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Comparative Analysis of Delay Assessment Techniques on a Real-Life Case-Study

by

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I want to dedicate this achievement to my parents, teachers and friends who always encourage and support me in every crucial time.

CERTIFICATE OF APPROVAL

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1. **Ali, M.A,**, and Ali, M. (2022). "An overview on selection of appropriate delay analysis technique." *1st International Conference on Engineering and Applied Natural Sciences Konya, Turkey. Paper ID: 667.*

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Muhammad Arslan Ali

Abstract

An international trend in the construction sector is delays. Regardless of how difficult the project is, in the construction sector, delays are frequent. A project taking longer to complete is what is referred to as a construction delays, which are detrimental to the project's performance in terms of time, cost, and quality. Over time, the delay analysis techniques (DATs) that are currently in use to assist in this decision-making have been useful, but these have not been able to reduce the high incidence of conflicts related to the resolution of delay claims. The limitations and capacities of the approaches in their practical use are a major source of disagreement. That's why it is crucial to develop the knowledge about these DAT's. Which will help the different parties involved in the project evaluate the delays and develop a methodical strategy to monitor the delays and distribute responsibilities.

The aim of this research is to increase knowledge and comprehension by assessing the most typical DAT's using a real-time building case study project. For this purpose, a critical literature-based review is carried out. A critical review of different DAT's is carried out, and three DAT's are selected for this study. A building project , New Islamabad International Airport Project-Packaged Additional Airside Buildings, has been selected as a case study. The main sources of this data include the professional organisations that have been approached to conduct and report this study. The main sources of delays are then identified. Three selected DAT's (recommended by SCL protocal), i.e., Impact As-Planned (IAP), Time Impact Analysis (TIA), and Collapsed As Built (CAB), are then applied to the data. Primavera P6 is used for these methods. Results are then compared and analysed.

By evaluating different DAT's, it has been concluded that the project and the claim circumstances will determine which strategy is best for the claim. A total duration of 429 days is calculated by every technique, causing the project to be delayed by 273 days because the project only contained client-induced delays. The limitations of the DATs are also discussed, and Time Impact Analysis (TIA) was found to be the best delay analysis technique (DAT) in comparison.

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Abbreviations

APvAB	As-Planned vs As-Built
BC or GC	Bar Chart or Ghantt Chart
BL	Baseline
CAB	Collapsed As-Built
CPM	Critical Path Meathod
DA	Delay Analysis
DAT's	Delay Analysis Techniques
EC	Client caused delays
GIT	Global Impact Technique
IAP	Impact As-Planned
IDT	Isolated Delay Technique
NIT	Net Impact Technique
NN	Contractor caused delay
TIA	Time Impact Analysis
WA	Window Analysis

Chapter 1

Introduction

1.1 Background

In construction industry delays are a widespread issue [1]. Most construction projects are delayed, regardless of the complexity of the project [2]. Construction delays are defined as an increase in the amount of time it takes to finish a project. In other words, when a project is not completed within the agreed-upon schedule and budget, it is called a delay [3]. Construction delays are one of the most frequent problems in the construction industry, and these negatively influence the project's success in terms of time, cost, and quality [4]. As a result, time delays are important to the profitability of most construction projects. In most situations, the project's failure is due to the consultant, contractor, and owner's effects on the project's performance [5]. Many academics have highlighted these issues as factors that affect building project delays as well as the performance of companies and the general economy of the country.

Many reasons can cause delays in building projects, usually linked with time, money, and quality. However, throughout the last decade, researchers have identified and evaluated elements that cause construction project delays. However, a deeper understanding is still required to enhance this. A construction project is deemed successful when it is completed on time, under budget, in accordance with specifications, and to everyone's satisfaction [5]. For all parties concerned, delays are costly, and these typically result in conflicts, cost overruns, negotiation, litigation, project rejection, and project unfeasibility. Due to the many outside and inside factors that affect the building process, construction is a high-risk industry with a lot of unknowns. Owners, project managers, or contractors risk starting a project's delay when these are overly aggressive with their scheduling. Everyone wants to be known for completing things quickly and within their allocated budgets, of course. But it's also crucial to be realistic. Despite a carefully planned timeline, building delays can sometimes happen.

Development delays are frequently the result of delay events and can be considered as a risk associated with the duties that, if identified, delineated, and overseen in a written method at the onset, could be overseen, limited, shared, acknowledged, or avoided to produce some positive results and decrease the likelihood of future delays. A development task might be viewed as a fruitful venture until the point that it fulfils the cost, time, and quality constraints connected to it. However, it is not unusual to witness a development project fall short of completing its task within the budgeted amounts of time, money, and quality. To counter the unexpected delays in availability, the domain of delay management is turned to, which helps in the avoidance of the delay. The successful management of workflow forms is required for delay management, which is the use of knowledge, skills, tools, and approaches to prolong activities to fulfil project requirements. To understand the impact of these delays on the construction projects, there is a need to analyse the delays. Analysis of delays indicates why construction projects are delayed, and these might have an impact on the whole program. The result of the analysis could lead to legal action by one of the parties to the agreement [6]. Project teams and scheduling (timing) analysts frequently have to analyse complex delays and resolve the disputes that ensue. In addition, most construction contracts do not specify which technique will be adopted to assess and analyse delays. When it comes to assessing and establishing who is to blame for the delay, the contractor and the customer, on the other hand, have opposite opinions. That is why forecasting delays and defining who is responsible for what is a significant issue [5]. That is why project managers need a methodical strategy to monitor delays and distribute responsibilities.

In the past, different researchers used different techniques to access the delay, like the Bar chart technique, Time impact technique, Critical path method, Collapsing technique, Global impact technique, Net impact technique, Impacted as-planned technique, Collapsed as-built technique, Snapshot technique, Isolated delay type technique, etc [6],[7]. All have different specifications and have different results for the same delays. So, the selection of effective delay assessment methods for calculating a project's delay impact is a crucial decision. That is why it is necessary to provide a comparative analysis of these techniques to get the most viable technique for the delay analysis.

1.2 Research Motivation and Problem Statement

Regardless of how difficult the projects are, delays in construction are common. Delays have bad impact on all parties involved in the project, and these frequently lead to disputes, cost overruns, arbitration, litigation, complete abandonment, and project unfeasibility. When a delay occur, there are differences between the contractor's and the client's perspectives when determining who is to blame for the delay. Determining who is accountable for each act and planning for delays are therefore crucial, which causes disputes among the different parties involved in the project. To resolve the disputes or to minimize these disputes to some extent to provide a dispute-free environment among the parties involved in the project is important. For this, there is a need for a particular approach or delay analysis technique to analyse or access the delays to mark who is responsible for which delay event? Thus, the problem statement is stated as follows:

Delays in the construction industry are a global trend. Delays affect all the participants involved in the respective project. So, there is a need to access the delays. To analyse delays and define who is responsible for what is a significant issue, different techniques have been used in the past, all with different specifications and resulting in different results for the same delay scenarios. The selection of an appropriate delay assessment technique (DAT) to claim the Extension of Time (EOT) remains an unresolved flaw.

1.2.1 Research Questions

- Which technique is relatively easy and which one is complicated among frequent used techniques?
- Which method can give results traceable to actual case in as-built schedule in building related projects?
- Among these shortlisted DAT's, which DAT is good for projects in Pakistan to claim EOT?

1.3 Overall Aim of the Research Program and Specific Objective of this MS Thesis

The overall aim of the research program is to provide a comprehensive guidelines for resolving the disputes between different parties involved in the construction projects and distribute responsibilities to the respective party, who is responsible for which act.

The specific aim of this MS thesis is to examine the comparative behaviour of delay assessment techniques (DATs) to claim the Extension of Time (EOT) and to recommend a particular technique for the specific prevailing conditions in the construction industry.

1.4 Scope of Work and Study Limitation

The scope of the work consists of a critical literature review, problem identification, and an analysis of the different literature-based Delay Assessment Techniques (DATs) for Extension of Time (EOT) using a real-life project. The project contained the construction of the Satellite Fire Station, the Northwest Apron Control Tower, and the Blue Water Disposal Facility East and West. Primavera P6 is used for the delay analysis.

Only one building project is taken under consideration. The analysis is carried out for only Extension of Time (EOT). Three literature-based delay assessment techniques are selected for this study.

1.4.1 Rationale Behind Variable Selection

The selected case study faced major delays. The case study contained three different types of construction i.e., Satellite Fire Station, Construction of North-west Apron Control Tower and Construction of Blue Water Disposal Facility East and West. Three most recommended Delay Assessment Techniques (DAT's) i.e., Impact As-Planned (IAP), Time Impact Analysis (TIA) and Collapsed As-Built (CAB) by [8] were selected for delay analysis due to their reliable and dependable nature [9]. These techniques were also recommended by SCL Protocol [10].

1.5 Novelty of Work, Research Significance, and Practical Implementation

It is an analytical work; it is revealed that delays are the common factor affecting the construction industry [2]. In the past, many researches have been carried out on delay assessment techniques (DATs) to analyse the delays occurring in the construction industry. It is observed that different types of techniques are being used for different types of projects, each having its own significance and effectiveness. The research carried out in the past has mostly been based on a literature review or on analysing the delays using a single DAT. A few studies have been carried out on the comparison of these DATs, but these are based on the demo case studies. To the best of the author's knowledge, there hasn't been any research conducted on the comparison of various delay assessment techniques using real-life case study.

The choice of a delay analysis approach is crucial to accurately estimating delays. When choosing a delay analysis methodology, a number of elements must be taken into account, including contractual requirements, the availability of source data, budget, time allotted for the study, and the scope of the dispute. The delay analysis techniques (DAT's) that are now used to support this decision-making have proven to be helpful over time, but these techniques have not been able to lower the high incidence of conflicts associated with the resolution of delay claims. The data obtained in the present study will therefore provide a guide to selecting the appropriate technique to claim the Extension of Time (EOT).

This work is a step forward in eliminating the disputes caused by the delays, or at least minimizing the disputes to the greatest possible extent. The findings of this study will help different parties involved in the project to evaluate the delays and select a strategy to monitor delays and distribute responsibilities.

1.6 Brief Methodology

A critical literature review is carried out of the previous research, and then the problem statement, objectives of research, scope of work, and study limitations are defined. In this research, a case study of a building project is selected, and data analysis is carried out. The original construction programme, which is obtained as secondary data from the concerned organization, is analyzed, and delay events faced by the selected project are identified. In this case study research, three of the most commonly used literature-based delay analysis techniques (DATs) extracted from previous research are then applied to the selected project. A comparison of the delay assessment techniques used is also performed. At the end, the results of the analysis have been interpreted to draw the conclusion and future recommendations of the research study.

1.7 Thesis Layout

This thesis is comprised of five chapters, and these are as follows:

Chapter 1: This chapter goes over the background, research motivation, problem statement, research questions, overall aim of the research program, specific objective of the MS thesis, scope of work, study limitations, rational behind the variable selection. novelty of the work, research significance, practical implementation, brief methodology and thesis layout.

Chapter 2: This chapter provides a critical literature review of the previous studies related to real-life contract applications and types of delays, causes and impacts of delays, delay analysis techniques and pros and cons of DAT's.

