessed a project delay of 6 weeks. In my opinion, the apportion of delays performed is not accurate due to the huge size of first window.

Recommendation:

One of the big problems we have seen in the previous section was the use of the first window to around 13 weeks (~3 months). The contractor got the first update (13 weeks) signed in the week of 13. This is because, the update were waiting to be signed until the baseline was signed. However, while doing so, it is recommended to the contractor to get it signed with short periods of one month each instead of one big period like 13 weeks in this case. Thus, the contractor can get three updates for those 13 weeks separately.

And this would have allowed using many windows in the start of the project, thus giving more accuracy and smooth forensic analysis. This would give a solid proof of the schedule for dispute resolution.

It is true that use of different window sizes gives different results. This has been also shown with an example from chapter 4. However, there is research that mentions that it is recommended not to use lager windows (Menesi, 2008). The author mentions that the use of large windows would not accurately consider the changes in critical path and thus the apportionment of delays is not as accurate as when using small windows. Thus, when small windows are used, the delays are apportioned with higher accuracy.

Generalization:

Schedule updates are the heart of accuracy for a more accurate delay apportionment. This is because the more the schedule updates the more the critical path shift can be witnessed and leads to more accurate apportionment. Thus, it necessary for the planners in general to create as many updates as possible for their construction projects.

4. Pacing Work Notice

Observation:

Looking at the project records in chapter 6, one of the scenarios where the contractor could have a strategically advantage was the pacing work notice. The contractor did not perform this for his foundation designs and this made him equally responsible for the delays of the project completion. How and when the pacing work notice could have been delivered is elaborated in the solutions section.

Recommendation:

In the case we discussed, according to the baseline, the piling construction S/C shall be awarded on week 5 and cast their first pile in week 9. However, the client delayed the award by two weeks and asked the piling s/c to cast their first pile week 12. This created a delay for the first pile construction by atleast by 3 weeks. This information was received by the contractor well before hand. At such moments, he could have asked the client to pace his work which might be to his advantage. This is explained in detail below.

One can observe that the first pile was constructed late, which inturn the first foundation can be casted late. Concurrently, the contractor had his foundation designs late with insufficient man power. In such situations, the contractor can ask the client for pacing his work in accordance to the first foundation construction date, so that those foundation design delays of the contractor would not be the reason to impact the project end. This would help removing concurrent delays with contractor foundation designs and the contractor would receive fewer shares of damages.

By providing pacing work notice for the foundation designs, the contractor could have saved all his civil foundation design delays that accounted to 4 concurrent delays (refer Window 1 table MIP 3.3 Analyis – EC1 activity). The total number of activity delays caused by the contractor on all activities is 19. This will reduce the total number of contractor delays from 19 to 15, i.e. a reduction of about 20% delays of his delays.

Generalisation:

Whenever there is a possibility for the contractor to decelerate his work in accordance with the owner's/subcontractor's activities, this recommendation can be performed to use that extra time to prevent from concurrent delays and save cost. Also this kind of an approach might not only occur in the EPC industry, but in the construction world in general and thus can be applied by anyone related to those situations.

9.3 SCHEDULE ASPECTS

These recommendations are formulated by pointing out various observations in the As-planned schedule of the case (chapter 6). For each observation, a solution is proposed on how the scheduling could have been done better with respect to the schedule quality checks to improve the outcome of the forensic analysis. The generalization of the recommendations cannot be made on a broader scale because the design and requirements of the schedule changes from project to project. However, if scenarios of the schedule are similar to this case, these recommendations shall be implemented.

1. <u>The representation of the milestones</u>

<u>Observation:</u>

If one looks at the name of the milestones for the "Engineering Deliverables – Piling AFC (sufficient for construction contractors to start)" and "Engineering Deliverables – Piling AFC (sufficient for construction contractors to start)", there is a lot of ambiguity in the representation of these milestones. The name "sufficient deliverables" is very ambiguous and can give space for argument in dispute resolution. This is because, the milestone "Engineering Deliverables – Piling AFC (sufficient for construction contractors to start)" has been indirectly quantified in the schedule by linking the EP1, EP3, and EP5 to that milestone (EP2 & EP4 was not a part of this as it was not connected to that milestone); i.e. EP5 was connected to the M3 milestone and EP1 and EP3 was sequential to EP5. This creates the perception that these piling designs are being promised for that milestone without which the construction cannot start.

In reality, the contractor submitted only the designs of EP1, EP2 and EP3 and considered it sufficient for construction to start. This is followed by making the milestone "Engineering Deliverables – Piling AFC (sufficient for construction contractors to start)" as finished in the schedule, i.e. if u look at the as planned and as built schedule, this milestone didn't have any delay, though the EP5 designs are on delay due to change order of the client. The contractor was convincing the client that the construction could still start and need not be disturbed due to EP5. This was also to represent that they were on time with the deliverables and they weren't the cause of the project completion delay. This was done at the cost of disrespecting the logic in the schedule, thus, affecting the outcome of the forensic analysis. Above all, what happened to EP4 piling design? Though not connected to the M5 milestone, practically it was supposed to be a part of the work front. And delays were witnessed in this activity. All these might trigger the opposition to raise arguments on the delays of the piling designs.

Wrong representation can cause the contractor to lose his entitlement during the forensic analysis. Thus, representation of these milestones should be done with utmost care.

<u>Recommendation:</u>

In consultancy with the planner of this project, he said that they had to use the same name of the milestone as it was a part of the original contract (confidential) used in the project. In addition, the contract also obligates to handover the piling engineering deliverables on week 9. The planner initially thought that the first 5 piling designs were mandatory for sufficient work front of the project. Also that, the end of 5th piling design coincided to satisfy M3 milestone. This is responsible for the schedule to be set up to the one initially presented in the baseline.

In this case, the planner missed defining the apt work front. The apt work front is the first three designs that happened in reality. But defining them as work front would have made the M3 piling milestone to be completed on week 8. In order to meet the contractual date of week 9, the contractor will be forced to use the "finish on or before" constraint on the milestone. According to the quality checks in chapter 4, this will affect the quality of the schedule. Thus, in defining the true work front, the quality of the schedule should be traded off.

In my opinion, a better solution to the contractor is to keep the initial plan of connecting the 5 piling designs with the milestone so that using of a constraint will not be needed. In addition, I would suggest the contractor to mention what the milestone promises in the schedule narrative. For e.g., saying “EP1, EP2, EP3, EP4 and EP5 are assumed to be necessary work front for construction to start. However, changes can be possible according to circumstance” in the schedule narrative to highlight the milestone, it would have helped the contractor to reserve the rights to make changes in the milestone and then play the dispute better with material proof.

Also the other problem indicated was the indirect quantification of the M3 piling Milestone, i.e. EP5 was connected to the M3 milestone and EP1 and EP3 was sequential to EP5. This physical relationship will not hold true when the finish to start relationships are not respected, where in reality this disrespect did happen. Thus I suggest the planner to individually connect all the piling design activities promised to the M3 piling Engineering Deliverables milestone.

2. Indirect use of hard Constraints

Observation:

According to the contract, it is an obligation for the contractor not to use hard constraints in this schedule. However, in the first update, the milestone M3 was marked as finished without the completion of EP5. This is an indirect way of making the milestone M3 a hard constraint. EP5 activity has a change order from client. Any delay in that activity will be attributed to the client. Now by making the M3 a hard constraint (by marking it as finished), the effect of the EP5 delay is not attributed to the project delay. No matter, how many days the EP5 is delayed, it won’t have effect on the project end. In chapter 5 of logic checks, it has been identified that hard constraints violate schedule logic. It is not recommended to mark finish on such milestones when dependant activities are still running.

Recommendation:

The solution to this problem is to properly quantify and linking the appropriate work front to the M3 milestone that is needed for construction to start. If M3 Piling milestone was finished without the finish of EP5 Piling design, then EP5 was not a part of the work front. The other solution is to reserve the rights to change the Piling designs required to satisfy the M3 milestone. This can be done my including the explanation of the milestone in the schedule narrative as explained in the previous aspect.

In summary of the two aspects, the following is recommended to the contractor:

Milestones are the focus in a schedule. All eyes will be on the milestone on the strategic level. Such milestones should be given the highest priority when developing the network of the schedule. In our case we have seen that these milestone lack clarity in their representation. It is my recommendation to include the following while representing a milestone.

- Name the milestone aptly for a given situation.
- Pen down the promises that the contractor issues for the milestone
- Include a schedule narrative for important milestone to give in more clarity to what the contractor is promising.
- Proper care should be administered while giving relationship links to the milestone and check whether it is depicting the true meaning of what the contractor is promising.

3. <u>"Area ready by client" milestone</u>

Observation:

In the baseline schedule, the area ready by client is linked finish to start from the "Start project execution" activity and by a "finish on" constraint. This relationship is not proper and does not depict the physical relation between the two. In case of a dispute, the client may not agree that the Project start is driving his activity. And this can affect the calculations of the forensic analysis. Such arguments should be minimised for proper forensic analysis. This is possible by truly depicting the actual physical meaning of that particular milestone.

Recommendation:

It is true that the client milestone "area ready by client" is not driven project start. Infact, it is not dependant on any preceding activity. In such a scenario, I would suggest the planner not to link the client's milestone by a preceding activity. It is true that the milestone will have open ends if a preceding activity is not linked and open ends are not a good scheduling practice as per the quality checks in Chapter 5. At the same time, it is not logical to link any preceding milestone/activity just to satisfy that open end.

In my opinion, an open end on the predecessor can be agreed for the client's milestone and be driven only by a constraint. This way the true meaning of the milestone is drawn in the schedule. This also directly improves the output of forensic analysis.

4. <u>Improper links</u>

Observation:

If one looks at the piling designs in the baseline schedule, the links between the design activities are finish to start. This is done keeping in mind the resource dependency, i.e. the engineering team finish one design and then go to the other. However, in the as built schedule, the piling design activities started irrespective of the relationships. The relationships between activities were not respected. This is because the piling designs were performed by a team of members and the work can be manoeuvred among the team. This resource dependency relationship affects the outcome of forensic analysis and there might be arguments between parties on the impact of project end date because of the delays in piling designs.

If the resources are not really driving the successive piling design activities, finish to start relationships between them wouldn't serve the purpose. There is a need for some other relationship that should drive the start of the piling designs.

The problem and theory are explained with an example and not the real case. This is to facilitate easy understanding. In our schedule the piling designs were driven by finish to start relationships as shown in the diagram below.

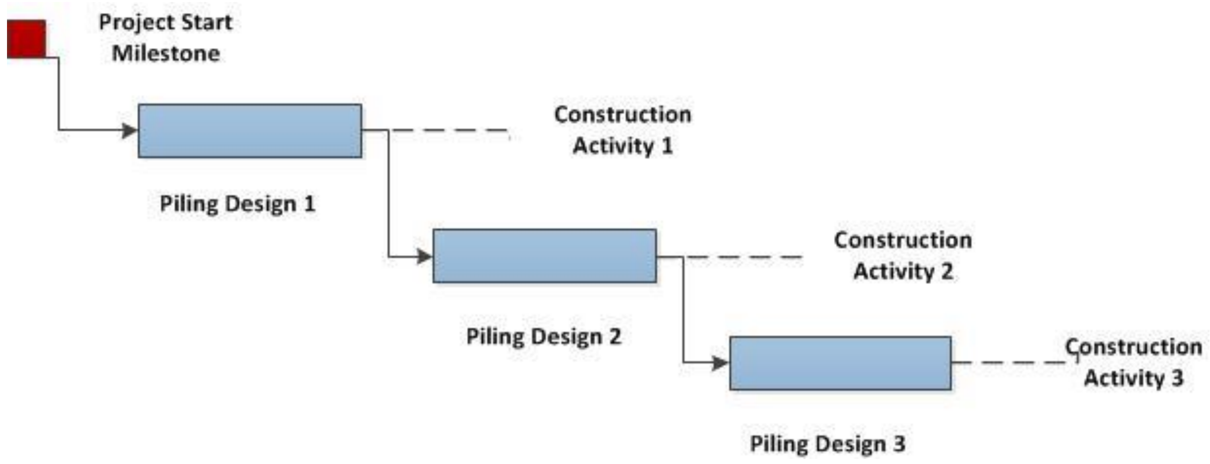


FIGURE 32: PROBLEM

In this example, the piling designs are driven by finish to start relationships of the previous design, just like in our real case. However, as explained before, the 'finish to start' do not hold the real value of relationship as witnessed in our case. Something else needs to be driving the start of these piling designs. In a brainstorming session, I came up with a solution. Before discussing the solution, it is to remind that the start of the piling design activities were never a problem. Keeping this in mind the solution was formulated