Chapter 3: This chapter contain the background,study area, nature and source of data, identified delayed events imposed in all DAT's and analysis procedure.

Chapter 4: Comprises the results of Impacted As Planned Analysis, Time Impact Analysis, Collapsed As Built Analysis and Comparative Analysis of DAT's.

Chapter 5: It provides a conclusion and recommendation on the basis of the findings.

Bibliography is provided at the end of chapter 5.

Chapter 2

Literature Review

2.1 Background

Delays in the construction industry are a global trend [1]. Regardless of how hard the project is, the majority of construction projects are delayed [2]. A project taking longer to complete is what is referred to as a "construction delay." In other words, a project is said to be delayed when it is not completed on schedule and on budget [3]. These negatively affect the project's success in terms of time, cost, and quality [4]. For all parties concerned, delays are costly, and these typically result in conflicts, cost overruns, negotiation, litigation, project rejection, and project unfeasibility. Due to the number of exterior and interior elements that influence the construction process, construction is a high-risk industry with many uncertainties. In the past, different delay assessment techniques have been used to analyse and access the delays and all have different specifications, and have different results for the same delays scenarios. The current chapter provides the detailed literature review on real life contract applications and types of delays. It also briefs the different causes that results in the delaying of the construction project and impact on the construction projects. The review of different Delay Assessment Techniques (DAT's) is carried out that have been previously used to analyse the delays in construction projects and their pros and cons are also discussed.

2.2 Real-Life Contract Applications and Types of Delays

In construction, real-life contract applications are of great significance. Contract applications are project-related activities that follow specific rules. A situation that could have been encountered or could be encountered in the near future, usually based on a skill obtained from regular school subjects, was referred as real-life application [11]. It was discovered that it was used to demonstrate how what the person were studying are applicable to their daily lives or to help them be more prepared for such situations [12]. Keeping the preceding in mind, contract application in construction refers to the practises that are involved in the project from the signing phase to the complication phase and finally to the project handover date.

Delays between contractors and project owners are common. There are different types of delays discussed in the literature that affect the project. Liquidated damage, conflicts, or litigation over contracts were found to be the main issues as a result of delays [13]. With definitions and analysis, several authors offered their various opinions on delay types and the issues faced by parties in contracts over the years [14]. Delays in large-scale construction projects could be attributable to a wide range of factors [15]. One method of categorising delay types is to divide them into four categories: excusable delay, compensable delay, critical delay, and concurrent delay [6]. Fig. 2.1 shows the different types of delays that occur in the projects. Keeping the foregoing in mind, it has been discovered that delays occur frequently and have a negative impact on projects. It should also be noted that delays have a negative impact on projects regardless of the type of delay.

2.2.1 Excusable or Non-Excusable Delays

An excusable delay is one that results from an unforeseen circumstance outside of the control of the contractors or the subcontractor. Any delays that are avoidable or within the contractor's control are not considered excusable. The difference between these two options is crucial because it establishes blame for the delay [6]. In a similar vein, it determines whether or not a contractor is entitled to a time extension and, potentially, whether or not the contractor is entitled to payment for the additional time [16]. Contractors (or their suppliers) are to blame for non-excusable delays, and it is not the owner's fault in a construction project [12]. It can be noted that in cases of excusable delay, the contractor is entitled to time relief. On the other hand, in cases of non-excusable delay, the contractor is frequently denied relief, either financially or in terms of time, and must compensate the owner in other ways to make up for the time lost.

2.2.2 Compensable or Non-Compensable Delays

An event is considered a compensable delay if it was neither reasonably foreseeable nor under the contractor's control. In this case, the contractor is entitled to additional remuneration as well as a delay in the completion of the job. Conflicts, unusual weather patterns, natural events such as earthquakes and fire outbreaks, as well as governmental actions, are frequently responsible for this type of delay [17]. As a rule, the government is to blame when there is a compensable delay. The contractor is usually not entitled to compensation for such delays but is entitled to a time extension [18]. Non-compensable delays are caused by third parties or circumstances that are beyond the control of the contractor and the owner. This means that a non-excusable delay does not qualify for extra money or a time extension [12]. However, the duration of the building contract is the major factor that determines the extent to which a delay is compensable. It can be noted that a contract typically outlines the kinds of delays that aren't considered compensable and for which the vendor is not authorized to receive any further compensation. However, contractor may be given a time extension in such circumstances.

2.2.3 Critical or Non-Critical Delays

Delays that are considered critical are those that affect the settlement date or, in some cases, a milestone date; on the other hand, non-critical delays don't have such an effect. The project completion date or a milestone date will be postponed if these activities are postponed. Essentially, this is a delay caused by any of the participants in the construction projects, with the remaining parties bearing no responsibility for it [19]. This frequently occurs if one of the work tasks requires more time than the scheduled period to complete [20]. The Critical Path Method (CPM) is indeed a tool used to determine the duration of such a delay, as well as the resulting cost and its impact on other activities. Furthermore, CPM assists in identifying and informing the party responsible for the delay, as well as conveying responsibility and the costs associated with the delay [19]. Non-critical delays do not affect the project's completion or a milestone date [21], whereas significant delays cause schedule delays that affect the project's completion or a milestone date by influencing critical tasks. Due to severe delays, the contractor is unable to complete the work by the agreed-upon time frame in the construction contract. It may be noted that delays that affect project completion or, in some cases, a milestone date are classified as critical, while delays that don't affect project completion or a milestone date are classified as noncritical. If these tasks are delayed, the project's completion date or a landmark date will be delayed as well.

2.2.4 Concurrent or Non-Concurrent Delays

The term "concurrent delays" refers to delays that occur at or around the same time. Typically, multiple causes delay a project in an overlapping manner, making the situation more problematic. Both owners and contractors might have contributed to this delay. Because the delays are complex and interrelated, it is difficult to assign blame and decide how to deal with them [6]. Concurrent delay is commonly defined as a condition in which two or more delay actions occur at different times but the consequences are partially or completely felt at the same time [17]. This is common when both the investor and the supplier are to blame for the delay, i.e., when the delay is excusable but not compensable. Such delays do not have to occur simultaneously, but can occur on two simultaneous critical path chains [22]. Concurrent delays, on the other hand, can result in an excusable delay thru compensation that may provide the contractor with some relief in terms of time extension, termination of fines on damages, and sometimes a probable delay of damages, subject to the specific situation and the recommended agreement.

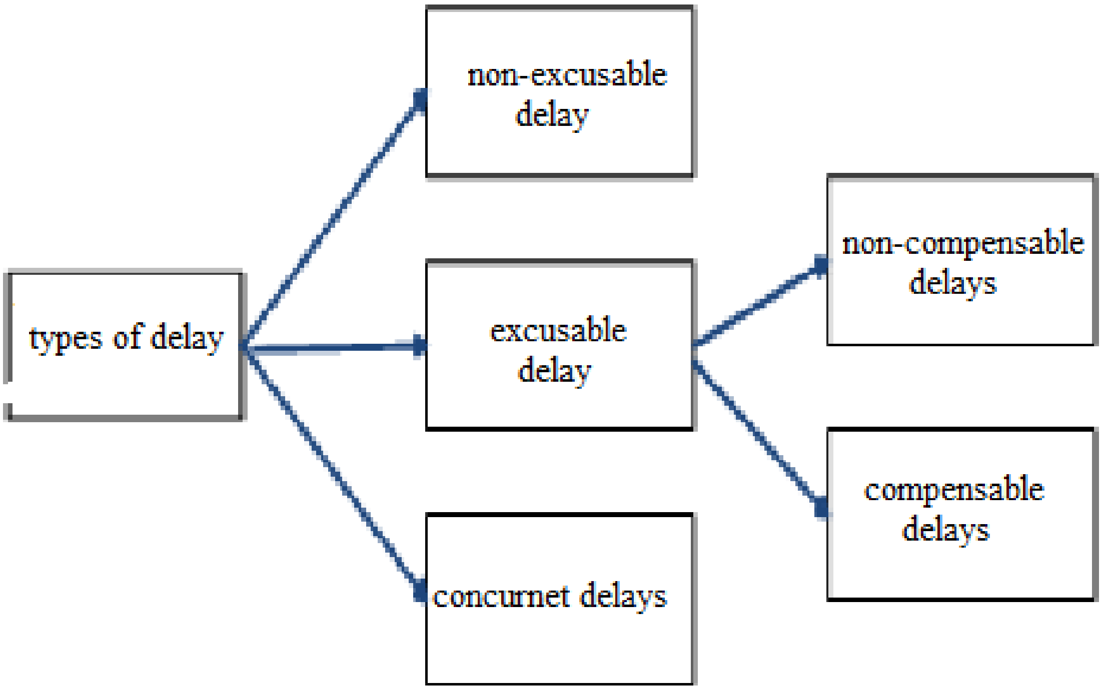


FIGURE 2.1: Types of Delays [7]

2.3 Causes and Impact of Delays

One of the most common issues on construction projects is delay. Delays can lead to costs and lost work time, as well as disagreements between property owners and contractors about payment terms. Construction delays can have a variety of different effects, including delayed completion, lost productivity, accelerated completion, contract termination, and increased costs. Time overruns and client capital being exhausted due to the project not being finished were determined to be the major reasons for construction delays. A project delay doesn't only originate from within the internal environment of the project. External delays are another significant cause of project delays. A detailed discussion is made on the causes and impacts of delays. The first discussion is made on the numerous reasons and main causes of delays. And then the different impacts of delays, i.e., impact on reputation, time and cost, total termination and overall impact are discussed.

Delays in construction projects can be caused by a variety of factors. Many studies have been conducted in the past to identify the main causes based on country, region, project type, and procurement methods, as well as the perspectives of various stakeholders [23, 24]. González et al. [25] performed a study on the causes of delays and stated that delays had a significant impact on project performance. Divya and Ramya [26] studied the causes of delays that were resulting in construction delays and Owolabi et al. [27] performed a comprehensive analysis to understand the causes of delays that were resulting in the late delivery of the project. Kadry et al. [28] investigated the causes of construction delays, focusing on politically risky countries. A lot of research has been carried out on the causes of delays. A review of the research on project delays reveals that there is widespread interest in determining the causes of construction project delays.

The identification of the main cause of the project delay is always remains a problem. Due to the delays, the connection between the owner and the contractor ended as a result of the delays in various settlements. Which also contribute to time and cost overruns. Durdyev and Hossein [29] examined the causes of delays, and the top ten causes of delays were determined, i.e., weather/climate conditions, poor communication, lack of coordination, stakeholder conflicts, ineffective or improper planning, material shortages, financial challenges, payment delays, equipment shortages, a lack of experience/qualification/competence among project stakeholders, labour shortages, and substandard site management. The above-mentioned factors were found to be the main reasons for delays in the construction projects [9]. The analyses were carried out by Divya and Ramya [26], and the main reasons for delays were identified. It was observed that changes in the drawings, slow decision-making by the contractor, the contractor's bankruptcy, variations, a lack of funding to finance the project to completion, erroneous information from consultants, a problem with project management, differences in the contract document, equipment unavailability, construction errors; inclement weather, and changing building material prices and labour were the main causes of building delays [27]. Table 2-1 illustrates some of them. It may be noted that it is important to determine the real cause of the delay in order to minimise and eliminate the delays and associated costs.

Table 2.1: Causes of Delays

Author	**Causes of delays**
Divya.R, S. Ramya [26]	Categorization of delay causes into 8 groups. Political Environment Delay in progress payments by the owner Lowest bidder receives the project Poor site management by the contractor Contractor's Poor Preparation Delays in contractor's progress Design Changes
S. Shujaa Safdar Gardezi, Irfan Anjum Manarvi, S. Jamal Saf dar Gardezi [30]	Owner induced delays Contractor induced delays Delayed by a third party Delays caused by the interaction of two activities Delays resulting from independent actions
Issaka Ndekugri, Nuhu Braimah, Rod Gameson [31]	Insufficient project information Unfamiliarity with the methods Poor schedule updates Improbable baseline schedule Critical Path Method isnt defined
Abdullah Alsehami, Lauri Koskela, Patricia Tzortzopoulas [32]	Shoddy planning and management Inadequate site management Lack of Productivity and Labor Insufficient Material Supply Design Modification Weather Poor Communication
Mohamed M. Marzouk, Tareq I. El-Rasas [33]	Owner Related Contractor Induced Consultant induced Material related Labor issue External issues Project related

Continued Table 2.1 Causes of Delays

Author	**Causes of delays**
Owolabi James, Amusan Lekan, Oloke, Olusanya, Tunji-olayeni, OwolabiDele, PeterJoy, Omouhignatious [27]	Lack of fund Slow decision making Building material price changes Equipment availability Lack of adequate information from Consultants Weather Labor Strikes
Nasser Alotaibi, Monty Sutrisna and Heapyih Chong [34]	Contractors' inefficient project planning and scheduling Inadequate experience or training of contractors' staff Client's protracted payment delay Alterations made during construction
MS. Culfik, O. Sarikaya and H.-Altun [33]	Delays relating to finances Delays due to labour issues Delays connected to changes Delays due to contracts Delays caused by the environment Delays caused by equipment
Prakash Rao, B. and Joseph-Cameron Culas [35]	Client Consultant Equipment Labor Material Consultant
Michal Gluszak, Agnieszka Les niak [29]	Mistakes and inconsistency in Design documentation Workforce quality Poor quality of management and supervision Contractor company's internal problems Difficulty in acquiring the necessary permits to implement the work Unrealistic period of project implementation Insufficient necessary equipment

Continued Table 2.1 Causes of Delays

Author	**Causes of delays**
Chazi Saad A Elawi, Mohammed Alghtny and Dean Kashi Wagi [36]	Contractor lack of experience Financial constraints by the owner Slow decision making by the owner Design changes Change order Material availability
Desai Megha, Dr. Bhatt Rajiv [37]	Original contract duration is too short Legal disputes between various parties Difficulty in financing project by the owner Delay in site mobilization Rework due to errors in construction Conflicts between consultant and design engineer Complexity of design Unclear drawings
Do, Sy Tien, Viet Thanh Nguyen, Cuong NN Tran, and Zwe Man Aung [38]	Shoddy planning and management Inadequate site management Lack of Productivity and Labor Insufficient Material Supply Design Modification Weather Poor Communication

Delays are common in the construction industry, and they frequently have a negative impact on the life of a project. To understand the impacts of delays on the construction projects a lot of studies have been carried out. It was observed that due to the negative influence of consultants, contractors, and owners on project performance, most projects failed [39]. Delays in construction projects always had an impact on both developers and buyers. Delays were not only costly for the contractor, but these also harmed the company's reputation and the productivity of the owners, who suffered as a result of the delays [40]. Risk and uncertainty were inherited in the construction industry because of a wide range of external and internal factors [41]. It can be concluded from the foregoing that mismanagement of one or more events during construction is a common cause of delays, which can be viewed as a risk for projects that, if identified, analysed, and managed in a systematic process from the start, can be controlled, reduced, shared, mitigated, or accepted with positive outcomes and a lower chance of more delay.

The factors that contribute to delays in the on time completion of building construction projects are important to be identified. Clients, subcontractors, and consultants all suffer when a construction project runs behind schedule, leading to increased hostility, mistrust, litigation, arbitration, and cash flow issues [42]. It is not possible to declare a construction project a success until it has been completed within the specified budget, schedule, and quality parameters [43]. However, it is not uncommon for a construction project to fall short of its intended outcome in terms of budget, schedule, and quality [44]. It is common practise to employ techniques from the field of "project management" to prepare for and deal with delays that may arise. Effective project management necessitates the application of knowledge, expertise, tools, and procedures to project operations in order to fulfil project requirements. Construction project delays are always costly, regardless of the reason for the delay. Construction debt with interest, managerial employees dedicated to the project whose expenses are time-dependent, and constant pay and material price escalation are all to blame for these delays [45]. It may be noted that delays can result in increased expenses, a loss of production and revenue, numerous disputes between owners and contractors, and the termination of contracts, among other negative repercussions.

If the construction process is delayed, this leads to many circumstances and disputes. This will have many negative impacts on all the parties involved in the project. But what is the factor that impacts the parties the most? Many studies have been conducted in this regard in the literature. Gebrehiwet and Luo [40] performed an analysis on the delay's impact on the construction industry. For this purpose, a comparison was performed, and it was concluded that time overruns, cost overruns, termination of the project, arbitration, and litigation are the critical impacts of delays. Sambasivan and Soon [46] studied the impact of delays on the Malaysian construction industry by conducting a questionnaire survey, and time overruns, cost overruns, disputes, arbitration, litigation, and total abandonment of the project were found to be the six major impacts of delays. It was observed that many contractual parties, including the contractor, consultant, subcontractor, supplier, and other relevant parties, were undoubtedly affected by total project abandonment [47]. It may be noted from the above discussion that delays have many determinable impacts, among which total termination of the project is a significant impact.

It is crucial to identify the causes that cause delays in the timely completion of building construction projects. A substantial amount of literature has been produced in order to address this domain. Rashid [48] concluded that time overrun, cost overrun, total abandonment, and litigation were the critical impacts on delays in the construction industry. Hashim and Yahya [49] investigated the impact of delays on the construction industry. For this purpose, a survey was performed and the data was analysed through RII, and it was concluded that time overruns, cost overruns, and total termination are the three major impacts of delays. Amoatey et al. [50] examined the effects of delays occurring in the development of state-owned housing in Ghana and concluded that time overruns, cost overruns, litigation, a lack of continuity by the client, and arbitration were the crucial impacts of delays on the projects. Santoso and Soenge [51] explained that the time overrun was the major factor in the delays on the construction projects. But despite this, the cost and quality of the project were also affected. It may be highlighted that delays frequently result in time overruns, money overruns, arbitration or legal proceedings, and project abandonment. Fig. 2-2 shows the most common impact of delays on construction projects.

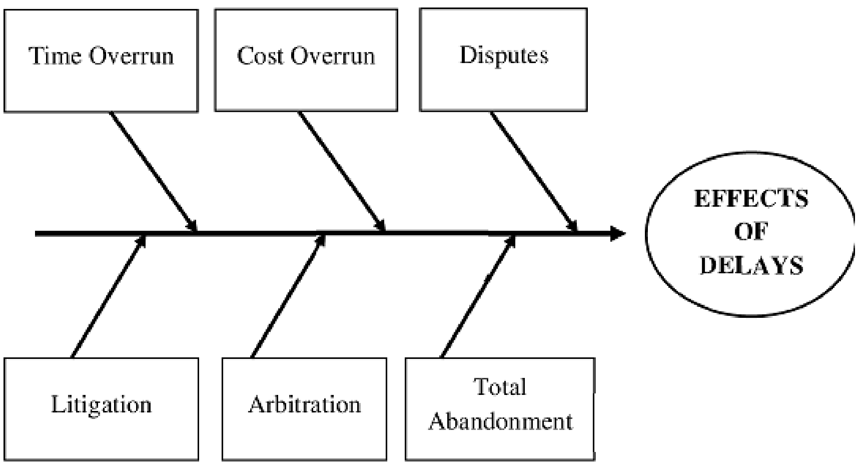


FIGURE 2.2: Impacts of Delays [52]

2.4 Delay Assessment Criteria

2.4.1 Delay Analysis Techniques (DAT's)

Many projects wind up costing more money and taking longer to complete than expected as a result of these delays. A systematic approach to determine each of these components' influence, timing, and contributing effect on the overall delay should help the parties resolve it without litigation [53]. There are several factors that contribute to a project's completion time being extended, including stoppage of work, disruptions in job performance, and the contractor's efforts to speed up work on the project to meet or minimise the project's completion time [54]. In the past, different delay analysis techniques which were frequently used are summarised from the literature review: (a) As-Planned vs As-Built (APvAB), (b) Impacted As-Planned (IAP), (c) Collapsed As-Built (CAB), (d) Time Impact Analysis (TIA) and (e) Window Analysis (WA), (f) Bar Chart (BC), (g) Critical Path Method (CPM), (h) Global Impact Technique (GIT), (i) Net Impact Technique (NIT) and Isolated Delay Technique (IDT). Shabbar et al. [9] performed a study on the empirical evidence of extension of time in construction projects in Pakistan and stated that five delay assessment techniques, i.e., IAP, TIA, CAB, APvAB, and WA, have been normally used for the delay analysis. These five techniques are also mentioned under contract management in the FIDIC Red Book by the Pakistan Engineering Council [55]. Among these five DATs, only three DATs, i.e., IAP, TIA, and CAB, were selected for this study as these are more reliable and accurate than other techniques [9]. These techniques helps to analyse the delays and resolve the disputes. A brief summary of literature-based delay analysis techniques (DATs) is shown in Table 2.2.

The Impacted As-Planned delay analysis technique is prospective. This strategy simply inserts all delayed actions into the baseline schedule in a potential manner, assuming that the baseline logic, sequence, and durations have not altered. Owner-caused delays are added to the as-planned schedule to identify the owner's contribution to delays, whereas contractor-caused delays are not considered in this technique [8]. It contains significant flaws, such as failing to account

TABLE 2.2: Summary of DAT's [45, 56, 57]

S. No.	Technique	Brief Description
A	Impact As Planned	It is based on the notion that you may calculate the completion date by adding delays to the original schedule.
B	Time Impact Analysis	It is assumed that by executing a series of assessments on schedule updates, the impact of delays on a project may be measured.
C	Collapsed As-Built	To determine what would have happened if the delays hadn't happened, delays are taken out of an as-built timetable.
D	As-Planned vs As-Built	The discrepancy among an as-planned and an as-built schedule is observed.
E	Window Analysis	The predicted delay in the available progress data is observed at different time periods to determine the delay.
F	Bar Chart or Ghantt Chart	It identifies and compares critical activities in its timetable to critical activities in the planned schedule.
G	Critical Path Method	This technique makes use of the CPM and the development As Built schedule. This method merely depicts the overall impact of all asserted delays in project completion time.
H	Global Impact Technique	By adding up all delays that are experienced during the completion of activities, this technique determines the overall project delay.
I	Net Impact Technique	This method merely uses a bar graph to represent the total stated delay. When using this strategy, all activities that experience delays are taken into account, but only their combined overall impact is taken into account.
J	Isolated Delay Technique	This method makes an effort to take into account all 3 principles (delay categorization, simultaneous delay consideration, and real-time delay analysis)

for any changes to a crucial route and assuming that the schedule is still true [58]. Ekanayake et al. [59] performed the study on the Sir Lanka projects and it was found that Impacted As Planned (IAP) was found as the most appropriate delay analysis technique during their research work on delay analysis of the road projects in Sri Lanka. The Impacted As-Planned technique calculates how much the delays have affected the original schedule. The delays are shown as activities that are added to the original schedule to demonstrate the impact of every delay and how the project is lagging. The amount of delay is equal to the time difference between the project's timetables before and after the impacts.