<u>Recommendation:</u>

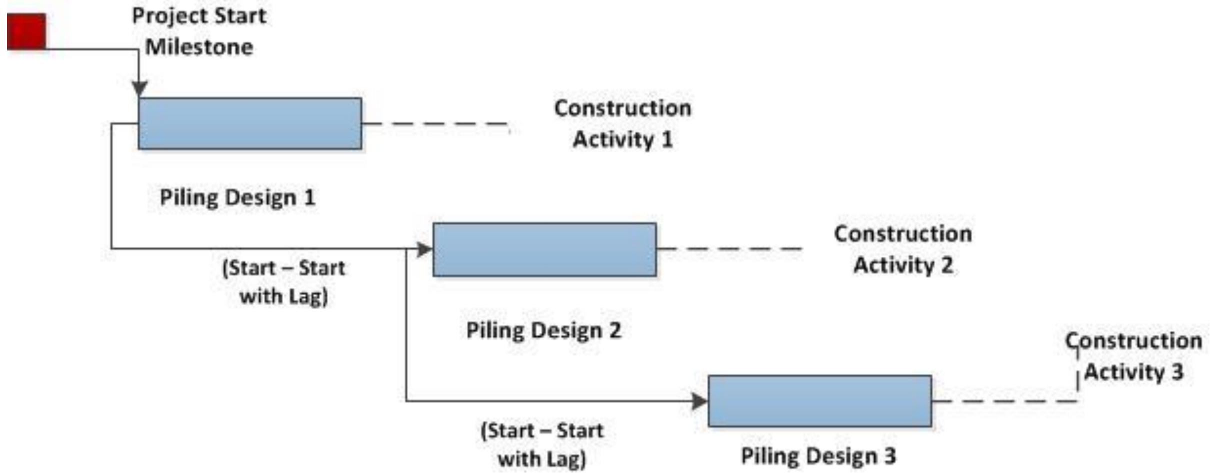


FIGURE 33: SOLUTION

In this solution, there is a possibility to drive the piling designs with the Start- Start relationship of the previous activity with a lag having a value of the duration of the preceding activity. This would allow starting the activities without the influence of the finish of the previous activity. And the true impact of the project end can be calculated with less ambiguity.

It is true that, from chapter 5, the use of lags and start to start relationship diminishes the quality of the schedule. But it is the only possible way to sequence the schedule to depict the true meaning of the project execution. Thus I would also suggest the contractor to be reminded of the trade-off that should be done to attain a proper schedule. I would also suggest the contractor to substantiate the use of lags, so that confusion during a forensic analysis can be removed.

This solution holds true, if the sequence of the start of piling activities holds good. However, if for instance, the vendor data was not received to start piling design 2, but the contractor has vendor data for piling design 1 and 3. According to the schedule, the designer cannot start piling design 3 until piling design 2 started. But this is not practical and designers should not be idle during a project. Thus at such situations, the engineering team will start piling design 3 without the start of Piling design 2. If that happens, the logic will be disrespected. Thus a better solution is needed to serve the purpose considering all possibilities in mind.

Reformulated Recommendation:

In the previous solution there were three problems: lags, start to start relationship and dependability of vendor data. Keeping this in mind, the new solution is formulated.

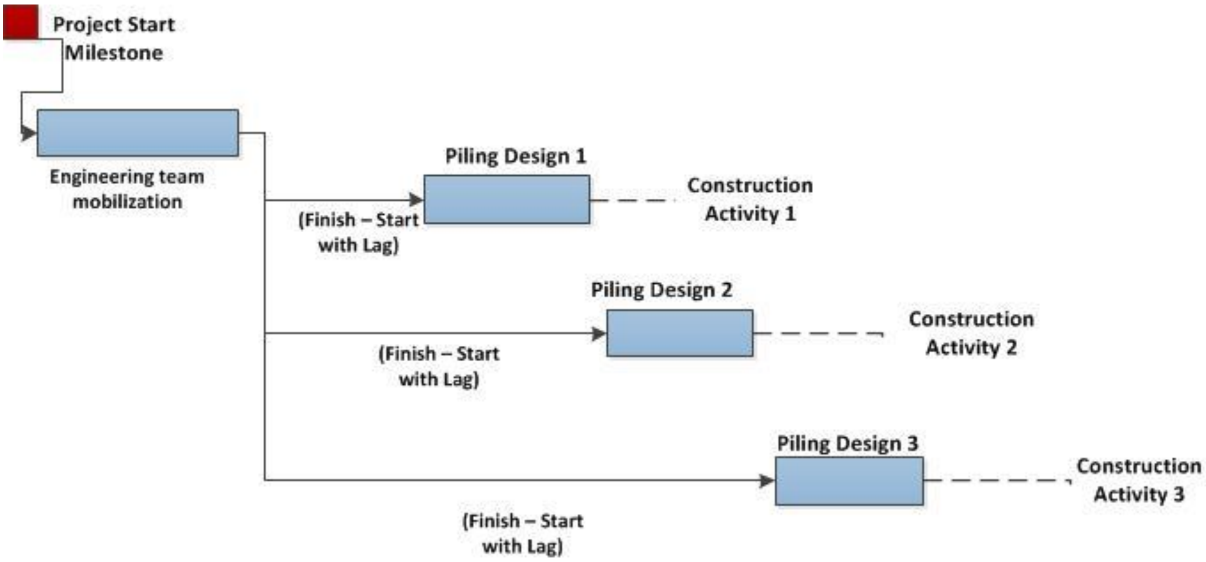


FIGURE 34: REFORMULATED SOLUTION

In this solution, an external mobilisation activity was introduced and the succeeding activities are connected with finish to start relationship with lags. The problem of dependency on preceding piling designs and the start to start relationship is rectified. However, the use of lags was not been able to solve. In addition, a new problem arose that the value of a lag is increasing with chronological order of piling designs. This can be compromised by substantiating the use of lags, so that the meaning of the lags is known during the critical path analysis.

With this solution, the critical path analysis can be improved and the actual impact of the project end can be calculated with less ambiguity and improved reasoning.

9.4 Conclusion

I suggest the following recommendations to the EPC contractor while building his schedule:

1. If there are metrics in a schedule that affect the quality but require for proper sequencing, I would recommend the contractor to pen down a substantiation report to support those metrics.
2. Use proper link that give the real physical meaning of what is being performed in reality.
3. Take care for representing the milestone its meaning both in representation and explaining it in schedule narrative.
4. Take care in linking the milestone to the activities promised and see to that it is depicting the meaning of the actions of the project.
5. If the contractor wants to protect his entitlement, it is highly recommended for the contractor issuing notice for an owner delay. If relationship with the client is of high priority, then contractor should try

to make the client aware of his delay through informal correspondence and not sit silent. This would increase the chances in a delay claim to protect the contractor's entitlement.

6. Use pacing work notices to consume available time and protect from concurrent delays
7. Reach consensus in writing before starting an analysis technique.
8. Approve as many updates as possible from the client to increase the accuracy of delay for usage of smaller windows.

CHAPTER 10: SUMMARY, LIMITATIONS AND FUTURE RESEARCH

10.1 SUMMARY

This section answers the research questions framed for this thesis report in chapter 1.

How can EPC contractors be better prepared to take on a forensic schedule analysis, so as to improve the chances of getting the fair entitlement that is legally just?

This research question is answered with the assistance of several sub questions and with the help of this thesis report, these sub questions are individually answered below:

- ***Which analysis method best suits the EPC contractors?***

In the EPC business, a lot of money is at stake and projects are huge involving complex and tight planning. At circumstances like these, it is the accuracy of the delay that is the focus. It is seen from this thesis report that the MIP 3.3/3.4 analysis technique is more appropriate for the EPC contractor to use. The usage of windows, the consideration of critical path shift, inability to manipulate and analysing delays in a unit basis are all the advantages of using this technique.

- ***What are the guidelines recommended to the scheduler to build good quality schedules?***

The thesis report concludes one main important guideline for scheduling using Primavera P6:

  - Use the retained logic option for indicating the progress of activities.

This option will assist in observing and analysing only the activities that cause a direct impact on the project end date where liquidated damages apply. This setting also facilitates the burden of proof required for criticality of the schedule under UK English law.

- ***Is there a methodology/process that revolves around the forensic analysis? If so, how can the methodology be built?***

There are list of processes that should be followed to assist in fair apportioning of delays while performing the forensic analysis:

- Different analysis techniques give different results. Agree in writing about the choice of analysis technique before starting the apportionment to prevent disputes related to its choice.
- Baseline schedule shall be prepared keeping in mind the contract as well. Some clauses relating to critical activities can cause an impact of the contractor's actions during the project and the forensic analysis in the dispute (referring to 'area ready by client' milestone- where soft constraint was used but behaved like hard constraint because of statusing it complete before the predecessor activities have completed).
- Baseline schedule shall be as close to depicting the contractor's real physical actions and proper respect shall be given to logic. If the logic is violated, it means the quality of the schedule is diminished and becomes void for forensic analysis.
- If there are quality metrics in a schedule that affect the quality but are required for facilitating project management, I would recommend the contractor to pen down a substantiation report to support those quality metrics.

- Milestones shall be given prime importance in the baseline schedule. The milestone represented shall depict the true meaning, linking and narrative in a very clear manner. This is because the main focus will be on the milestones.
- Contractor is obligated to issue notices to the client. However, tradeoffs are necessary for different scenarios:
    - If entitlement is main priority, then the contractor should issue formal notices.
    - If both relationship and entitlement is of top priority, then the contractor should make arrangements for informal correspondence to increase his chances for fairness in a dispute.
- If there is a potential delay caused by the owner in the critical path, make use of pacing work notices. This help in consuming the float caused by that delay, but not account it for concurrent delays.
- Get as many schedule updates possible to validate the use of a window. This will help in accurate apportioning of delays.

All the answers of the research questions above are steps that the EPC contractor can take proactively and thus can be prepared to face a delay dispute confidently to prove their entitlement. It is also that the answers of these research question also increases the accuracy and reliability of the apportionment of the delays and thus if followed can grant the EPC contractor with the fair entitlement.

10.2 Limitations

The limitations of this thesis are enlisted below:

- The schedule quality and the recommendations are limited to the MIP 3.3 technique.
- This thesis is limited to delay claims involving a lot of money. If the delay claim involves a small amount of money, performing the MIP 3.3 is not feasible as it needs expertise which might be costly.
- Contractual recommendations are limited to UK English common law in an academic point of view. Even then, I would recommend the industry to have a legal advice before implementing them on practical grounds.
- This thesis did not take into consideration the resource loading of schedules. Thus, results may vary when those are taken into consideration.
- The recommendations are limited for the case explained in chapter 6.
- Scheduling can be done using different software available in the market. However, the recommendations are only limited for the Primavera P6.

10.3 Suggestions for Further Research

Below are the enlisted points where further research is possible in the area of schedule claim prevention:

- This thesis did not consider resource allocation. In the real world, schedules are resource loaded to assist in resource allocation during the project. Thus, this subject can be expanded considering the resource allocation.
- This thesis dealt with technical aspects for schedule claim prevention. In my opinion, a lot more benefit for preventing claims can be done when focussing on the client behaviour and collaboration of the project. Thus a study on this is also recommended.
- Sampling was performed on a small schedule which was separated of from the original schedule which is even more complex. Research can be continued for original entire schedules.
- This thesis was performed only for the EPC industry. Extension of time claims can also occur in other sectors of the construction industry. Further research can be done in this area.

Chapter 11: Reflection on delay claims through schedules

This thesis has researched in developing schedules with legal considerations to help the EPC contractor to assist in solving disputes at the negotiation level so as to prevent handling claims in legal proceedings that costs extra effort, time and costs. In my opinion this approach of dealing with schedule claims is a very offensive approach and hinders project success. Thus, this chapter would deal with my reflection on dealing delay disputes offensively and suggest a defensive approach to deal them through collaboration.

11.1 The offensive approach

The current of approach of the thesis of dealing delay claims prepares schedules with legal considerations, waits for a dispute to occur and involves rounds of negotiations to settle. This kind of an approach is in my opinion is offensive and hinders the project. The various problems associated with this approach are explained below.

Problems

Control of schedules with contractor

The contractor is the one who is fully responsible for the schedule of the project. Hence the overall control and design of the activities of the project is in his hand. In such circumstances, the interface of the owner and contractor is also controlled by him. A skillful planner can make a design such a way that the owner activities can be in the critical path. This makes the owner to be very stringent with his activities and the flexibility is arrested. At such circumstances, any delay by the owner in the critical path will grant the contractor with the extension of time according to the legal approach by the UK English law (exception is the ownership of float).

Liability Approach

When building schedules from a legal approach, the parties are more concentrating on liabilities rather than completion of the project. Parties might resist collaborating and trust becomes deficient. This is not a healthy approach as it hinders project progress.

Extra effort and Energy

The contractor and the owner will have to put in more energy and effort in proving, negotiating and discussing about the dispute. This involves procedures to make the report, gathering project records, calculating delays etc. All these need extra effort. This will tend the parties to more focus and work to resolving the dispute rather than concentrating on the completion of the project. All those extra effort which can be used in effective project management is traded to resolving the dispute. This might witness a loss in project progress at such circumstances.

Relationship

Due to the claiming environment between the parties, the trust between the parties goes down making the relationship and communications very ineffective to the point that everything has to be proved or validated. This would slow down the speed of the project and escalates costs. Both parties loose in this scenario.

Inference

Schedules are used to help project management and complete the project in the most effective way. In this thesis, the approach of the contractor is to be prepared with schedules along with legal considerations to help negotiation and avoid claims in legal proceeding. Though parties resolve disputes in negotiation, this approach of solving claims takes in extra effort and energy disrupting the purpose of schedule and hindering project progress. In this approach both parties loose and offensive in nature. There is a need for a defensive approach where both parties can win. The next section would discuss how claims can be avoided with a defensive approach.

11.2 Defensive Approach

In the offensive approach, the preparedness was more towards the aftereffects of a dispute and as discussed above it has serious consequences. In my opinion, the contractors should more focus on the prevention rather than the cure which brings to a defensive approach that involves prevention of a dispute. To move towards prevention, the owners and contractors shall opt for a collaborative approach rather than an adversarial approach (Nestel, 2011). This section would discuss a model by which EPC contractors and owners can collaborate from a schedule perspective.

The collaborative model

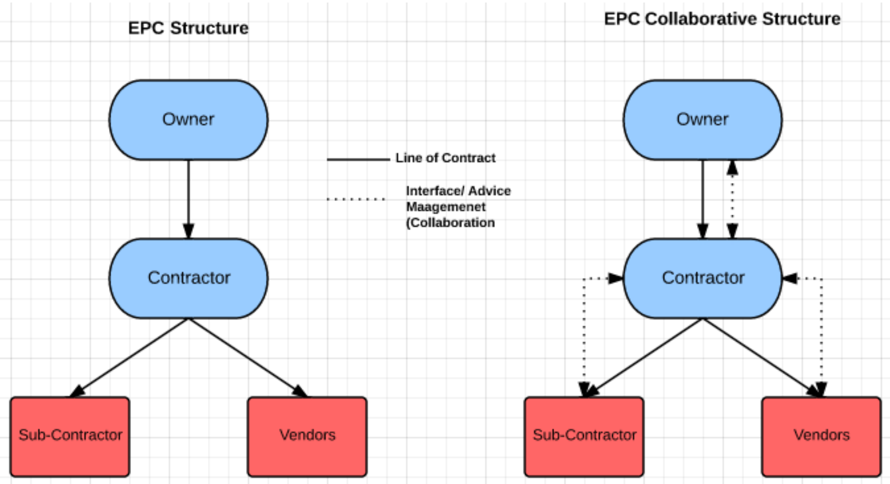


FIGURE 35: EPC COLLABORATIVE STRUCTURE

In the EPC model of contract, the contractor has to execute and deliver the project in an agreed time and budget. The risk of the schedule and budget lies with the contractor. The owner will have a representative who will be present in the contractor's office and overlook at the works carried out by the contractor with the agreed scope of work and the contract. In this model, one can see the contractor to be the executer and the owner to be a verifier/controller for the project. This model has a single point of responsibility to the players with clear divisions of liabilities and obligations (Weidinger, 2010). The line of collaboration is hardly present in this model. And this could sprout differences between the players which can cause disputes and can affect the project. There is a need for a in advice/interface management outside the contract. This would help to properly execute the interfaces between the owner and the contractor and support smooth running of the project.

Time for collaboration

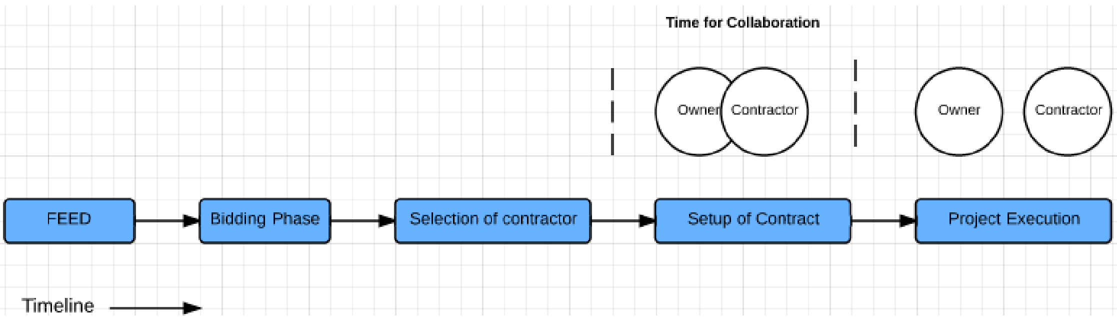


FIGURE 36: TIME FOR COLLABORATION

The above diagram depicts the process of an EPC project. First the Front End Engineering and Design (FEED) for the EPC project is performed. The whole design of the project is fixed at this stage. Then with the FEED the proposal phase for the main construction of the project is performed where EPC contractors can bid their proposals. The owner chooses the EPC contractor with the best bid and then makes a contract. After the contract, the involvement of the EPC contractor starts and the project is executed (Weidinger, 2010).

The collaboration of the employer and the contractor shall not be throughout the project. This is because, the EPC contract model focuses more on individual responsibility and does not involve too much of owner intervention (Weidinger, 2010). If this exists, the responsibility of the intervention will lead to even more disputes.

Areas of collaboration

1. Collaborative Contracting

This section will be discussed in terms of the FIDIC standard conditions of contract for EPC/Turnkey Projects. This is because of the dominance of the FIDIC conditions of contract that is preferred by the global construction Industry (Seifert, 2005). There are many conditions of contract published by the FIDIC. Since this thesis is more concerned with EPC projects, the EPC version of the FIDIC will be discussed in this section.

On careful observation of the FIDIC conditions of the contract, one can find that it is more reactive and hindsight based approach of contracting (the areas would be explained below). This would mean that the events are expected to occur first and then the parties react with each other. This is more of an offensive approach by which it has its impacts as explained in the previous section. There is a need for proactive and foresight based approach (these solution areas are also explained below) for keeping the disputes preventable and achieve project success in a collaborative way. These areas are now discussed below.

Risk Register

If one observes the FIDIC clause 8.4 [Extension of Time for completion], the contractor will react with a notice after any of the purpose of delays (enlisted in the clause) has occurred in the project. This means the approach of the contractor towards the owner is more reactive, that is performing actions after a particular event has occurred. Incorporating the FIDIC conditions, a significant number of cases has been recorded at the ICC court, UK. The stats of arbitration in ICC court have remained constant at a staggering 14% in the past two decades and it has not changed[25] (Baker, 2013). In order to reduce disputes, the players of the project shall move towards a more collaborative process with a proactive approach. This can be done by implementing a risk register, that behaves like an early warning mechanism, from both the contractor and the owner that can help them conduct risk reduction meetings to come, discuss and solve potential risks and concerns much before they can occur. This kind of an approach enhances cooperation and communication right from the start of the project. The risk register can be created and updated along with the submission of the program of the project as the events and information of the impact of the risk will be related to the schedule of the project. Such an early mechanism process shall be enforced in the contract, to make the players obligated to perform the risk reduction process for the benefit of the project. If such conditions are absent, the contractor might not follow such a mechanism and possibility of reactive play can be witnessed which will hinder project success.

Program of the Project

The FIDIC gives less importance to the program of the project which is explained in clause 8.3 [Program]. The program is highly biased by making the contractor the sole creator of the program without giving the power to the owner to accept or reject it (unless and until it does not comply with the contract). The program might also contain activities that belong to the owner. A skilful planner can place the owner activities in the critical path to have an advantage of getting an extension of time if in case the owner causes a delay. And any events

[25] FIDIC Contracts: Law and Practice, By Ellis Baker et al, 2013, page 1.36

delayed later can erupt disputes about the blame of that delay. The line of collaboration cannot be witnessed in this scenario. For a more collaborative approach, the owner shall be empowered, through the contract, with the program creation (which is done in the start of the project). The areas where in which such collaboration can be done are discussed in detail in the next section. While structuring this kind of an approach in the contract, care should be taken to prevent any joint liability of the delays, which would otherwise erupt even bigger disputes over delays. This is because, the EPC model has a single point of responsibility to the players with clear divisions of liabilities and obligations (Weidinger, 2010) and this would cause a bigger confusion over the responsibility of delays when having a joint liability. The program shall be designed collaboratively, but after the program is created the players shall take their positions of their responsibilities for their respective project activities.

2. DESIGN OF PROGRAM OF THE PROJECT

This section would concentrate on the areas where the contractors and the owners can collaborate in the schedule's perspective for reducing disputes and enhancing project success.

The program of the project is created by the contractor. This means the contractor has the full control of creating the schedule. A skilful planner can place the owner activities in the critical path to have an advantage of getting an extension of time if in case the owner causes a delay. This would arrest the flexibility of the owner activities and highly vulnerable for disputes to take place in case of owner delay. The contractor shall collaborate with the owner in making the program to provide the owner's activities with sufficient float so that the owner has flexibility in his deliverables.

Also sometimes, the schedule for the project might be too optimistic. This is because of the difference of the expectation of the owner and the need to complete the project within the project completion date. The owner and the contractor shall collaborate in ensuring enough float between activities to make the completion date feasible. This shall also take into account the possibility of unforeseen risks like bad weather, so that the completion date is a feasible one. When the time provided for the project is set in a safe zone at the beginning of the project, the chances of disputes for extension of time will decrease.

11.3 OFFENSIVE APPROACH AND DEFENSIVE APPROACH: COMPARISON

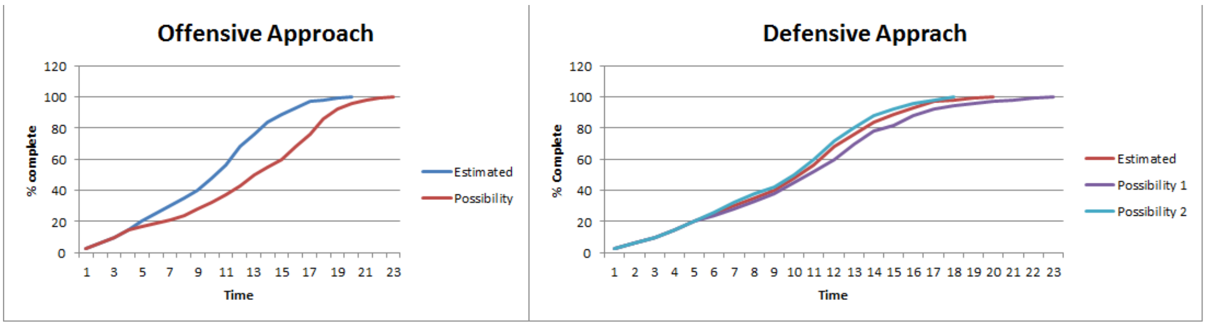


FIGURE 37: COMPARISON OF BOTH APPROACHES

The difference between the two approaches is explained in terms of project progress. If one looks at the offensive approach graph, the project progress has a broad negative shift, which means the project progress is affected badly. This can be due to factors like the liability approach, interference of a dispute, shift of focus to disputes etc. This will also impact increased costs and time for settling the dispute and finishing the project.

If the parties tend to collaborate via the defensive approach, one can see that there are two possibilities. The first possibility shows that the project can be completed faster than estimated. This is because, the schedule is collaborated in such a way that there is sufficient float for activities and also if unforeseen risks are also included in the schedules and did not occur during the project, the project has increasing chances to complete fastly. In possibility two, there is a slight negative shift of the project progress, but not as much as the offensive approach. This might be because of the increased effect of unforeseen risks than estimated. Overall, the defensive approach has grater chances of project success than the offensive approach. Additional advantages also include the good relationship and trust between parties.

11.4 Summary

Building schedules from a legal approach hinders project success and the relationship between parties become unhealthy. Instead, the parties should seed in trust and collaboration and have an approach to prevent a dispute rather than curing it.

REFERENCES

(2003). *PFI: Construction Performance .* THE COMPTROLLER AND AUDITOR GENERAL.

AACE. (2011). *Recommended Practice 29R-03.* AACE.