Time Impact Analysis is a real-time method for analysing delays. This is a vibrant approach that allows for the creation of new sub-networks for every event that may be settled among the parties, and then these subnets can be incorporated into the project-updated schedules in every related time-period [56]. The final time period will have a completely revised schedule that includes every delay action and takes into consideration all as-built information [57, 60]. Arditi, D., and Pattanakitchamroon, T. [61] conducted their study on choosing a method of delay analysis to settle construction disputes. For this purpose, analysis was performed, and it was observed that TIA was the most credible delay analysis technique to asses the impact of delays in construction projects. Time Impact Analysis is a method for analysing schedule delays that involves adding delays or modifying the plan up until the day before the delay actually occurs. To determine whether the project's eventual completion date is impacted negatively or positively by the delays.

The Collapsed As-Built strategy is also known as the but-for schedule method. Retrospective analysis is used in this methodology. This method is frequently used in claim representations because it is easy for layers of fact to comprehend [62]. Different parties may lead to different adjusted schedules. This method is moderately difficult and necessitates the use of a pre-built schedule as well as information on the delay actions. Yang and Yin [63] introduced a new approach to delay analysis in construction projects using the isolated collapsed but-for method. This method needs as-planned and as-built schedules as well as liability documents that list key delay events in order to do its analysis approach. It is appropriate for difficult applications, but it cannot deal with concurrency concerns or the varying behaviour of the critical path [64]. This method also has the benefit of taking less time and money than time impact analysis. The collapsed as-built analysis, which offers a strong combination of advantages, is the most feasible technique, according to Lovejoy [65]. The earliest date at which the project's completion date or a necessary milestone may have been met if not for delays caused by the project's owner or contractor is determined using schedule delay analysis using collapsed as-built data.

The As-Planned vs. As-Built technique compares planned activities (baseline) with as-built activities; it necessitates the use of a baseline as well as an as-built schedule or as-built data. Its primary characteristics are that it does not present a complicated analysis, does not necessitate the use of software, and is easy to perform [64]. Its drawbacks include the inability to deal with concurrent delays and other complex delay circumstances, as well as failing to consider changes in the critical path [58]. This approach to delay analysis is contemporaneous [10]. The as-planned vs. as-built method was not advised by McCullough [66] and Arditi, D., and Pattanakitchamroon, T. [61], as it simply calculates the net impact of all delay events rather than examining each delay event separately. This is the simplest and fastest approach to use and prepare for delay analysis. This approach only requires as-built data. As it is a simple comparison of the planned and actual execution of the work, the schedule is left alone due to its inability to consider actual progress.

The window analysis method is a real-time method for analysing delays. This technique divides a project's lifespan into manageable segments known as windows and evaluates delays that occur inside each window. Window sizes are frequently chosen in combination with schedule milestones, significant adjustments, or significant delays. Finally, the total delay is the sum of all delays on each window [67]. This methodology's key strength is its ability to account for the critical path's dynamic character. However, because of the time and work required to complete it, it is usually more expensive [54]. Bubshait et al. [60] stated that WA and

TIA are almost same. Slice Windows Analysis is a windows-based observational methodology that focuses on comparing project schedules as-planned, revised, and as-built in order to discover and quantify delays to the project's critical path. WA is observed much similar with TIA.

Bar Chart or Gantt Chart identifies and compares critical activities in its timetable to critical activities in the planned schedule. A graph with bars Gantt charts are built on a horizontal axis that represents the total duration of the project and is divided into increments. These increments can range from days to weeks to months. The project's various tasks and activities are represented by the vertical axis. Each horizontal bar along the Gantt bar chart is different in length and represents the timing, duration, and sequence of each task [56]. The bars on the Gantt bar chart may occasionally cross each other. It identifies and compares critical activities in its time table in the planned schedule [57]. This means that these tasks are being completed concurrently and independently of one another. Some tasks may be dependent on others. This means that one task must be completed before proceeding to the next. This approach is very old and only be applicable for the project which have limited number of activities. It fails to analyse the large or complicated projects.

Critical Path Method This technique makes use of the CPM and the development As Built schedule. This technique shows only the net effect of all claimed delays in project completion time. In order to evaluate and allocate the consequences of delays and other impacts on the project schedule, an expert uses the Critical Path Method (CPM) methodologies in conjunction with a forensic assessment of project documentation and other related data. The results usually show how long a party may be eligible to receive damages. The behavior of different delay analysis techniques was studied by Alkass et al. [57], and it was found that although this technique used the CPM format but it was failed to identify the type of delays. Except that the CPM format gives a more sophisticated impression of an analysis, it is not much better than the net impact technique. Another issue is that claimants always link the delaying events to the critical path [68]. Delaying events that are the claimant's responsibility may be shown, but are more probable to be concealed in the schedule and not linked to the critical path. That's why this technique isn't much preferable.

The Global Impact Technique collects all delays that are imposed during the completion of operations to determine the overall project delay. This technique is a straightforward way to show how delay-causing events have an impact. This approach plots every delay and interruption on a bar graph. For each event, the delayed start and finish dates are determined. The sum of all delaying event durations is used to compute the project's overall delay. Alkass et al. [57] performed a comparison of different delay analysis techniques, and it was stated that this technique had a lot of issues. It was found that this method ignored several problems, including the impact of concurrent delays, analysing delay kinds, and assuming that each delayed event had an equal influence on project duration [68]. Due to delays, this can and frequently does result in a blatant overstatement of the claim. The justification for this is that the time saved by accelerating the project is equal to or greater than the difference between the entitlement completion date and the as-built completion date. In rare situations, the total of the delays may increase the project's as-built completion date. This technique isn't preferable because it has many deficiencies.

Net Impact Technique just shows a bar graph of the entire stated delay. When using this strategy, all activities that experience delays are taken into account, but only their combined overall impact is taken into account. By using this method, an as-built timetable is plotted, including all delays, interruptions, modification orders, and suspensions. The difference between the completion dates for the project as planned and as built is thus equal to the requested time extension [56]. Only the overall impact of all delays is evaluated. Alkass et al. [57] stated that the net impact technique made an attempt to address the problem of concurrent delays, but it didn't examine different delay kinds. The number of delays affecting the project's completion date could therefore be overestimated [69]. The exact impact of a delay on the total project's completion date is also difficult to assess because a network is not utilised. That's why this method isn't preferable.

The Isolated Delay Analysis Technique makes an effort to take into account all three principles (delay categorization, simultaneous delay consideration, and real-time delay analysis). The correctness of this study depends on the number of analyses that are perform. When comparing the completion dates before and after the delaying events are added to the plan, the project's completion date may have changed, which is necessary for performing analysis, which also necessitates the availability of an event log and exact documentation of the information system from the project's start. Alkass et al. [57], during the study of the comparison of different delay analysis techniques, proposed a new approach, by combining the systematic and unbiased approaches of the time impact and snapshot procedures with the questioning approach of the but-for technique, the isolated delay type technique attempts to address all three problems. Periods are chosen based on significant delays or after a string of delays, whichever comes first. The IDT technique merely applies the pertinent fraction of the delays during that time period while respecting the various delay types within the delaying events [56]. When comparing the completion dates before and after the delaying events are added to the plan, the project's completion date may have changed. This discrepancy can be attributed to schedule delays.

However, a prospective analysis often ignores contemporaneous delays and compensability issues and simply deals with an estimate of what might occur on a project prior to the delays actually materialising. When negotiating a request for an extension of the contract duration during a project, prospective analysis might be extremely valuable. An analyst should use the best information available, as-built data, to create the "as-built" critical path for the project's completion and to designate the source, extent, cause, and responsibility of any related critical delays to the right stakeholders in a retrospective circumstance. It is critical to choose an appropriate delay analysis method in order to accurately quantify delays. When choosing a delay analysis methodology, several factors must be considered, including but not limited to contractual requirements, source data availability, budget, and the size of the dispute. Every delay analysis technique has its own analysis type, delay impact determination and data required for the process. Table 2-3 illustrates the specification and requirements of the DAT's.

TABLE 2.3: Specification and Requirements of DAT's

Delay Analysis Techniques	**Analysis Type**	**Critical Path Determined**	**Delay Impact Determined**	**Requires**
Impact As-Planned	Causes and effects	Prospectively	Prospectively	Logic linked baseline program. A selection of delay event to be modeled.
Time Impact Analysis	Causes and effects	Contemporaneously	Prospectively	Logic linked baseline program. Update programs or program information with which to update the baseline program. A selection of delay event to be modeled.
Window Analysis	Causes and effects	Contemporaneously	Retrospectively	Logic linked baseline program. Update programs or program information with which to update the baseline program.
As-Planned vs As-Built	Causes and effects	Contemporaneously	Retrospectively	Baseline Program. As built data.
Collapsed As-Built	Causes and effects	Retrospectively	Retrospectively	Logic linked baseline program. A selection of delay event to be modeled.

Table 2.4: Specification and Requirements of DAT's Contd.

Delay Analysis Techniques	**Analysis Type**	**Critical Path Determined**	**Delay Impact Determined**	**Requires**
Bar Chart or Ghantt Chart	Causes and effects	Retrospectively	Retrospectively	Logic linked baseline program. A selection of delay event to be modeled.
Critical Path Method	Causes and effects	Retrospectively	Retrospectively	Logic linked baseline program. As Built Data. A selection of delay event to be modeled.
Global Impact Technique	Causes and effects	Retrospectively	Retrospectively	Logic linked baseline program. All the delay events to be inserted in the project baseline.
Net Impact Technique	Causes and effects	Retrospectively	Retrospectively	The Baseline Program. Delay events to be modeled in the schedule.
Isolated Delay Technique	Causes and effects	Retrospectively	Retrospectively	Logic linked baseline program. A selection of delay event to be modeled.

2.4.2 Pros and Cons of DAT's

By literature reviewing, it is observed that every DAT has its on specification and its own pros and cons. Some of them are discusses as follow [10, 55, 56, 69, 70].

A. Impact As-Planned (IAP): The methodology of this delay analysis tool is prospective. By adding the event to a model of the initial baseline programme to calculate the influence of those activities, it forecasts the outcome of a specific delay. The real progress of the work completed is not considered.

Pros

- Comparatively easy to learn and prepare.
- Actual work progress is not necessary because it depends only on the baseline schedule.

Cons

- It is presumptive that the baseline is accurate.
- Does not consider the real progress of the works completed.
- It is unreliable since it does not account for changes in sequence, should the situation progress to dispute settlement.
- Concurrent delays are challenging to evaluate since these are simple to ignore.
- Unsuitable for use on complicated projects.
- Used to calculate potential delays instead of real ones.

B. Time Impact Analysis (TIA): This approach of delay analysis is contemporaneous. It considers the progression and duration of delay events that have an impact on the works. This approach needs accurate records, including as-built data to upgrade the schedule, as well as an accurate baseline programme that is essential to its operation. It is assumed that by executing a series of assessments on schedule updates, the impact of delays on a project may be measured

Pros

- Was the SCL protocol's preferred approach.
- Takes into account changes to the project's critical path as events happen.
- Considers the contractor's poor progress and delays.
- Causes and effects are shown.
- Requires multiple sources of scheduling data to complete.

Cons

- It starts off by making a generalisation about the reasons for the delay.
- Best employed while the project is still in progress; hence, it has a finite time window for use.
- throughout the project, calls for dependable and frequent CPM schedule updates.
- It takes a long time to complete.
- Requires a high level of technical knowledge and expertise.

C. Window Analysis (WA): This contemporaneous technique is often referred as as a time slice analysis. This method assesses delays that take place inside each of a project's manageable windows, which are divided into time periods. The time slice is regarded as dynamic since it takes into account the complex behavior of the critical path and depends on the evaluation of actual progress information. The building phase is divided into several time slices, and the time slice analysis looks at the impacts of delay as it happens. The ability of this methodology to take into consideration the critical path's dynamic nature is its main strength. However, because of the time and work required to complete it, it is usually more expensive.

Pros

- Relies on records from the moment the programme was updated.
- Rather easy to carry out.
- Justifies an unacceptable delay.
- able to effectively handle a massive amount of delay events.
- Various approaches can be used in each window to ensure that the analysis is applicable to the activity.
- Produces the most trustworthy findings.
- Accurate

Cons

- requires a significant amount of time and work because it calls for a lot of data and the timetable needs to be changed frequently.
- Projects without tight administrative guidelines and current schedules might not be appropriate.
- Expensive
- Can take a lot of time.
- Current basis; no consideration given to any future adjustments.

D. As-Planned vs As-Built (APvsAB): This approach of delay analysis is contemporaneous. The simplest and fastest to use and prepare approach of delay analysis is this one. Since it is a simple comparison of the planned and actual execution of the works, the schedule is left alone. Therefore, this solution needs an as-built software and precise as-built records. The discrepancy among an as-planned and an as-built schedule is observed.

Pros

- Extremely simple to use and learn.
- It is easy to carry out.
- Can be carried out using the information at hand.
- As-built records serve as evidence for the conclusions.

Cons

- Very simple to execute and easy to understand.
- It is easy to carry out.
- Can be carried out using the information at hand.
- As-built records serve as evidence for the conclusions.

E. Collapsed As-Built (CAB): This retrospective approach to delay analysis is sometimes referred to as the But For approach. The CAB is often conducted on a single-base as-built schedule, depending on a simulation of a "what if" scenario based on the contractor's actual timings and durations rather than the contractor's goals. The Impacted As Planned employs an additive technique, which entails introducing delays into a predetermined order, whereas the CAB employs a deductive approach.

Pros

- This is dependent on an as-built plan.
- When a baseline or upgraded programme is flawed, this option may be appropriate.

- Doesn't call for a baseline programme.
- Does not need to be updated with progress.

Cons

- As-built times are distinguishable as compensable delays.
- Recreates the CAB model of analysis, which necessitates making irrational assumptions.
- As-built logic construction is subjective.
- sequencing and mitigation are ignored.
- Complicated, challenging, and time-consuming process.

F. Bar Chart or Ghantt Chart (BC or GC): This type of delay analysis is retrospective.It compares the critical tasks in the original schedule to the critical tasks that were done in accordance with its timetable. On a y axis that splits the project's overall time into portions, bar-chart graphs are produced.

Pros

- It evaluate how delays will affect the entire project.
- It identifies the root cause and the person accountable for any delays that affect the project's completion.
- It is a cheap strategy when a planned and an actual timetable are available.

Cons

- The schedule programme doesn't use CPM calculations as its foundation.
- Information like the use of flotation, amendments to the project timetable, and changes to the vital route are not included in this method.

- The process takes time, and it should be carried out based on professional judgement, investigation, and evaluation.

G. Critical Path Method (CPM): This type of delay analysis is retrospective. This method makes use of the CPM and the As Built timeline for development. It is a method for identifying tasks that are essential to the execution of a project and determining scheduling flexibility. This method is comparable to the Net Impact Method because both solely display the net result of any stated delays in project completion. The results usually show how long a party may be eligible to receive damages.

Pros

- Simultaneous delays are taken under consideration.
- In comparison to the Net Impact Technique, this method is better.
- It can be easily analysed if there is available information, such as an As-Built programme.

Cons

- The types of delays are not thoroughly examined.
- It is impossible to simultaneously analyse the delays.
- Even though these might be indicated in the schedule, claim-causing delay events are most likely unclear and not on the critical route.

H. Global Impact Technique (GIT): This type of delay analysis is retrospective. This technique achieves the overall project delay by gathering all delayed events that are applied in the finalization of activities. This technique makes it simple to demonstrate the impact of events that cause delays. This method creates a bar graph that displays each delay and interruption. The start and end dates of each delay are identified for each occurrence. The overall project delay is calculated as the sum of the durations of all delaying events.

Pros

- It is simple to analyse the data.
- It dont requires the activites and relationships to analyse the data.

Cons

- This approach disregards concurrent delays.
- There is the lack of precise delay determination in this method.
- It is unable to locate the crucial route and perform floating operations.

I. Net Impact Technique (NIT): This type of delay analysis is retrospective. This method merely shows a bar graph of the total stated latency. The sole effects of the delays that were caused on the activities are employed in this method, which takes into consideration all the actions that cause delays. The net impact technique attempts to solve the issue of concurrent delays but does not investigate various delay types.

Pros

- This meathod consider overlapping delays.
- This approach includes all As-Built schedule delays, errors in task completion, work orders, and suspensions.
- It only figures out the overall net impact of all delays.

Cons

- It is unable to accurately identify the different forms of delays.

- It is difficult to assess the true effect of a delay on the project's final completion while the networks facility is not being used.
- It has inability to identify the essential path.

J. Isolated Delay Technique (IDT): This type of delay analysis is retrospective. This method makes an effort to take into account all 3 principles (delay categorization, simultaneous delay consideration, and real-time delay analysis). This requires an event log and accurate information system documentation to be present from the start of the project. Nevertheless, the number of analyses that were performed affects how accurate this analysis is.

Pros

- This meathod accurately reflect the impact of delays.
- In order to solve the issue of the overestimation of the time extension, concurrent delays are examined and modified.
- Both parties utilise the float.
- Since it may be used by both sides simultaneously, the analysis is impartial.
- An integrated computer system that makes use of current management tools, such as scheduling, spreadsheets, databases, and expert systems, can accommodate the technique.

Cons

- The types of delays are not thoroughly examined.
- It is unable to accurately identify the different forms of delays.
- It is difficult to assess the true effect of a delay on the project's final completion while the networks facility is not being used.
- It has inability to identify the essential path.

From the literature review, Impact As-Planned, Time Impact Analysis, and Collapsed As-Built are found to be the better techniques among the others to claim the extension of time (EOT). It has been found that Impact As-Planned performed prospective analysis, which means looking forward to analyse what will happen, and it is easy to learn and perform. Time Impact Analysis is a dynamic and prospective method that can also be used retrospectively. It is a better technique as it considers the actual site progress. On the other hand, Collapsed As-Built is a retrospective approach. It determines what would have happened if the delay hadn't occurred. It separately elaborates the delays caused by the contractor and client by subtracting them from the as-built schedule.

2.5 Summary

It is concluded from the above discussion that delays are one of the most common issues in the construction industry, and these negatively influence the project's success in terms of time, cost, and quality. For all parties concerned, delays are costly, and these typically result in conflicts, cost overruns, negotiation, litigation, project rejection, and project unfeasibility. Due to a number of exterior and interior elements that influence the construction process, construction is a high-risk industry with many uncertainties. It has also been observed from the literature review that different delay analysis techniques (DAT's) were used to assess the delays, all having different specifications and having different results for the same delays scenarios. It has been observed that these DATs will help different parties involved in the construction projects to resolve disputes among themselves. Among these techniques, the three most recommended and highly ranked DATs, which are generally perceived as more reliable than the other simplistic methods [9], have been shortlisted from the literature, i.e., Impact As-Planned (IAP), Time Impact Analysis (TIA), and Collapsed As Built (CAB), to evaluate the selected case study.

Chapter 3

Research Methodology

3.1 Background

This chapter details the methods and tools used in the research to answer the problem statement and achieve the objectives of the study. This chapter is comprise of the study area of this research, nature and source of data, identification of delayed events and analysis procedure. This chapter has been divided into four phases, according to the research framework by following the ISO standard guidelines.

- The phase 1 deals with the problem identification, objectives and scope of study by conducting a critical literature review of previous works.
- Phase 2 addresses the case study attributes, data acquisition and analysis procedure.
- Phase 3 describes the analysis of data along with the tools and methods and comparative analysis of DAT's.
- Whereas the last phase, the results of analysis have been interpreted to draw the conclusion and future recommendation of research study.

The graphical representation of detailed methodology is shown in Fig 3.1.