Abboshi, M., & Yahya, A. (2013). *Construction Delay Claims*. Retrieved 2013, from Najah.edu: http://staff.najah.edu/sites/default/files/Ch%2012.pdf

Acumen. (2013). *Customers*. Retrieved from Acumen.com: http://www.projectacumen.com/company/customers/

Acumen. (2014). *GAO Scheduling Best Practices*. Retrieved February 2014, from www.project Acumen.com: http://www.projectacumen.com/resource/gao-scheduling-best-practices/

Assaf, & Al-Hejji. (2006). Causes of delays in large construction projects. *International Jounal of Project Management*, 349.

Baker, E. (2013). *FIDIC Contracts: Law and Practice.* Informa.

Bara, E. M. (2002). *Delay and Time extension.* navigating consulting Inc.

Braimah, N. (2013). *Construction Delay Analysis Techniques—A Review of Application Issues and Improvement Needs.* UK: Brunel University.

Canadian Fuels. (2012). *Fuels and Mobility: Fuel Markets and Pricing*. Retrieved November 2013, from Canadian Fuels Association: http://canadianfuels.ca/index_e.php?p=94

Chalmers, S. (2012, February). *Choice of law in international contracts: An English law primer*. Retrieved September 2013, from King & Spalding Energy News Letter: http://www.kslaw.com/library/newsletters/EnergyNewsletter/2012/February/article5.html

DeMotte, R. D. (2014, jan). *Recent Article helps in navigating Foresnic schedule analysis*. Retrieved Jan 2014, from http://www.klconstructionlawblog.com: http://www.klconstructionlawblog.com/2014/01/articles/articles-and-publications/recent-article-offers-help-in-navigating-forensic-schedule-analysis/

Faridi, & El-Sayegh, S. M. (2006). Significant Factors causing delay in UAE contruction Industry. *Construction Management & Economics Journal*, 1167-76.

Galloway, P. (2006). CPM Scheduling - How Industry Views its use. *Cost Engineering (AACE)*, 24-29.

Gorse, C. A. (2006). *Practicalities of Delay Analysis: Retrospective Analysis.* Birmingham: 22nd ACOM Conference.

Government Accountability Office. (2012). *GAO Schedule Assessment.*

Hinze, J. W. (2012). *Construction Planning and Scheduling.* Pearson.

Hodges, P. (2013, July 11). *Butadiene Price Collapse sends warning on H2 demand*. Retrieved from http://www.icis.com: http://www.icis.com/blogs/chemicals-and-the-economy/2013/07/butadiene-prices-down-64-from-peak-as-demand-destruction-continues/

Hulett, D. (2011). *Practical schedule Risk Analysis.* Gower Publishing.

Jergeas, O'Toole, J., & George. (2010). *Lump Sum Contracting on Western Canadian Oil and Gas Capital Projects: Industry Opinion.* Alberta Finance and Enterprise.

Kasab, M., Hipel, K., & Hegazy, T. (2006). Conflict Resolution in Construction Disputes using graphic model. *Journal of construction engineering and management* , 1043-1052.

Keane, P. J., & Caletka, A. F. (n.d.). Delay Analysis in Construction Contracts. Wiley-BlackWell.

Kelly, P. M. (2013). *The Future Of Forensic Schedule Analysis: The Good, the Hard and the Scary* . Retrieved October 2013, from Arcadis: http://www.arcadis-us.com/Future_of_Forensic_Schedule_Analysis_Good_Hard_Scary.aspx

Leon, G. P. (2010). Guide to the Forensic Scheduling Body of Knowledge—Part 1.

Lyer, K., & Jha, K. (2006). Critical factors afecting schedule performance: Evidence from Indian construction Projects. *Journal of construction Engineering and Management, ASCE*, 871-881.

McCaffrey, G. (2003). *The Devil is in the detail.* Edinburgh: Adjudication Society.

Menesi, W. (2008). construction delay analysis under multiple baseline updates. (p. 28). University of Waterloo.

Motaleb. (2009). *An investigation into the causes,effects and handling of construction delays in the United Arab Emirates.* Unpublished MSc thesis, Robert Gordon, Aberdeen, UK.

Nestel, D. L. (2011). *Deconstructing Adversarial Contracting: Towards Success-Focused Contracting.*

Nicholas, J. M., & Steyn, H. (2012). *Project Management for Engineering, Business and Technology.* New York: Routledge.

Oomes, V. (2012). Dutch Oil & Gas Conference 2012. (pp. 16-21). Rotterdam: Deloitte.

Ridder, & J.Long. (2013). *Analysis of concurrent/pacing Delay.* Long International.

Ron Winter Consulting LLC . (2002). Checks and Balances: Baseline Schedule Review. *2002 Primavera Users Conference.*

Samantha. (2002). An overview of construction claims: How they arise and how to avoid them. *Lorman Seminar for construction Conracting for Public Entities in British Columbia* (pp. 7-9). Clark Wilson LLP.

Seifert. (2005). *International construction Dispute Adjudication under International Federation of Consulting Engineers Conditions of Contract and the dispute Adjudication Board.* Journal of Construction Engineering and Management.

Smyte, S. (2012, July). *Construction Completion Dates: There and Back Again* . Retrieved December 2013, from Real Estate matters: http://news.mccarthy.ca/en/news_template.asp?pub_code=5951&news_code=1769&single_page=1

Society of construction law. (2002). *Delay and disuption protocol.* Society of construction law.

Tennant, S., & Mbele, V. (2013). *The consumer protection act and five common law principles.* South African Legal Information Institute.

Weidinger, G. (2010). *Contracting strategies in the oil and gas industry.*

Winter, R. (2009). Much Ado About Dates. *AACEi Annual Conference*, (pp. 18, 19).

World Bank. (2006). *Key Features of Common Law or Civil Law Systems* . Retrieved December 2013, from Worldbank.org: http://ppp.worldbank.org/public-private-partnership/legislation-regulation/framework-assessment/legal-systems/common-vs-civil-law

WPL Publishing. (2014). *WPL Publishing to Host Webinar on Forensic Schedule Analysis in Construction* . Retrieved 2014, from http://www.prweb.com: http://www.prweb.com/releases/2013/10/prweb11202798.htm

APPENDIX

APPENDIX: CLASSIFICATION OF FORENSIC ANALYSIS

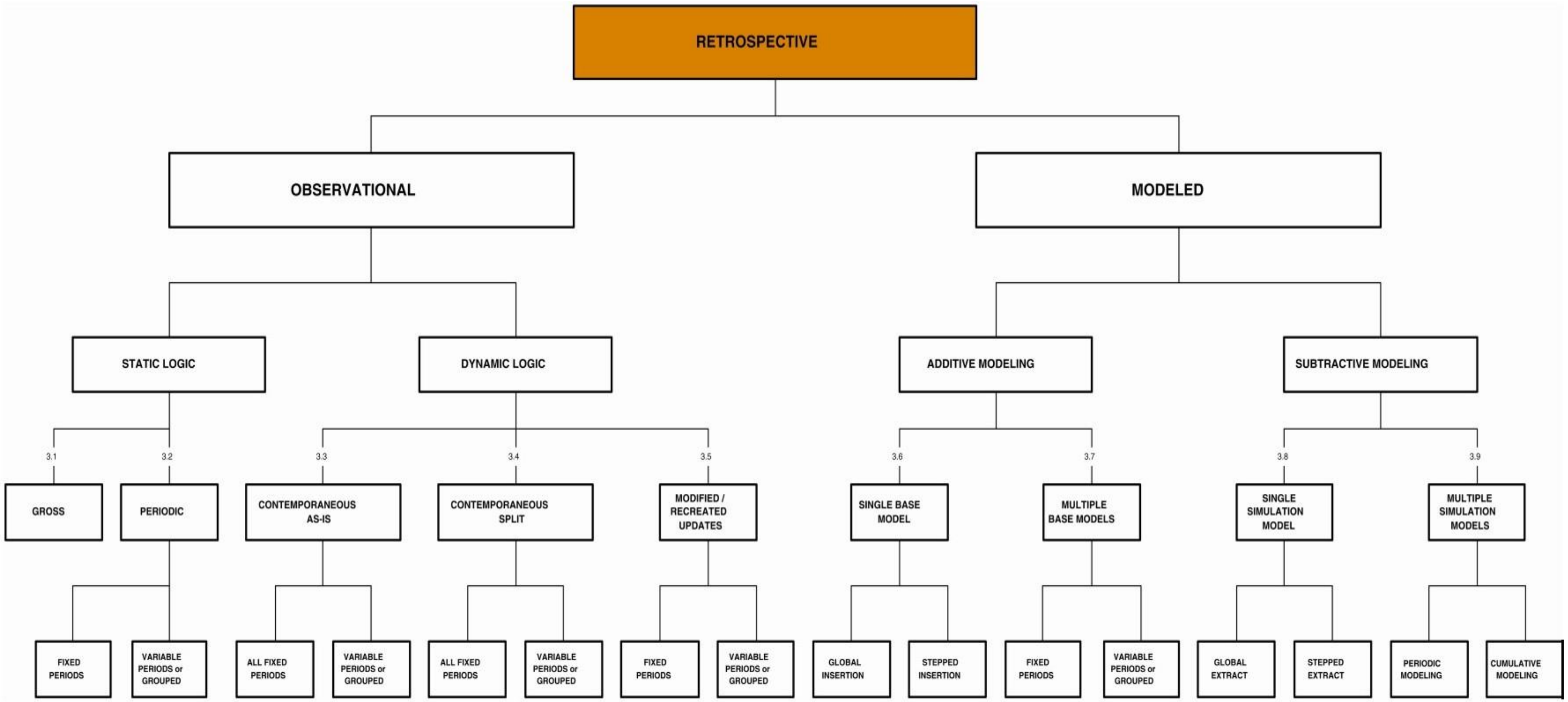


FIGURE 38: CLASSIFICATION OF VARIOUS METHODS OF ANALYSIS INVALID SOURCE SPECIFIED.

APPENDIX: VALIDATION OF DELAY FOR THE CASE

Validity of Delay matrix:

TABLE 11: LIABILITY MATRIX

Activity Delayed by	Notice Given	Delay Liability
Contractor Activity	YES	CONTRACTOR
Contractor Activity	NO	CONTRACTOR
Owner Activity	YES	OWNER
Owner Activity	NO	CONTRACTOR

With the help of the matrix, the liability of a delay event is formulated below:

TABLE 12: DELAY LIABILITY BASED ON LIABILITY MATRIX

Activities	Activity ID	Delay	Cause	Notice	Liability
MILESTONES					
Start Project Execution - Effective Date	M1	NO	-	-	-
Area ready for Piling (By Client)	M2	YES	Owner	NO	Contractor
Engineering Deliverables - Piling AFC (sufficient for construction Contractors to Start)	M3	NO	-	-	-
Start of Piling Works	M4	YES	Owner and Piling S/C	YES	Owner
Engineering Deliverables - Civil AFC (sufficient for construction constructors to Start)	M5	YES	Contractor	YES	Contractor
Project End	M6	YES	-	YES	NOT KNOWN
ENGINEERING					
PILING					
Pipe Rack Piling Design	EP1	YES	Contractor	NO	Contractor
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	YES	Contractor	NO	Contractor
Column 22, Column 31 Piling Design	EP3	YES	Contractor	NO	Contractor
Structure 2 Piling Design	EP4	YES	Contractor	NO	Contractor
Column 34 Piling Design	EP5	YES	OWNER	YES	OWNER
Compressor Piling Design	EP6	YES	OWNER	YES	OWNER
CONSTRUCTION					
Pipe Rack South Foundation Design	EC1	YES	Contractor	YES	Contractor
SUBCONTRACTING					
PILING					
Piling Works S/C Award	SP1	YES	Owner	YES	Owner
Piling Works S/C Mobilization	SP2	YES	Owner and Piling S/C	YES	Owner

CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	NO	-	-	-
Civil S/C Req. Issue Inquiry	SC2	NO	-	-	-
Civil S/C Req. Bids Opening	SC3	NO	-	-	-
Civil S/C Req. Bid Evaluation and POR	SC4	NO	-	-	-
Civil Works S/C Award	SC5	YES	Owner	YES	Owner
Civil Works S/C Mobilization	SC6	YES	Owner and Piling and civil S/C	YES	Owner
CONSTRUCTION					
PILING					
Pipe Rack Piling - Machine1	CP1	YES	S/C	YES	NOT KNOWN
Structure 1, Column 21, Colum 41, Column 45 - Machine 2	CP2	YES	S/C	YES	NOT KNOWN
Structure 2 - Machine 2	CP3	YES	S/C	YES	NOT KNOWN
FOUNDATION					
Pipe Rack South Part	CC1	YES	S/C	YES	NOT KNOWN

APPENDIX: ANALYSIS 1 – IMPACTED AS-PLANNED

In the impacted as planned method, the contractor and owner's delays are separately diagnosed. First the contractor caused delays are inserted in the schedule and the project completion date is observed. This gives the contractor's delay impact on the project.