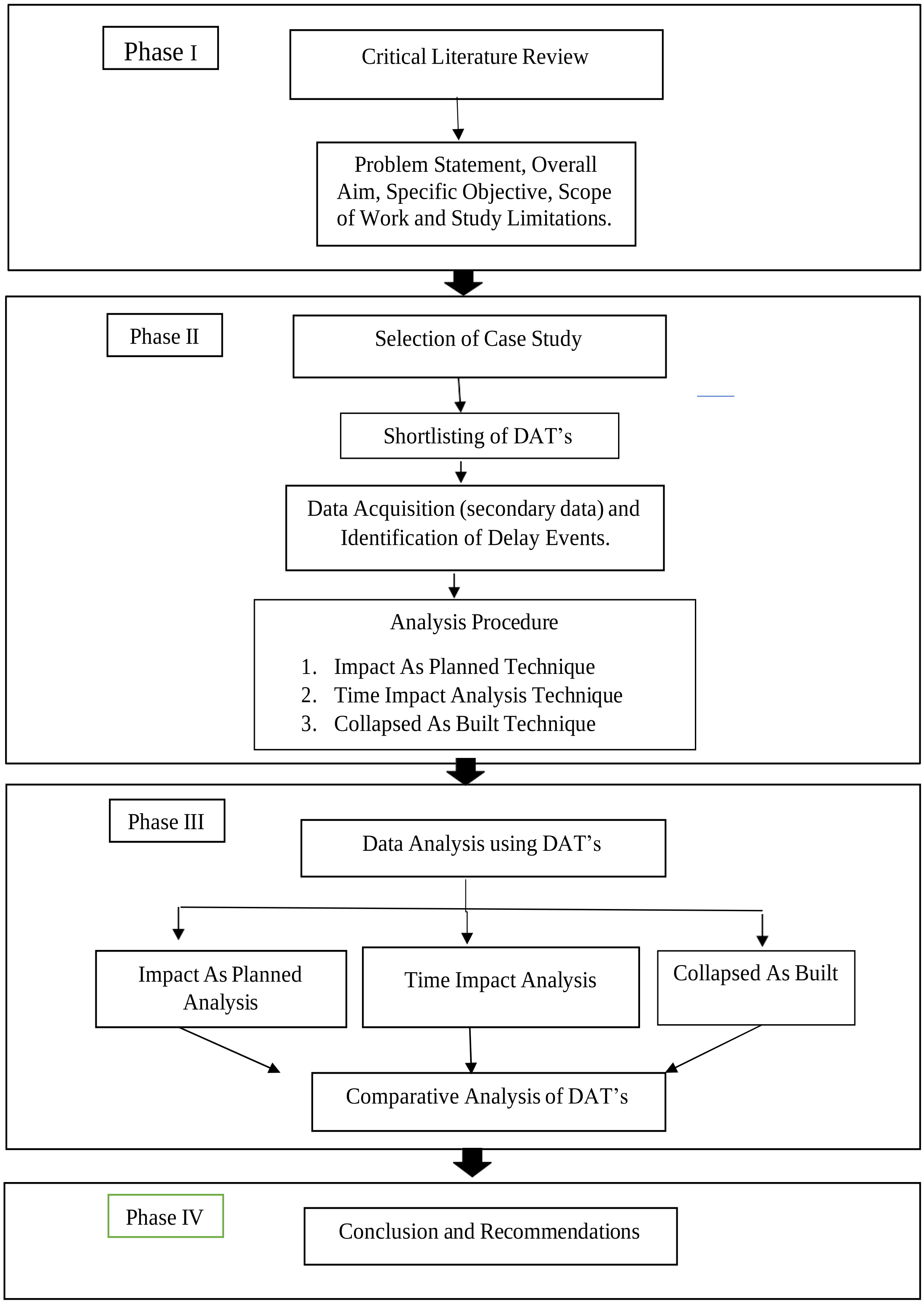


Figure 3.1: Graphical Representation of Detailed Methodology

3.2 Study Area

The majority of the research literature evaluated delays using different tools and techniques to perform delay analysis (DA). There are a majority of research studies conducted on different DAT's, but very limited work has been done on comparative analysis of different DAT's in real life applications. This aspect remains grey and requires attention. To compare and contrast the different commonly used delay analysis techniques (DATs), a lot of research needs to be done.

In order to evaluate the results of various causes affecting the constructions delays events on the project's on-time completion, a real building project has been chosen as a case study. Construction delays were a common occurrence for the project. The project name is New Islamabad International Airport Project – Packaged Additional Airside Buildings. The project is located in Islamabad, Pakistan.

3.3 Nature and Source of Data

There are two types of data, i.e., primary data and secondary data. The term primary data refers to information that has been collected directly by the researcher. On the other hand, secondary data is data that was gathered earlier by some other party. The current research study only involves secondary data. The main sources of this data include the professional organisations that have been approached to conduct and report this study and have published the literature on this topic.

3.4 Identified Delayed Event Imposed in All DAT's

To examine the existing DAT's, a building project was selected named as the New Islamabad Airport Project – Packaged Additional Airside Buildings, Islamabad, Pakistan. The plan for the case study included creating an airside structure at the airport in Islamabad. The project was planned for a total duration of 156 days, starting from 28-Feb-17 and finishing on 02-Aug-17. Fig 3.2 shows the As-Planned schedule/baseline schedule of the selected project. The project began according to plan, but later delays and events impacted its progress. To evaluate and analyse the impact of delays on the progress of the project, first of all, the main sources of delays were identified, and information was gathered regarding these delays. A total of eight types of delay events were identified, all of which were caused by the client. The following were the delays and events that were being faced during the phase of completion. Table 3.1 illustrates the delays and events that affected the selected project.

Event 1: Issuance of Construction Drawings

The site situation as presented in tender drawings was different than the actual site situation. To cater for the actual site situation, revised construction drawings were issued to the contractor on 30th March 2017. The contractor was unable to perform foundation works and, thus, all subsequent activities were delayed.

Event 2: Not Foreseeable Physical Conditions

The plan was to execute the project as per the given tender drawings, but the site conditions were totally different than mentioned. The drawings were revised to cater for changes later on, as mentioned in event 01. The scope of work increased tremendously, thus resulting in it taking more time than planned. After mobilisation on site, different physical conditions were encountered, which were not foreseeable by any contractor. In order to sort out issues, revised drawings were prepared, and it was found that several extra tasks has to be performed to excute the tasks, which drastically impacted the pace of execution and took longer than estimated. It approximately took 60 days to complete.

Event 3: Additional Works of Rapid Sand Filtration Works

Additional work was added to the contractor's original scope of work on the 25th March 2017. The increase in scope of work disrupts the progress of the contractor on the original scope of work. The contractor has to arrange additional resources like machinery, manpower, and materials to carry out this additional work. This event took 171 days to complete, which was comprised of many sub-activities. The delayed event ended on September 11th, 2017.

Event 4: Additional Works of Public Address System @ SFS

Additional work was added to the contractor's original scope of work on April 24th, 2017. The increase in scope of work disrupts the progress of the contractor on the original scope of work. The contractor has to arrange additional resources like machinery, manpower, and materials to carry out this additional work.

The event is composed of different stages like vendor selection, submittal preparation and approval, procurement and shipment, and then installation, connectivity with other systems, and testing and commissioning. The materials used for this system were not available locally. Therefore, the vendor placed an order in a foreign market. Material (foreign product) procurement, shipment, and clearance from customs normally takes 150 days, but in this case it took more than 221 days because of high demand, which resulted in a 329-day process.

Event 5: Additional Works of AOCC Building

Additional work was added to the contractor's original scope of work on June 23rd, 2017. The increase in scope of work disrupts the progress of the contractor on the original scope of work. The contractor has to arrange additional resources like machinery, manpower, and materials to carry out this additional work. This delayed event took 164 days to complete.

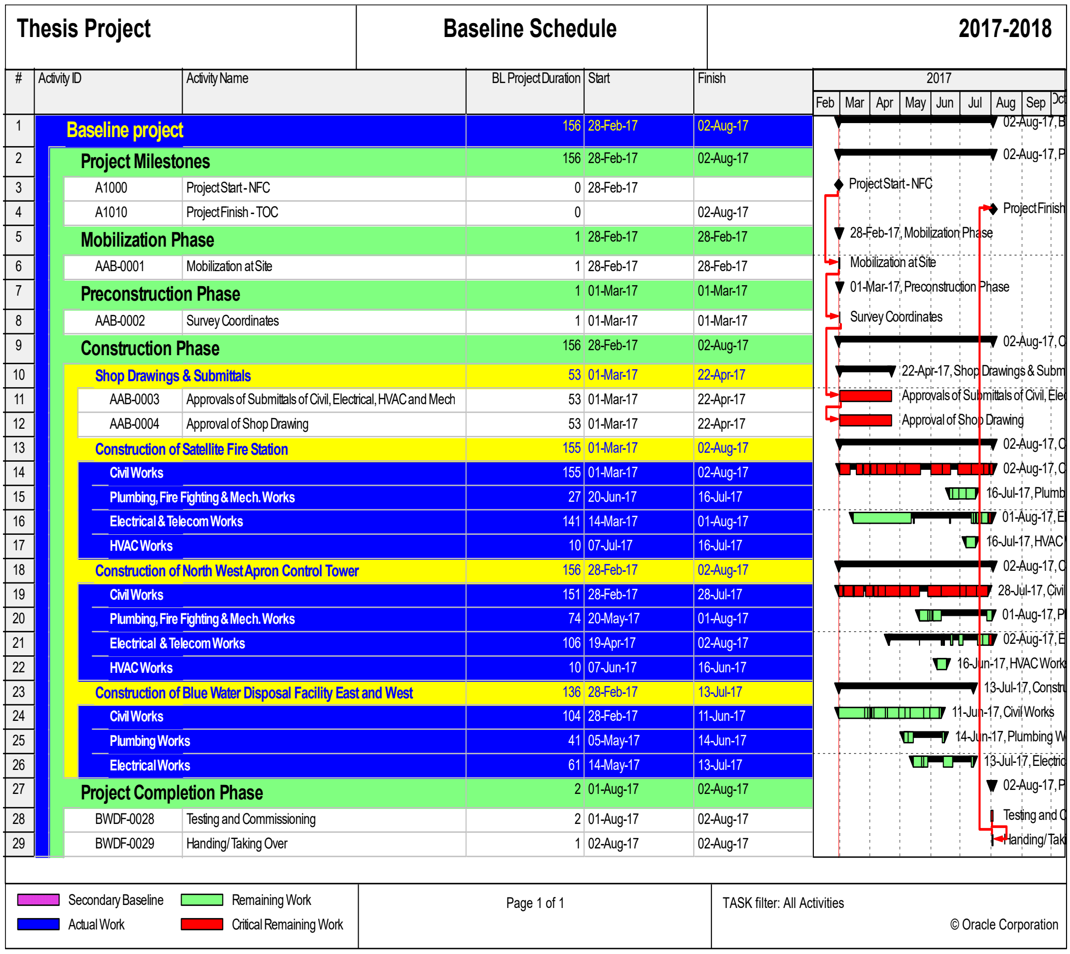
Event 6: Additional Works of Water Filling Point

Additional work was added to the contractor's original scope of work on November 4th, 2017. The increase in scope of work disrupts the progress of the contractor on the original scope of work. The contractor has to arrange additional resources like machinery, manpower, and materials to carry out this additional work.

The main issue was the arrangement of the fabricator of GRP pipes. Due to the specialised skills, the contractor had no choice but to wait for the team to arrive on site according to their schedule, and once arrived, water shutdown from the employer side was also required. This process took a total of 63 days.

Event 7: Delayed Execution of Raised Floor Activity Due to Package 7B

The Engineer was informed on October 14th and October 31st to inform Package 7B to mobilise and execute their activities so that raised floor panels could be installed. The contractor for Package 7B was never seen on site until January 2018. The area was handed over to us for work in the first week of February and suspended activities were completed up to February 14th, 2018, which made a total of 124 days.


Thesis Project | Baseline Schedule | 2017-2018

#	Activity ID	Activity Name	BL Project Duration	Start	Finish
1		Baseline project	156	28-Feb-17	02-Aug-17
2		Project Milestones	156	28-Feb-17	02-Aug-17
3	A1000	Project Start - NFC	0	28-Feb-17	
4	A1010	Project Finish - TOC	0		02-Aug-17
5		Mobilization Phase	1	28-Feb-17	28-Feb-17
6	AAB-0001	Mobilization at Site	1	28-Feb-17	28-Feb-17
7		Preconstruction Phase	1	01-Mar-17	01-Mar-17
8	AAB-0002	Survey Coordinates	1	01-Mar-17	01-Mar-17
9		Construction Phase	156	28-Feb-17	02-Aug-17
10		Shop Drawings & Submittals	53	01-Mar-17	22-Apr-17
11	AAB-0003	Approvals of Submittals of Civil, Electrical, HVAC and Mech	53	01-Mar-17	22-Apr-17
12	AAB-0004	Approval of Shop Drawing	53	01-Mar-17	22-Apr-17
13		Construction of Satellite Fire Station	155	01-Mar-17	02-Aug-17
14		Civil Works	155	01-Mar-17	02-Aug-17
15		Plumbing, Fire Fighting & Mech. Works	27	20-Jun-17	16-Jul-17
16		Electrical & Telecom Works	141	14-Mar-17	01-Aug-17
17		HVAC Works	10	07-Jul-17	16-Jul-17
18		Construction of North West Apron Control Tower	156	28-Feb-17	02-Aug-17
19		Civil Works	151	28-Feb-17	28-Jul-17
20		Plumbing, Fire Fighting & Mech. Works	74	20-May-17	01-Aug-17
21		Electrical & Telecom Works	106	19-Apr-17	02-Aug-17
22		HVAC Works	10	07-Jun-17	16-Jun-17
23		Construction of Blue Water Disposal Facility East and West	136	28-Feb-17	13-Jul-17
24		Civil Works	104	28-Feb-17	11-Jun-17
25		Plumbing Works	41	05-May-17	14-Jun-17
26		Electrical Works	61	14-May-17	13-Jul-17
27		Project Completion Phase	2	01-Aug-17	02-Aug-17
28	BWDF-0028	Testing and Commissioning	2	01-Aug-17	02-Aug-17
29	BWDF-0029	Handing/ Taking Over	1	02-Aug-17	02-Aug-17

Secondary Baseline | Remaining Work | Actual Work | Critical Remaining Work

Page 1 of 1

TASK filter: All Activities

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FIGURE 3.2: Baseline Schedule of the Project

Table 3.1: Delays events which affected the project

Delay Events	As planned duration	Description	Type	Duration (days)
01	00	Issuance of construction drawings	EC	0
02	00	Not Foreseeable Physical Conditions	EC	60
03	00	Additional Works of rapid sand filtration works	EC	171
04	00	Additional works of Public Address System @ SFS	EC	329
05	00	Additional works of AOCC Building	EC	164
06	00	Additional works of water filling point	EC	63
07	00	Delayed Execution of Raised Floor Activity due to Package 7B	EC	124
08	00	Additional Work of Louver Doors	EC	45

Event 8: Additional Work of Louver Doors

On March 18, 2018, the contractor was awarded additional work for louvre doors. The contractor started the process of vendor selection after receipt of the EI. After finalisation of the vendor agreement, procurement and shipment of material started. During that phase of procurement, the construction team was doing block and plaster work and scaffolding for external louvres in parallel. This additional work took 45 days to complete.

3.5 Analysis Procedures

The data for the evaluation of the selected project, secondary in nature, was acquired from the concerned organization. The next step after the acquisition of the data is the analysis of that data to evaluate the impacts i.e., the time impacts caused by identified delays. Primavera P6 is used to conduct delay analysis. The purpose of this analysis is to evaluate the extension of time. This delay analysis is prepared as per the Society of Construction Law—UK. The delayed events are required to be inserted into the work programme, creating a link with the original activities. Primavera calculates the impact of each event for us, and the completion date given by Primavera is considered the impacted completion date. This method doesn't take into account the actual progress on site. The same baseline work programme was turned into a P6 work programme so that delay analysis could be performed.

Different delay analysis techniques (DAT's) were used in past to analyse the impact of delays on construction projects. Cause and effect type analyses are predicated on the identification and description of an event and the subsequent establishment of its impact. There are also methods that begin with the identification of a crucial delay and then work backwards to determine possible causes for that delay. Since the effect and cause methods take into account every possible cause of the delay incurred, which are generally considered more forensically reliable when assessing an EOT application after the work is finished or after the effect of an employer risk event.

The availability of scheduling data, the analyst's familiarity with the capabilities of the software used in the project, and clear specifications in the contract concerning the treatment of concurrent delays and the ownership of float all play significant roles in determining the best analysis approach to employ. To assess the impact of delays on the selected case study, the three commonly used delay analysis techniques (DATs), based on their reliability and considerable results [9], listed below, were chosen from the SCL Protocol [10]. These techniques are Impact As-Planned, Time Impact Analysis, and Collapse As-Built.

3.5.1 Impacted As Planned Technique

The impact of the delays on the original plan is calculated using the Impacted As-Planned approach. The delays are modelled as tasks and subsequently added to the project's as-planned timeline to illustrate the cumulative impact of each delay. The length of time it will take to finish the project after the impacts have been factored in is equal to the time gap between the original and revised completion dates.

Ekanayake et al. [59] explained DAT's in their study Techniques appropriate for analysing delays in Sri Lankan road construction projects. Impacted As Planned (IAP) was found as the most appropriate delay analysis technique during their research work on delay analysis of the road projects in Sri Lanka.

3.5.2 Time Impact Analysis Technique

To analyse the effects of a delay on a schedule, a method called Time Impact Analysis can be used, which incorporates changes and delays to the schedule up until the day before the delay actually occurs. Check if the projected project end date has moved forward or backward due to the setbacks.

Arditi, D., and Pattanakitchamroon, T. [61] conducted their study on choosing a method of delay analysis to settle construction disputes. For this purpose, analysis was performed, and it was observed that TIA is the most credible delay analysis technique to asses the impact of delays in construction projects.

3.5.3 Collapsed As Built Technique

The Collapsed As-Built Analysis is a method of analysing project schedule delays in retrospect to find the earliest date by which the project completion date or a required milestone could have been reached in the absence of owner-caused or contractor-caused delays.

Yang Yin [63] introduced a new approach to delay analysis in construction projects using the isolated collapsed but-for method. This method needs as-planned and as-built schedules as well as liability documents that list key delay events in order to do its analysis approach.

3.6 Summary

Different delay analysis techniques (DAT's) are used in past to analyse the impact of delays on construction projects. Cause and effect type analyses are predicated on the identification and description of an event (a cause) and the subsequent establishment of its impact (the effect). There are also methods that begin with the identification of a crucial delay (an effect) and then work backwards to determine possible causes for that delay. For this research work above mentioned three DAT's are selected from the SCL protocol to analyse the impact of different delays on the selected case study.

Chapter 4

Results and Analysis

4.1 Background

In the past, different delay analysis techniques (DAT's) were used to analyse the impact of delays on construction projects. Cause and effect type analyses are predicated on the identification and description of an event (a cause) and the subsequent establishment of its impact (the effect). Three DATs, namely IAP, TIA, and CAB, were chosen for this research thesis to investigate the impact of delayed events on project completion dates. This chapter provides the detailed results that are driven by using the above-mentioned DAT's.

4.2 Impacted As Planned Analysis

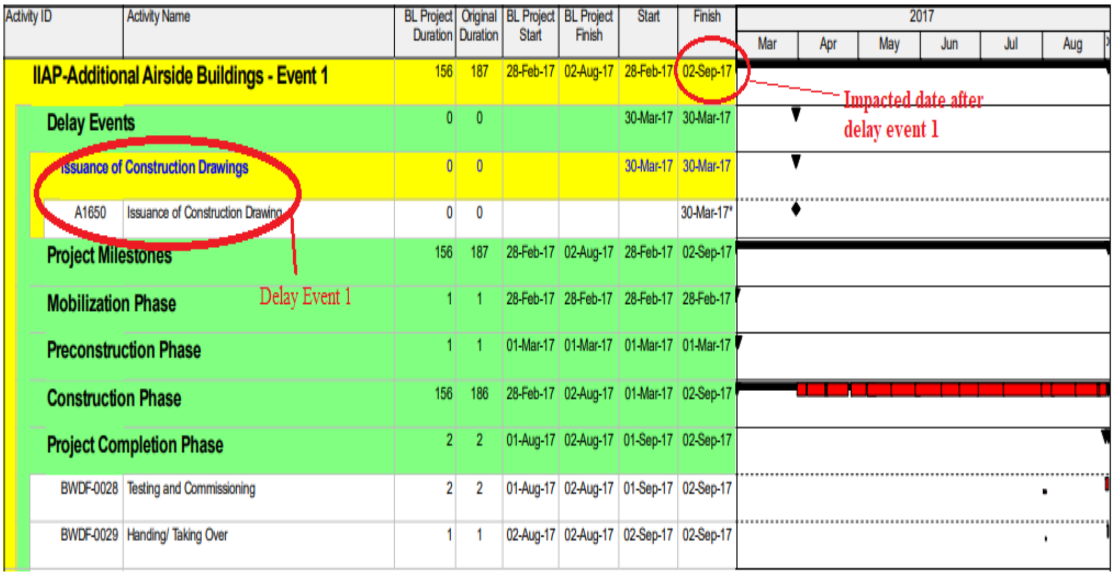
With this technique, the effect of delays was measured on the contractor's CPM timetable as intended. The different delays were organised as activities and added to the network that was originally designed in a chronological manner to display the impact of each delay individually and to illustrate how the project was progressing slowly. The amount of delay is equal to the variance in completion dates between the schedules before and after the impacts. The technique can be used to examine delays before, during, and after a project is finished.

This method was used to analyse the delays in the sample project by sequentially adding the delays to the original schedule. In this technique, the impact of every delay was analysed with individuality. Fig 4.1-4.8 shows the impact of each delay on the complication date. As shown in Fig 4.1, the impact of event 1 is shown. The revised construction drawing was issued on 30 March 2017. This resulted in the delay of all subsequent activities and impacted complications. The date after event 1 was September 02, 2017, which made a total of 31 days delay. Similarly, event 2 contained many extra activities, which resulted in the impacted date reaching November 1, 2017 as shown in Fig 4.2. which resulted in the project being delayed for 91 days. As shown in figure 4.4, the event 4 with additional public address system works at SFS began on April 24, 2017. The event is ending on March 20th, 2018, which means that the project completion date, i.e., November 1st, 2017, is impacted. Thus, the completion date is delayed by 230 days. Fig 4.8 illustrates the impact of delay event 8, i.e., additional work of the louvre doors.

Event 3-Additional works of rapid sand filtration works, Event5-Additional works of AOCC Building, Event6-Additional works of water filling point, and Event7-Delayed Execution of Raised Floor Activity due to Package 7B didn't have any effect on the final completion date of the project because of its non-critical path and due to their parallel activities with other events. Figs 4.3, 4.5, 4.6, 4.7 show that these activities have no impact on the final completion date. The limitations which were observed during the process of analysis are stated as follows.