Similarly, the owner delays are inserted in the schedule and the project completion date is observed. This gives the owner's delay impact on the project.

Both these impacts are analyzed and the EOT is calculated. Now let us perform this analysis in our case study.

Recalling from chapter 6, the following is the as planned and the as built schedule of the case:

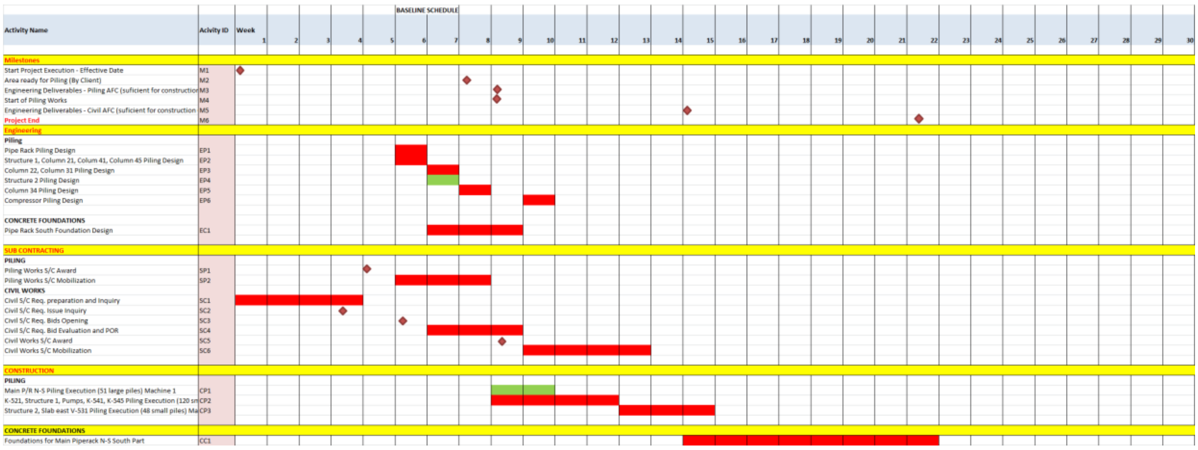


FIGURE 39: AS - PLANNED SCHEDULE

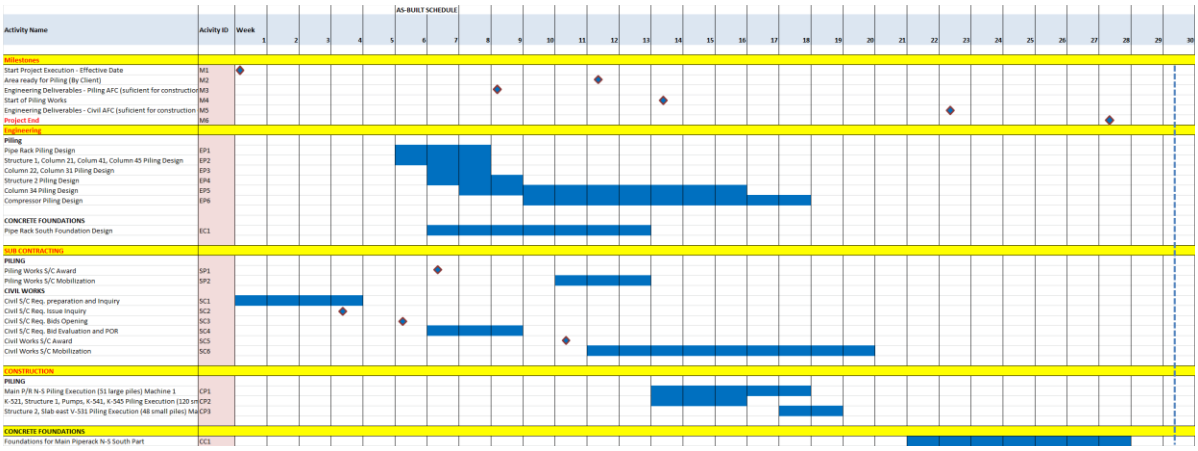


FIGURE 40: AS-BUILT SCHEDULE

Now we shall calculate the contractor and owner caused delays separately. First, we will calculate the contractor caused delays. This would only show case the contractor as built events in the as planned schedule and the project completion is calculated. The owner events remain as planned. This would give the result of the contractor caused delays on the project.

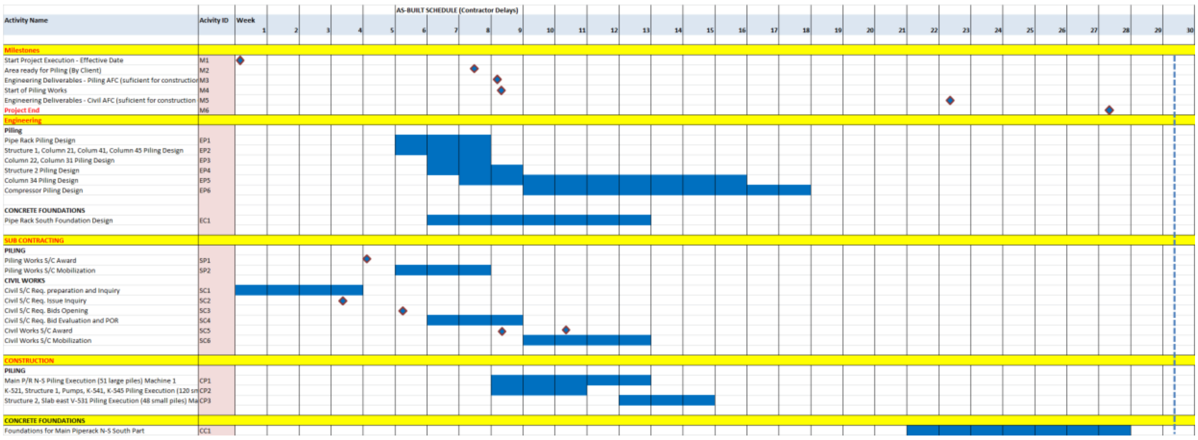


FIGURE 41: CONTRACTOR DELAY ON PROJECT

The contractor made a huge delay in the foundation designs deliverables ‘M5’, causing a late start of foundation activity CC1. Thus it can be seen that the project completion is on week 28. This means the contractor is responsible for the 6 weeks of delay.

Now let us calculate the owner caused delays. This would only show case the owner as built events in the as planned schedule and the project completion is calculated. The contractor events remain as planned. This would give the result of the owner caused delays on the project.

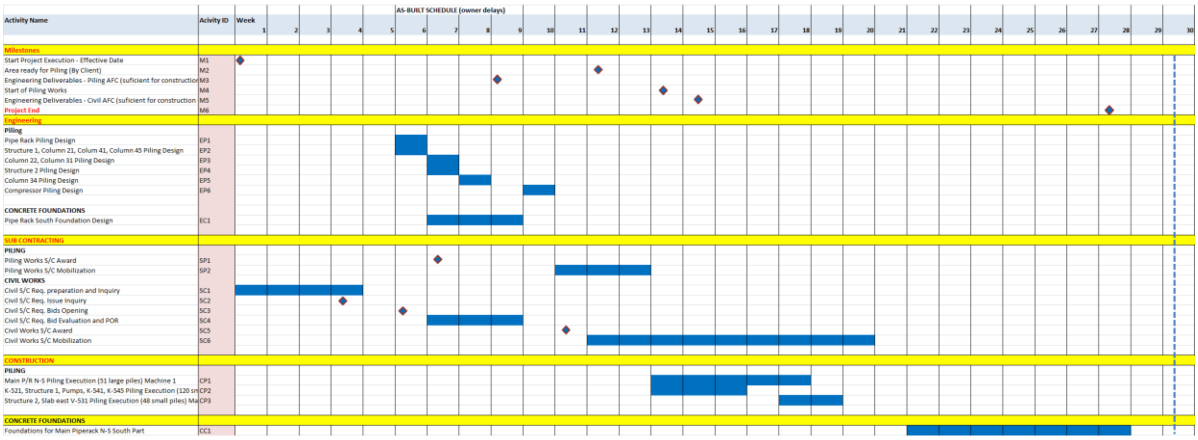


FIGURE 42: OWNER DELAYS ON PROJECT

The owner’s piling and civil subcontractor has caused a delay in their mobilization. Thus causing delay in construction activities of piling and foundation collectively. This caused a delay of the project completion to week 28, causing 6 weeks of delay. Thus the owner is also responsible for 6 weeks of delay for the project.

In summary, both the owner and contractor are responsible for 6 weeks of concurrent delay. According to the UK English law, the contractor’s delay to completion occurs concurrently with the employer’s delay to completion, the contractor’s concurrent delay should not reduce any EOT due. Thus, the EOT due by the owner is 6 weeks. In this analysis method, the share of delay is 50:50 share between the client and owner.

APPENDIX: ANALYSIS 2- MIP 3.3 OBSERVATIONAL TECHNIQUE

The monthly updates are used as discrete windows and net delays are calculated at the end of each window. This would help in fair apportioning of delays by considering the dynamic nature of the critical path.

The schedule observed 5 updates being created. Thus each of these updates is treated as separate window. The following is a table representing the windows and their corresponding weeks:

TABLE 13: WINDOWS TABLE

Window	Window Period	Schedule at Window Start	Schedule at Window End
1	Weeks 1 to 13	Baseline (As-Planned Schedule)	Update 1
2	Weeks 14 to 18	Update 1	Update 2
3	Weeks 19 to 22	Update 2	Update 3
4	Weeks 23 to 26	Update 3	Update 4
5	Weeks 27 to 31	Update 4	As-Built Schedule (Update 5)

WINDOW 1

Let us start the analysis with window 1. Here we observe two schedules – as planned schedule and the update 1 schedule.

Activity Name	Acivity ID	Original Duration	Remaining Duration	Total Float	Successors
Milestones					
Start Project Execution - Effective Date	M1	0	0	0	EP1, EP2, SP1, M2, SC1
Area ready for Piling (By Client)	M2	0	0	0	M4, CP1
Engineering Deliverables - Piling AFC (suficient for construction Constractors to Start)	M3	0	0	0	CP1
Start of Piling Works	M4	0	0	0	CP1
Engineering Deliverables - Civil AFC (suficient for construction Constractors to Start)	M5	0	0	0	CC1
Project End	M6	0	0	0	NIL
Engineering					
Piling					
Pipe Rack Piling Design	EP1	1	1	0	CP2, EP3, EC1
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	1	1	0	CP2,EP4
Column 22, Column 31 Piling Design	EP3	1	1	0	EP5
Structure 2 Piling Design	EP4	1	1	3	CP3
Column 34 Piling Design	EP5	1	1	0	M3, EP6
Compressor Piling Design	EP6	1	1	0	CP3
CONCRETE FOUNDATIONS					
Pipe Rack South Foundation Design	EC1	3	3	0	CC1, M5
SUB CONTRACTING					
PILING					
Piling Works S/C Award	SP1	0	0	0	SP2
Piling Works S/C Mobilization	SP2	3	3	0	CP1, CP2
CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	4	4	0	SC2
Civil S/C Req. Issue Inquiry	SC2	0	0	0	SC3
Civil S/C Req. Bids Opening	SC3	0	0	0	SC4
Civil S/C Req. Bid Evaluation and POR	SC4	3	3	0	SC5
Civil Works S/C Award	SC5	0	0	0	SC6
Civil Works S/C Mobilization	SC6	4	4	0	CC1
CONSTRUCTION					
PILING					
Main P/R N-S Piling Execution (51 large piles) Machine 1	CP1	2	2	4	CC1
K-521, Structure 1, Pumps, K-541, K-545 Piling Execution (120 small piles) Machine 2	CP2	4	4	0	CC1, CP3
Structure 2, Slab east V-531 Piling Execution (48 small piles) Machine 2	CP3	3	3	0	CC1 (SS)
CONCRETE FOUNDATIONS					
Foundations for Main Piperack N-S South Part	CC1	8	8	0	M6

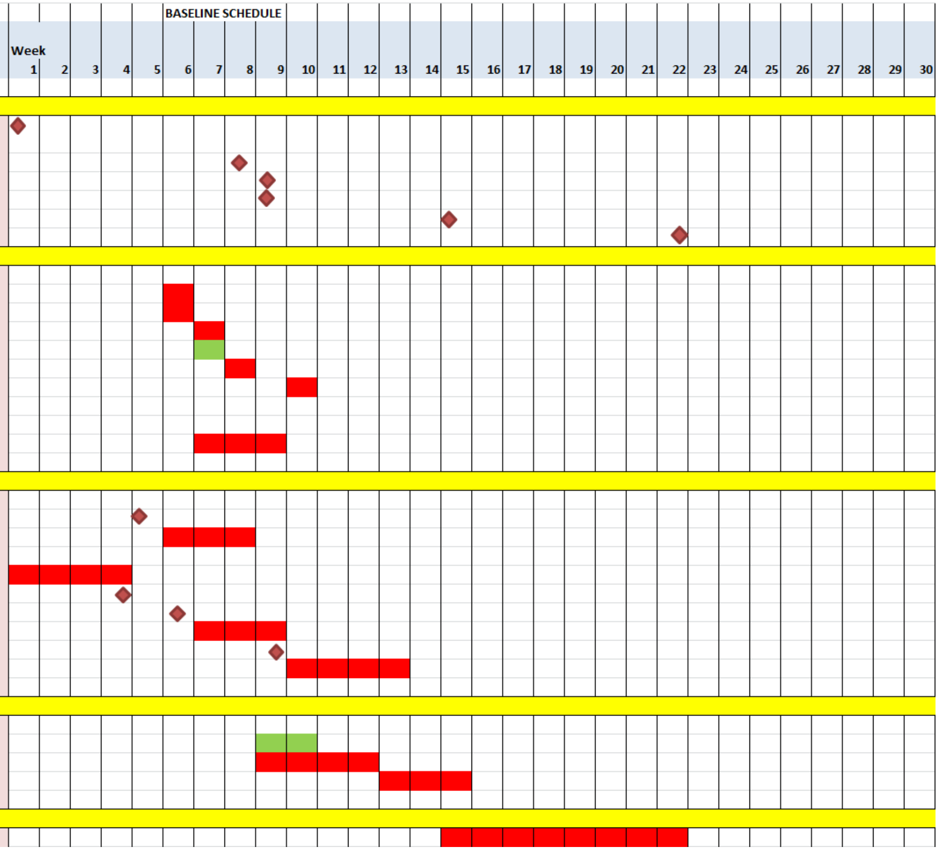


FIGURE 43: AS PLANNED SCHEDULE

Activity Name	Acivity ID	Original Duration	Remaining Duration	Total Float	Successors
Milestones					
Start Project Execution - Effective Date	M1	0	0		EP1, EP2, SP1, M2, SC1
Area ready for Piling (By Client)	M2	0	0		M4, CP1
Engineering Deliverables - Piling AFC (suficient for construction Constractors to Start)	M3	0	0		CP1
Start of Piling Works	M4	0	0	0	CP1
Engineering Deliverables - Civil AFC (suficient for construction Constractors to Start)	M5	0	0	0	CC1
Project End	M6	0	0		NIL
Engineering					
Piling					
Pipe Rack Piling Design	EP1	1	0		CP2, EP3, EC1
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	1	0		CP2,EP4
Column 22, Column 31 Piling Design	EP3	1	0		EP5
Structure 2 Piling Design	EP4	1	0		CP3
Column 34 Piling Design	EP5	1	1	0	M3, EP6
Compressor Piling Design	EP6	1	4	0	CP3
CONCRETE FOUNDATIONS					
Pipe Rack South Foundation Design	EC1				CC1, M5
SUB CONTRACTING					
PILING					
Piling Works S/C Award	SP1	0	0		SP2
Piling Works S/C Mobilization	SP2	3	0		CP1, CP2
CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	4	0		SC2
Civil S/C Req. Issue Inquiry	SC2	0	0		SC3
Civil S/C Req. Bids Opening	SC3	0	0		SC4
Civil S/C Req. Bid Evaluation and POR	SC4	3	0		SC5
Civil Works S/C Award	SC5	0	0		SC6
Civil Works S/C Mobilization	SC6	4	6	0	CC1
CONSTRUCTION					
PILING					
Main P/R N-S Piling Execution (51 large piles) Machine 1	CP1	2	3	4	CC1
K-521, Structure 1, Pumps, K-541, K-545 Piling Execution (120 small piles) Machine 2	CP2	4	5	0	CC1, CP3
Structure 2, Slab east V-531 Piling Execution (48 small piles) Machine 2	CP3	3	3	0	CC1
CONCRETE FOUNDATIONS					
Foundations for Main Piperack N-S South Part	CC1	8	8	0	M6

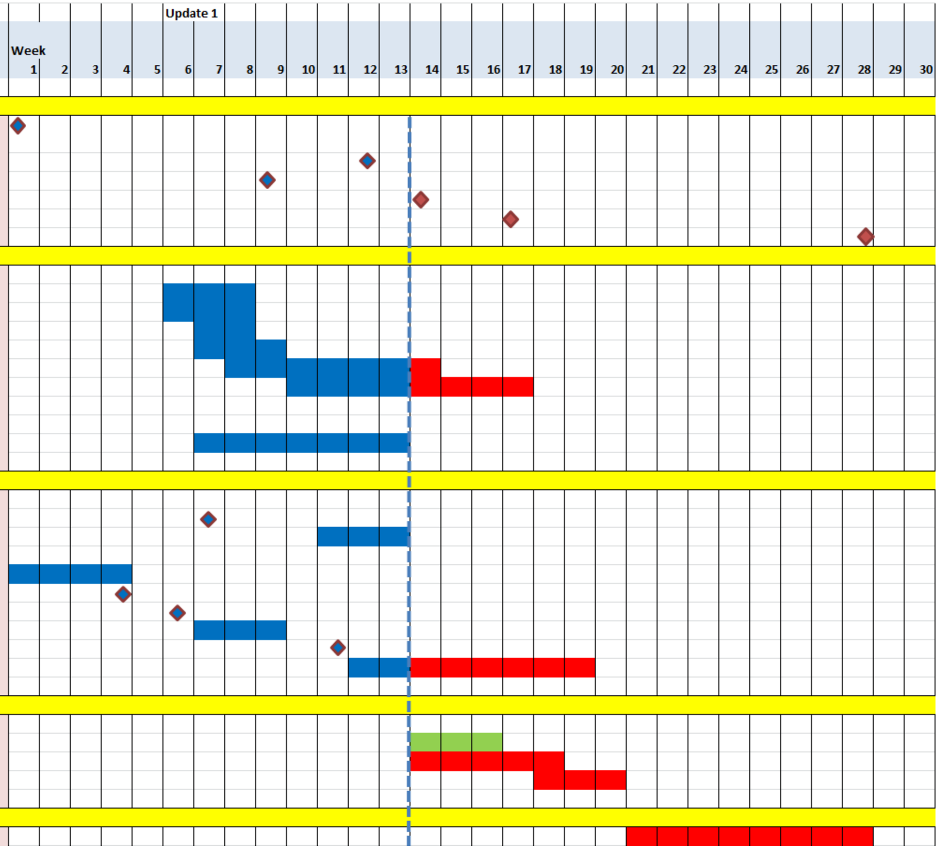


FIGURE 44: UPDATE 1

For apportioning the delays, the two windows are compared. All the activities are tabulated and the corresponding activity variance (activity delay) and the project delay are calculated. This will enable us to see the progress of the project delay with each activity delay occurring in the project. At the end of the table, the net delay is noted.

The numbers ending with 'a' are denoted as actual data dates. The activities where delays are occurring at the same time are concurrent delays and those delays are represented by ending activity variance number with "(c)". These concurrent delays have a combined effect on the total project delay.

The notes column in the table defines whether a activity has delays (or savings) experienced by a critical activity. The following are used: STE (Slower than Expected) and BTE (Better than Expected)

For each activity, the activity variance (activity delay) is calculated in one column, to which if there is an impact of the project complete, the delay of project is calculated in the next column. Likewise, all the activities are tabulated below:

TABLE 14: WINDOW 1 FORENSIC ANALYSIS

ID	Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
		Planned Start	Planned Finish	Revised Start	Revised Finish				
Window 1 (Baseline and Update 1)									
M1	Project Start	1		1a		0	0	22	As-Planned
SC1	Civil S/C Prep	1	4	1a	4a	0	0	22	As-Planned
SC2	Civil S/C Issue	4		4a		0	0	22	As-Planned
SP1	Piling S/C Award	5		7a		2	2	24	STE
EP1	p/r Pil Design	6	6	6a	8a	2	0	24	STE
EP2	Struc-1 Piling Design	6	6	6a	8a	2	0	24	STE
SC3	Civil S/C open bid	6		6a		0	0	24	As-Planned
SP2	Pil. S/C Mob.	6	8	11a	13	3(5-2)	3(c)	27	STE, sequential delay
EP3	C-22 Pil Design	7	7	7a	8a	1	0	27	STE
EC1	P/R Found Design	7	9	7	13	4	4(c)	27	STE
SC4	Civil S/C Eval	7	9	7a	9a	0	0	27	STE
M2	Area by client	8		12a		4	4(c)	27	STE
EP5	C-34 Pil	8	8	8a	14	6	0	27	STE

	Design								
M3	Piling AFC	9		9a		0	0	27	STE
M4	Stat Pil	9		14		5	0	27	STE
SC5	Civ S/C award	9		11a		2	2(c)	27	STE
CP2	Struc-1 Pil const	9	12	14	18	5	0	27	STE
EP6	Comp pil design	10	10	10a	17	5(7-2)	5(c)	27	STE, sequential delay
SC6	Civil s/c mob	10	13	12	19	6	5(c), 1	28	STE
CP3	Comp. piling	13	15	18	20	5	0	28	STE
						Window 1 Net Delays	6	28	

Piling Design EP4 was not considered in the analysis, as it has float and not impacting the project finish. The piling designs EP1, EP2, EP3 and EP5 has not caused any impact on the project delay as the milestone Piling Engineering Deliverables AFC has become a hard constraint (by giving actual data date) on the promised date and hence did not create an impact for the end of foundation construction activity CC1. This means the relationship given in the as planned schedule is not respected, but practically, the sufficient deliverables (EP1, EP2 and EP3) were submitted. In the activities of SP2 and EP6 one can see that the activity variance is derived from a difference of delays represented in the brackets. This is because the sequential delay is deducted from the total activity delay. And milestone M4 do not have any impact on the project finish as the milestone is just a representation of the start of piling works and hence not considered for the impact of the delay. SP2, EC1, M2, SC5, EP6 and SC6 are causing concurrent delays as they are having delays in different critical paths. Thus, the effective delay calculated for window 1 is 6 weeks and the project completion shifted from week 22 to week 28.

WINDOW 2

Here the update 1 and update 2 schedules are compared with one another and the activity variance and project delays are tabulated. Refer update 1 schedule from the previous window. The update 2 schedule is depicted below.

Activity Name	Acivity ID	Original Duration	Remaining Duration	Total Float	Successors
Milestones					
Start Project Execution - Effective Date	M1	0	0		EP1, EP2, SP1, M2, SC1
Area ready for Piling (By Client)	M2	0	0		M4, CP1
Engineering Deliverables - Piling AFC (suficient for construction Constractors to Start)	M3	0	0		CP1
Start of Piling Works	M4	0	0		CP1
Engineering Deliverables - Civil AFC (suficient for construction Constractors to Start)	M5	0	0	0	CC1
Project End	M6	0	0		NIL
Engineering					
Piling					
Pipe Rack Piling Design	EP1	1	0		CP2, EP3, EC1
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	1	0		CP2,EP4
Column 22, Column 31 Piling Design	EP3	1	0		EP5
Structure 2 Piling Design	EP4	1	0		CP3
Column 34 Piling Design	EP5	1	0		M3, EP6
Compressor Piling Design	EP6	1	0		CP3
CONCRETE FOUNDATIONS					
Pipe Rack South Foundation Design	EC1	3	0		CC1, M5
SUB CONTRACTING					
PILING					
Piling Works S/C Award	SP1	0	0		SP2
Piling Works S/C Mobilization	SP2	3	0		CP1, CP2
CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	4	0		SC2
Civil S/C Req. Issue Inquiry	SC2	0	0		SC3
Civil S/C Req. Bids Opening	SC3	0	0		SC4
Civil S/C Req. Bid Evaluation and POR	SC4	3	0		SC5
Civil Works S/C Award	SC5	0	0		SC6
Civil Works S/C Mobilization	SC6	4	2	0	CC1
CONSTRUCTION					
PILING					
Main P/R N-S Piling Execution (51 large piles) Machine 1	CP1	2	0		CC1
K-521, Structure 1, Pumps, K-541, K-545 Piling Execution (120 small piles) Machine 2	CP2	4	0		CC1, CP3
Structure 2, Slab east V-531 Piling Execution (48 small piles) Machine 2	CP3	3	1	1	CC1
CONCRETE FOUNDATIONS					
Foundations for Main Piperack N-S South Part	CC1	8	9	0	M6

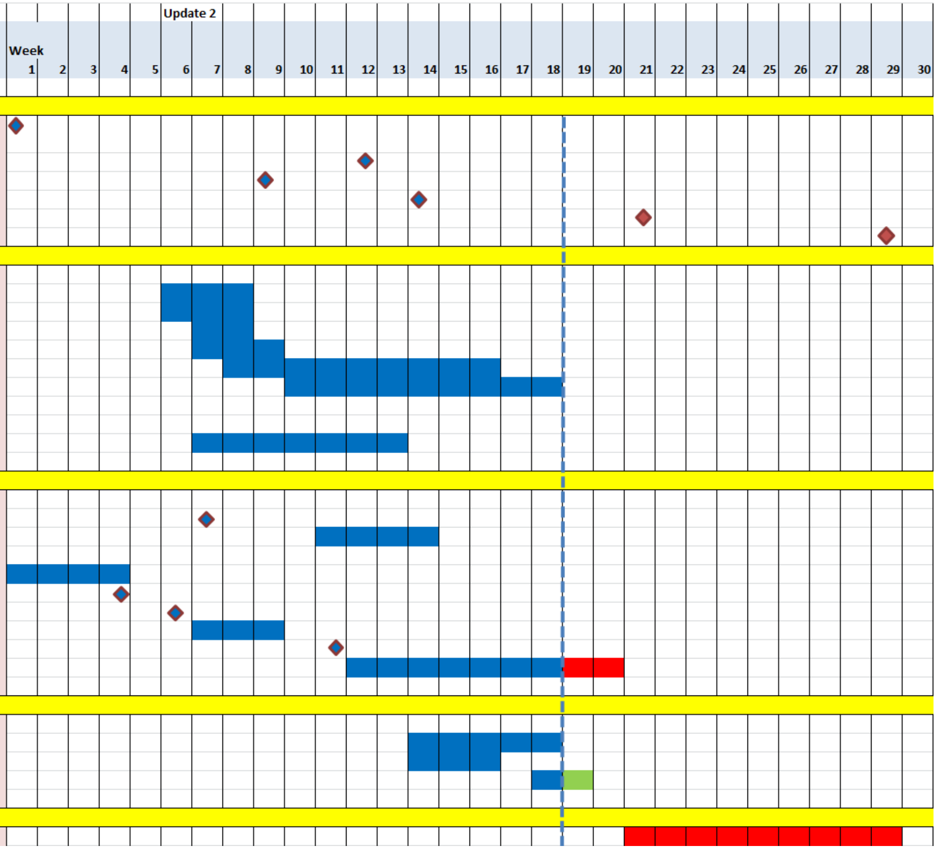


FIGURE 45: UPDATE 2

TABLE 15: WINDOW 2 FORENSIC ANALYSIS

ID	Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
		Planned Start	Planned Finish	Revised Start	Revised Finish				
						Window 1 Net Delays	8	28	
Window 2 (Update 1 and Update 2)									
EP5	C-34 Pil Design	14	14	14A	16A	2	0	28	STE
EP6	Comp pil design	14	17	14A	18A	1	0	28	STE
SC6	Civil s/c mob	14	19	14A	20	1	1(c)	28	STE
CP2	Struc-1 Pil const	14	17	14A	18	1	1(c)	29	STE
M5	Civil AFC	17		21		4	1(c)	29	STE
CP3	Comp. piling	18	20	18	19	(1)	0	29	BTE
						Window 2 Net Delays	1	29	

In this window one can see that one day delay was concurrently caused by 3 different activities causing a project delay of 1 week. Though the acceleration of 1 week was performed in the CP3 compressor piling design, there was no impact on the Project finish. Overall the window had a net delay of one week causing the project finish to delay by one week.

Window 3

Here the update 2 and update 3 schedules are compared with one another and the activity variance and project delays are tabulated. Refer update 2 schedule from the previous window. The update 3 schedule is depicted below.

Activity Name	Acivity ID	Original Duration	Remaining Duration	Total Float	Successors
Milestones					
Start Project Execution - Effective Date	M1	0	0		EP1, EP2, SP1, M2, SC1
Area ready for Piling (By Client)	M2	0	0		M4, CP1
Engineering Deliverables - Piling AFC (suficient for construction Constractors to Start)	M3	0	0		CP1
Start of Piling Works	M4	0	0		CP1
Engineering Deliverables - Civil AFC (suficient for construction Constractors to Start)	M5	0	0	0	CC1
Project End	M6	0	0		NIL
Engineering					
Piling					
Pipe Rack Piling Design	EP1	1	0		CP2, EP3, EC1
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	1	0		CP2,EP4
Column 22, Column 31 Piling Design	EP3	1	0		EP5
Structure 2 Piling Design	EP4	1	0		CP3
Column 34 Piling Design	EP5	1	0		M3, EP6
Compressor Piling Design	EP6	1	0		CP3
CONCRETE FOUNDATIONS					
Pipe Rack South Foundation Design	EC1	3	0		CC1, M5
SUB CONTRACTING					
PILING					
Piling Works S/C Award	SP1	0	0		SP2
Piling Works S/C Mobilization	SP2	3	0		CP1, CP2
CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	4	0		SC2
Civil S/C Req. Issue Inquiry	SC2	0	0		SC3
Civil S/C Req. Bids Opening	SC3	0	0		SC4
Civil S/C Req. Bid Evaluation and POR	SC4	3	0		SC5
Civil Works S/C Award	SC5	0	0		SC6
Civil Works S/C Mobilization	SC6	4	0		CC1
CONSTRUCTION					
PILING					
Main P/R N-S Piling Execution (51 large piles) Machine 1	CP1	2	0		CC1
K-521, Structure 1, Pumps, K-541, K-545 Piling Execution (120 small piles) Machine 2	CP2	4	0		CC1, CP3
Structure 2, Slab east V-531 Piling Execution (48 small piles) Machine 2	CP3	3	0		CC1
CONCRETE FOUNDATIONS					
Foundations for Main Piperack N-S South Part	CC1	8	5	0	M6

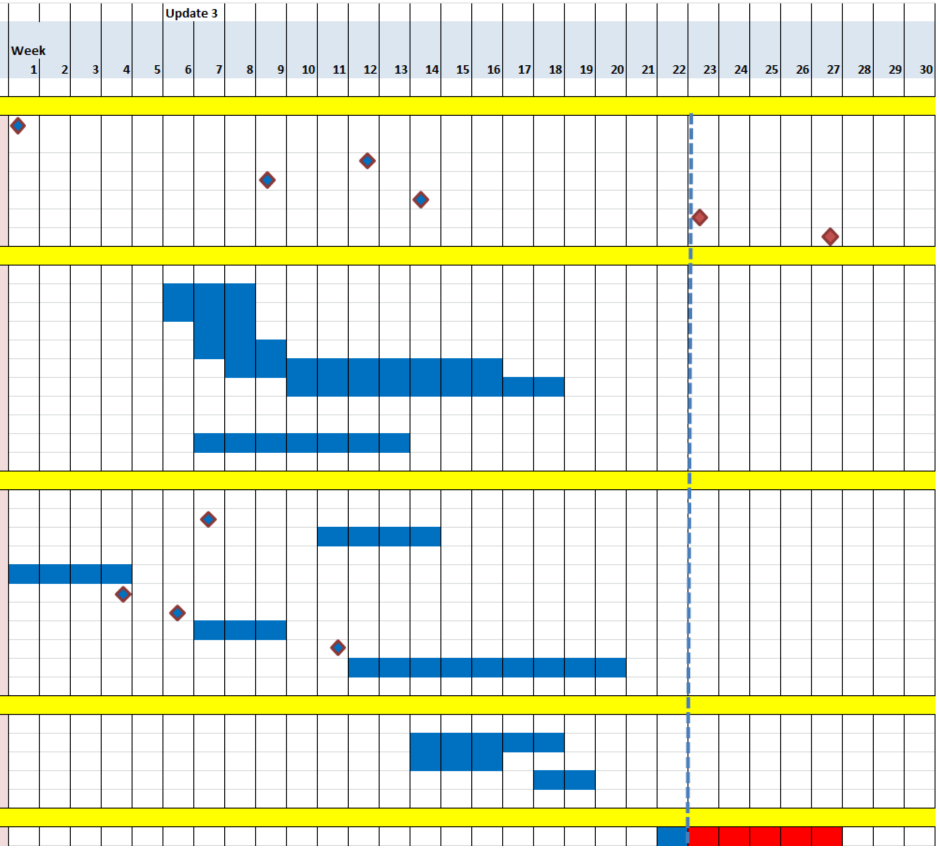


FIGURE 46: UPDATE 3

TABLE 16: WINDOW 3 FORENSIC ANALYSIS

ID	Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
		Planned Start	Planned Finish	Revised Start	Revised Finish				
						Window 2 Net Delays	1	29	
Window 3 (Update 2 and Update 3)									
SC6	Civil s/c mob	19	20	19a	20a	0	0	29	As planned
CC1	Pipe Found Const	21	29	22a	27	(2)	(2)	27	BTE
M5	Civil AFC	21		23		2	0	27	STE
						Window 3 Net Delays	(2)	27	

In this window, the CC1 foundation construction made an acceleration of 2 weeks saving 2 weeks of project delay. Though the M5 milestone activity, Civil Engineering Deliverables AFC – sufficient for construction, made a 2 week delay it did not affect the project finish as foundation construction started before the end of M5 milestone. Thus, the relationship was not respected between these activities.

WINDOW 4

Here the update 3 and update 4 schedules are compared with one another and the activity variance and project delays are tabulated. Refer update 3 schedule from the previous window. The update 4 schedule is depicted below.

Activity Name	Acivity ID	Original Duration	Remaining Duration	Total Float	Successors
Milestones					
Start Project Execution - Effective Date	M1	0	0		EP1, EP2, SP1, M2, SC1
Area ready for Piling (By Client)	M2	0	0		M4, CP1
Engineering Deliverables - Piling AFC (suficient for construction Constractors to Start)	M3	0	0		CP1
Start of Piling Works	M4	0	0		CP1
Engineering Deliverables - Civil AFC (suficient for construction Constractors to Start)	M5	0	0		CC1
Project End	M6	0	0		NIL
Engineering					
Piling					
Pipe Rack Piling Design	EP1	1	0		CP2, EP3, EC1
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	1	0		CP2,EP4
Column 22, Column 31 Piling Design	EP3	1	0		EP5
Structure 2 Piling Design	EP4	1	0		CP3
Column 34 Piling Design	EP5	1	0		M3, EP6
Compressor Piling Design	EP6	1	0		CP3
CONCRETE FOUNDATIONS					
Pipe Rack South Foundation Design	EC1	3	0		CC1, M5
SUB CONTRACTING					
PILING					
Piling Works S/C Award	SP1	0	0		SP2
Piling Works S/C Mobilization	SP2	3	0		CP1, CP2
CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	4	0		SC2
Civil S/C Req. Issue Inquiry	SC2	0	0		SC3
Civil S/C Req. Bids Opening	SC3	0	0		SC4
Civil S/C Req. Bid Evaluation and POR	SC4	3	0		SC5
Civil Works S/C Award	SC5	0	0		SC6
Civil Works S/C Mobilization	SC6	4	0		CC1
CONSTRUCTION					
PILING					
Main P/R N-S Piling Execution (51 large piles) Machine 1	CP1	2	0		CC1
K-521, Structure 1, Pumps, K-541, K-545 Piling Execution (120 small piles) Machine 2	CP2	4	0		CC1, CP3
Structure 2, Slab east V-531 Piling Execution (48 small piles) Machine 2	CP3	3	0		CC1
CONCRETE FOUNDATIONS					
Foundations for Main Piperack N-S South Part	CC1	8	2	0	M6

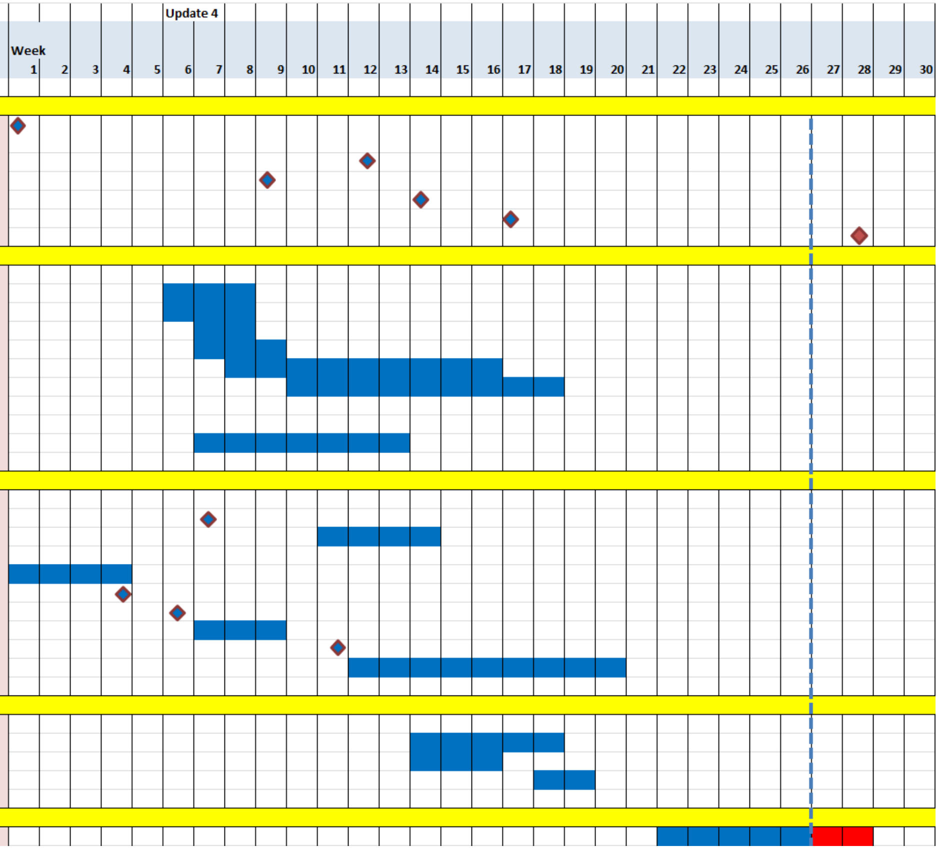


FIGURE 47: UPDATE 4

TABLE 17: WINDOW 4 FORENSIC ANALYSIS

ID	Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
		Planned Start	Planned Finish	Revised Start	Revised Finish				
						Window 3 Net Delays	(2)	27	
Window 4 (Update 3 and Update 4)									
CC1	Pipe Found Const	23	27	23a	28	1	1	28	STE
M5	Civil AFC	23		23a		0	0	28	As planned
						Window 4 Net Delays	1	28	

The pipe rack foundation construction CC1 was delayed by a week also delaying the project finish. Thus the net delay for this window is 1 week.

Window 5

Here the update 4 and update 5 schedules are compared with one another and the activity variance and project delays are tabulated. Refer update 4 schedule from the previous window. The update 5 schedule is depicted below.

Activity Name	Acivity ID	Original Duration	Remaining Duration	Total Float	Successors
Milestones					
Start Project Execution - Effective Date	M1	0	0		EP1, EP2, SP1, M2, SC1
Area ready for Piling (By Client)	M2	0	0		M4, CP1
Engineering Deliverables - Piling AFC (suficient for construction Constractors to Start)	M3	0	0		CP1
Start of Piling Works	M4	0	0		CP1
Engineering Deliverables - Civil AFC (suficient for construction Constractors to Start)	M5	0	0		CC1
Project End	M6	0	0		NIL
Engineering					
Piling					
Pipe Rack Piling Design	EP1	1	0		CP2, EP3, EC1
Structure 1, Column 21, Colum 41, Column 45 Piling Design	EP2	1	0		CP2,EP4
Column 22, Column 31 Piling Design	EP3	1	0		EP5
Structure 2 Piling Design	EP4	1	0		CP3
Column 34 Piling Design	EP5	1	0		M3, EP6
Compressor Piling Design	EP6	1	0		CP3
CONCRETE FOUNDATIONS					
Pipe Rack South Foundation Design	EC1	3	0		CC1, M5
SUB CONTRACTING					
PILING					
Piling Works S/C Award	SP1	0	0		SP2
Piling Works S/C Mobilization	SP2	3	0		CP1, CP2
CIVIL WORKS					
Civil S/C Req. preparation and Inquiry	SC1	4	0		SC2
Civil S/C Req. Issue Inquiry	SC2	0	0		SC3
Civil S/C Req. Bids Opening	SC3	0	0		SC4
Civil S/C Req. Bid Evaluation and POR	SC4	3	0		SC5
Civil Works S/C Award	SC5	0	0		SC6
Civil Works S/C Mobilization	SC6	4	0		CC1
CONSTRUCTION					
PILING					
Main P/R N-S Piling Execution (51 large piles) Machine 1	CP1	2	0		CC1
K-521, Structure 1, Pumps, K-541, K-545 Piling Execution (120 small piles) Machine 2	CP2	4	0		CC1, CP3
Structure 2, Slab east V-531 Piling Execution (48 small piles) Machine 2	CP3	3	0		CC1, CC1 (SS,FS)
CONCRETE FOUNDATIONS					
Foundations for Main Piperack N-S South Part	CC1	8	0		M6

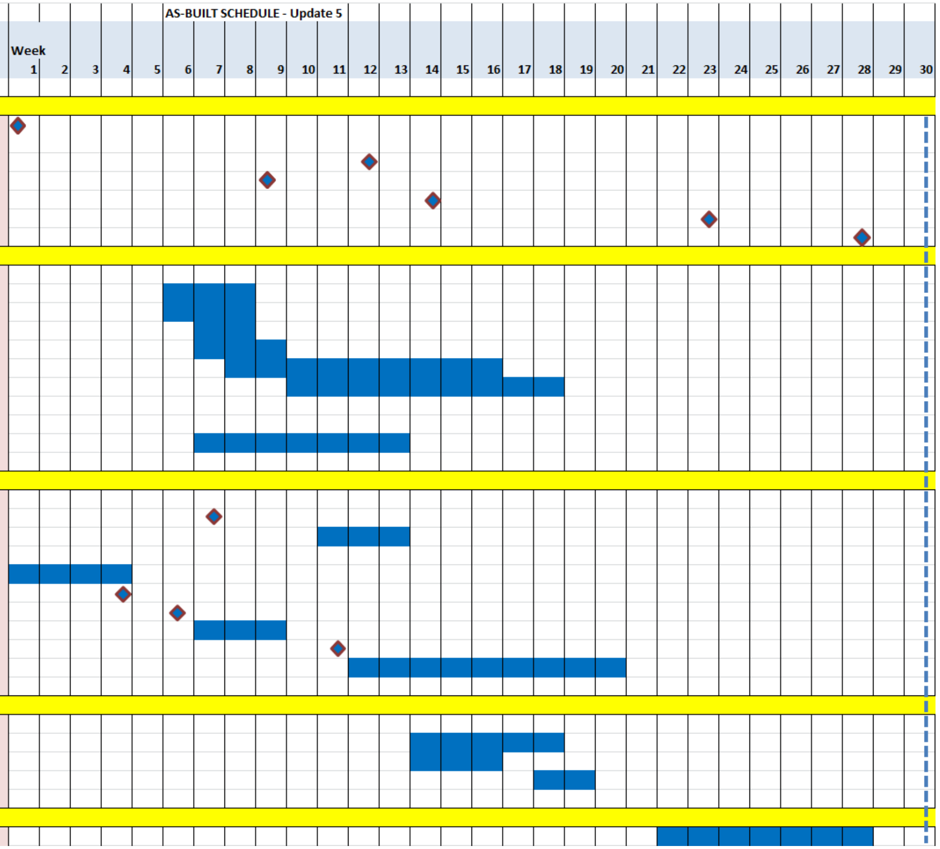


FIGURE 48: UPDATE 5

TABLE 18: WINDOW 5 FORENSIC ANALYSIS

ID	Activity	Start of Window		End of Window		Activity Delay (Savings)	Project Delay (Savings)	Forecast Project Finish	Notes
		Planned Start	Planned Finish	Revised Start	Revised Finish				
						Window 4 Net Delays	0	28	
Window 5 (Update 4 and Update 5)									
CC1	Pipe Found Const	27	28	27a	28a	0	0	28	As-planned
						Window 5 Net Delays	0	28	

This update saw no delays to activities as well as project delays. Everything was as planned from the previous update.

Now we have several delays in several windows, let us summarize all these into one tabular column.

TABLE 19: TOTAL DELAYS FOR WHOLE SCHEDULE

Activities	Activity ID	Window 1	Window 2	Window 3	Window 4	Window 5
MILESTONES						
	M1	0	-	-	-	-
	M2	4(c)	-	-	-	-
	M3	0	-	-	-	-
	M4	0	-	-	-	-
	M5	-	1(c)	0	0	-
	M6	-	-		-	-
ENGINEERING						
PILING						
	EP1	0	-	-	-	-
	EP2	0	-	-	-	-
	EP3	0	-	-	-	-
	EP4	-	-	-	-	-
	EP5	0	0	-	-	-
	EP6	5(c)	0	-	-	-
CONSTRUCTION						
	EC1	4(c)	-	-	-	-
SUBCONTRACTING						
PILING						
	SP1	2	-	-	-	-
	SP2	3(c)	-	-	-	-
CIVIL WORKS						
	SC1	0	-	-	-	-
	SC2	0	-	-	-	-

	SC3	0	-	-	-	-
	SC4	0	-	-	-	-
	SC5	2(c)	-	-	-	-
	SC6	5(c),1	1(c)	0	-	-
CONSTRUCTION						
PILING						
	CP1	-	-	-	-	-
	CP2	0	1(c)	-	-	-
	CP3	0	0	-	-	-
FOUNDATION						
	CC1	-	-	(2)	1	0
TOTAL		8	1	(2)	1	0

In the above table, in the critical path of piling designs to construction, the owner delays of EP6 and CP2 had caused an concurrent effect of 6 days of delay on the overall project. According to the UK English law, the contractor's delay to completion occurs concurrently with the employer's delay to completion, the contractor's concurrent delay should not reduce any EOT due. Thus, the EOT due by the owner is 6 weeks.

For comparing the statistical variance of the MIP 3.3 and impacted as planned, the share of delays is calculated. All the concurrent delays have to be distributed in accordance to their share for the total delay. The following table shows the final apportionment of the delays after all the delays have been shared. In the total column the delays of owner and contractor are differentiated by "(C)"and "(O)". The representation of owner and contractor delay is done with the help of the notice and liability matrix represented in the start of this chapter. The piling and civil construction activities' liabilities' were not known as activity delay would cause the owner to be liable and sequential delay would cause the contractor/owner (depending on preceding activity) to be liable. In this case, there was only activity delay (savings) and it attributed to the owner.

TABLE 20: APPORTIONING DELAYS

Activities	Activity ID	Window 1	Window 2	Window 3	Window 4	Window 5	Total (C/O)
MILESTONES							
	M1	0	-	-	-	-	
	M2	0.52	-	-	-	-	0.52(C)
	M3	0	-	-	-	-	
	M4	0	-	-	-	-	
	M5	-	0.33	0	0	-	0.33(C)
	M6	-	-		-	-	
ENGINEERING							
PILING							
	EP1	0	-	-	-	-	
	EP2	0	-	-	-	-	
	EP3	0	-	-	-	-	
	EP4	-	-	-	-	-	

		EP5	0	0	-	-	-	
		EP6	0.65	0	-	-	-	0.65(O)
	CONSTRUCTION							
		EC1	0.52	-	-	-	-	0.52(C)
SUBCONTRACTING								
	PILING							
		SP1	2	-	-	-	-	2(O)
		SP2	0.39	-	-	-	-	0.39(O)
	CIVIL WORKS							
		SC1	0	-	-	-	-	
		SC2	0	-	-	-	-	
		SC3	0	-	-	-	-	
		SC4	0	-	-	-	-	
		SC5	0.26	-	-	-	-	0.26(O)
		SC6	1.65	0.33	0	-	-	1.98(O)
CONSTRUCTION								
	PILING							
		CP1	-	-	-	-	-	
		CP2	0	0.33	-	-	-	0.33(O)
		CP3	0	0	-	-	-	
	FOUNDATION							
		CC1	-	-	(2)	1	0	(1)(O)
	TOTAL		6	1	(2)	1	0	5.98~6

CALCULATION OF NET DELAY:

EOT due by owner according to English Law = 6 weeks

Total number of contractor delays= 0.52+0.33+0.52 = 1.35 ~ 1.5 weeks

Total number of owner delays = 0.65+2+0.39+0.26+1.98+0.33-1 = 4.63~ 4.5 weeks

Total project delay = 1.5+4.5 = 6 weeks delay.

Ratio of percentage of the share of delay between contractor and owner = 1.5:4.5 which is equal to 25% :75%.