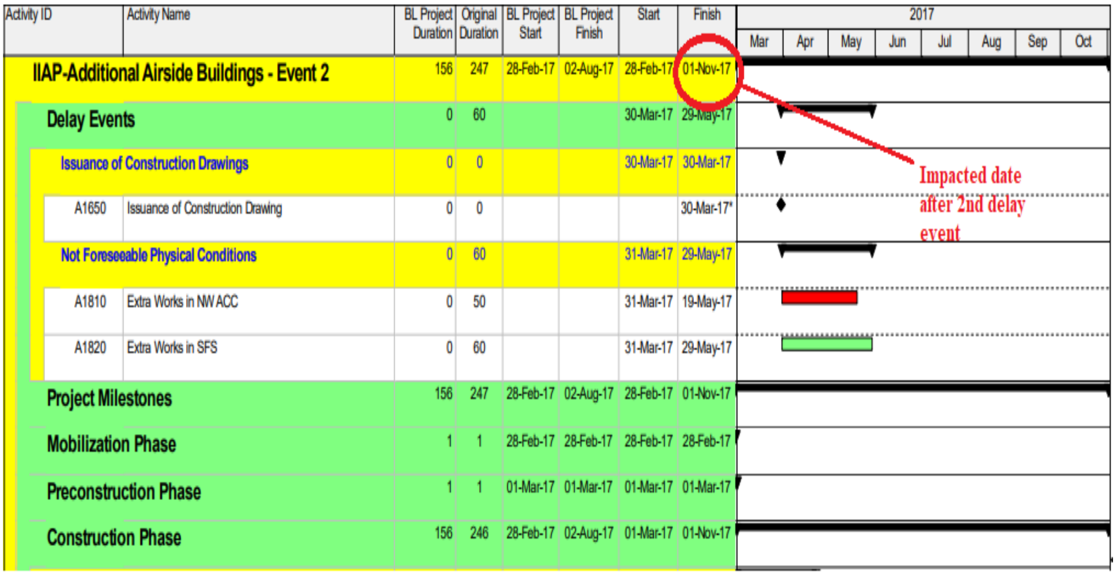
- It analyses delays that aren't related to context or time using a fixed, pre-determined timetable.
- A realistic model to base the entire study may not be the initial baseline program.
- It can fail to take into account everyone's delays, particularly the applicant's.
- Due to the fact that it is neither practical nor cost-effective to schedule the complete project in detail at the beginning, there may be disagreements on the suitability of the as-planned schedule.

In this analysis technique, there is a relationship between the baseline schedule and the newly delayed, impacted schedule. Delays caused by the client have been added to the schedule. While the delays caused by the contractor were not added (and there was also no delay caused by the contractor), it has been observed that this technique is relatively easy to perform and understand. Actual site progress and programme updates are not required for this approach. This DAT is suggested when a regular progress report is not available.



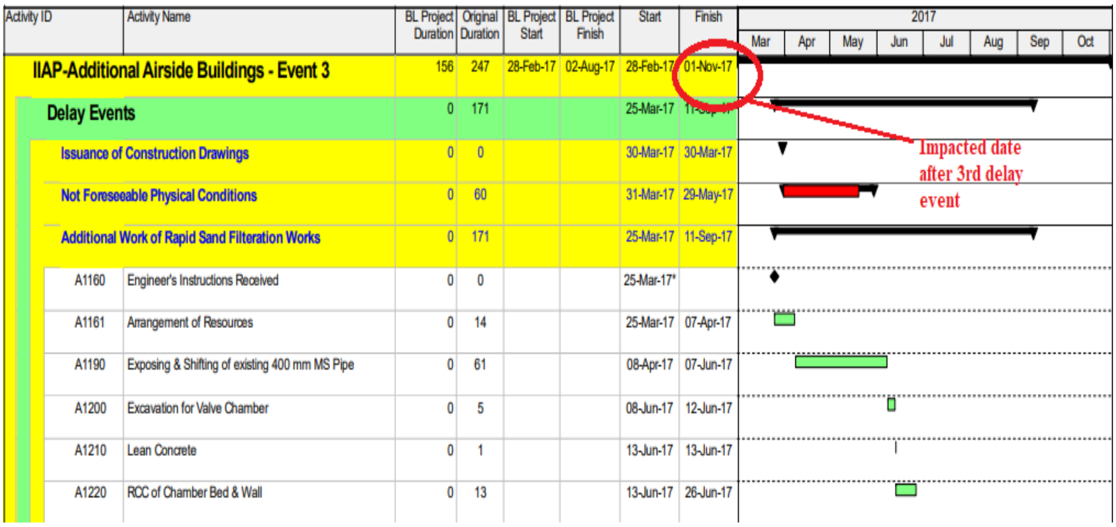
Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
	IIAP-Additional Airside Buildings - Event 1	156	187	28-Feb-17	02-Aug-17	28-Feb-17	02-Sep-17
	Delay Events	0	0			30-Mar-17	30-Mar-17
	Issuance of Construction Drawings	0	0			30-Mar-17	30-Mar-17
A1650	Issuance of Construction Drawing	0	0				30-Mar-17*
	Project Milestones	156	187	28-Feb-17	02-Aug-17	28-Feb-17	02-Sep-17
	Mobilization Phase	1	1	28-Feb-17	28-Feb-17	28-Feb-17	28-Feb-17
	Preconstruction Phase	1	1	01-Mar-17	01-Mar-17	01-Mar-17	01-Mar-17
	Construction Phase	156	186	28-Feb-17	02-Aug-17	01-Mar-17	02-Sep-17
	Project Completion Phase	2	2	01-Aug-17	02-Aug-17	01-Sep-17	02-Sep-17
BWDF-0028	Testing and Commissioning	2	2	01-Aug-17	02-Aug-17	01-Sep-17	02-Sep-17
BWDF-0029	Handing/ Taking Over	1	1	02-Aug-17	02-Aug-17	02-Sep-17	02-Sep-17

FIGURE 4.1: IAP, Impact of delay event 1



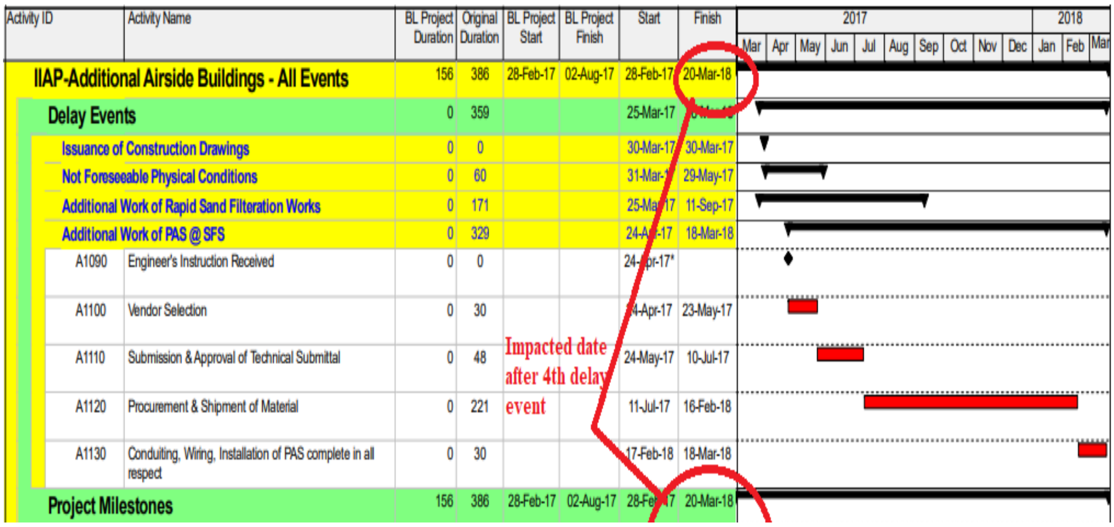
Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
	IIAP-Additional Airside Buildings - Event 2	156	247	28-Feb-17	02-Aug-17	28-Feb-17	01-Nov-17
	Delay Events	0	60			30-Mar-17	29-May-17
	Issuance of Construction Drawings	0	0			30-Mar-17	30-Mar-17
A1650	Issuance of Construction Drawing	0	0				30-Mar-17*
	Not Foreseeable Physical Conditions	0	60			31-Mar-17	29-May-17
A1810	Extra Works in NW ACC	0	50			31-Mar-17	19-May-17
A1820	Extra Works in SFS	0	60			31-Mar-17	29-May-17
	Project Milestones	156	247	28-Feb-17	02-Aug-17	28-Feb-17	01-Nov-17
	Mobilization Phase	1	1	28-Feb-17	28-Feb-17	28-Feb-17	28-Feb-17
	Preconstruction Phase	1	1	01-Mar-17	01-Mar-17	01-Mar-17	01-Mar-17
	Construction Phase	156	246	28-Feb-17	02-Aug-17	01-Mar-17	01-Nov-17

FIGURE 4.2: IAP, Impact of delay event 2



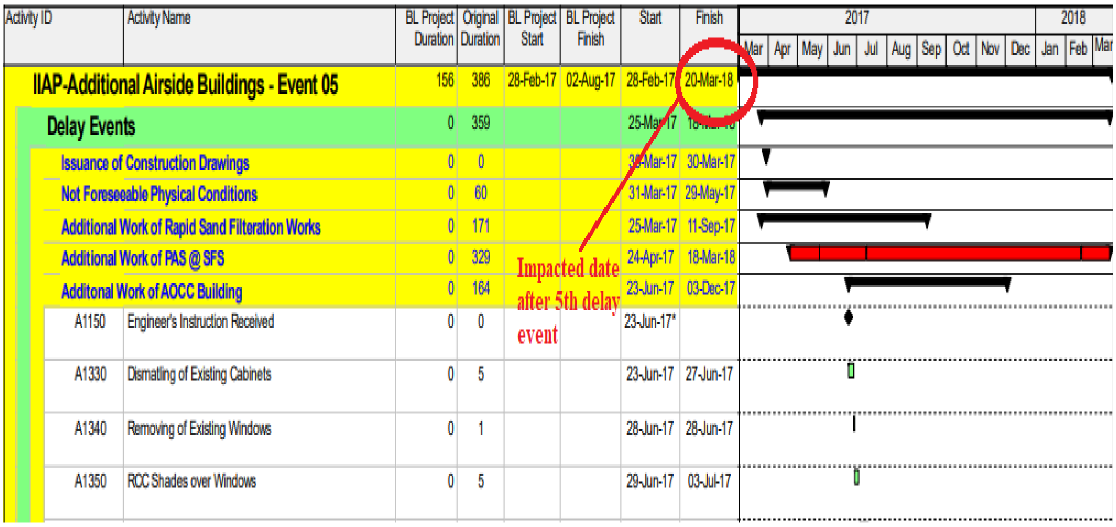
Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
	IIAP-Additional Airside Buildings - Event 3	156	247	28-Feb-17	02-Aug-17	28-Feb-17	01-Nov-17
	Delay Events	0	171			25-Mar-17	11-Sep-17
	Issuance of Construction Drawings	0	0			30-Mar-17	30-Mar-17
	Not Foreseeable Physical Conditions	0	60			31-Mar-17	29-May-17
	Additional Work of Rapid Sand Filteration Works	0	171			25-Mar-17	11-Sep-17
A1160	Engineer's Instructions Received	0	0			25-Mar-17*	
A1161	Arrangement of Resources	0	14			25-Mar-17	07-Apr-17
A1190	Exposing & Shifting of existing 400 mm MS Pipe	0	61			08-Apr-17	07-Jun-17
A1200	Excavation for Valve Chamber	0	5			08-Jun-17	12-Jun-17
A1210	Lean Concrete	0	1			13-Jun-17	13-Jun-17
A1220	RCC of Chamber Bed & Wall	0	13			13-Jun-17	26-Jun-17

Figure 4.3: IAP, Impact of delay event 3



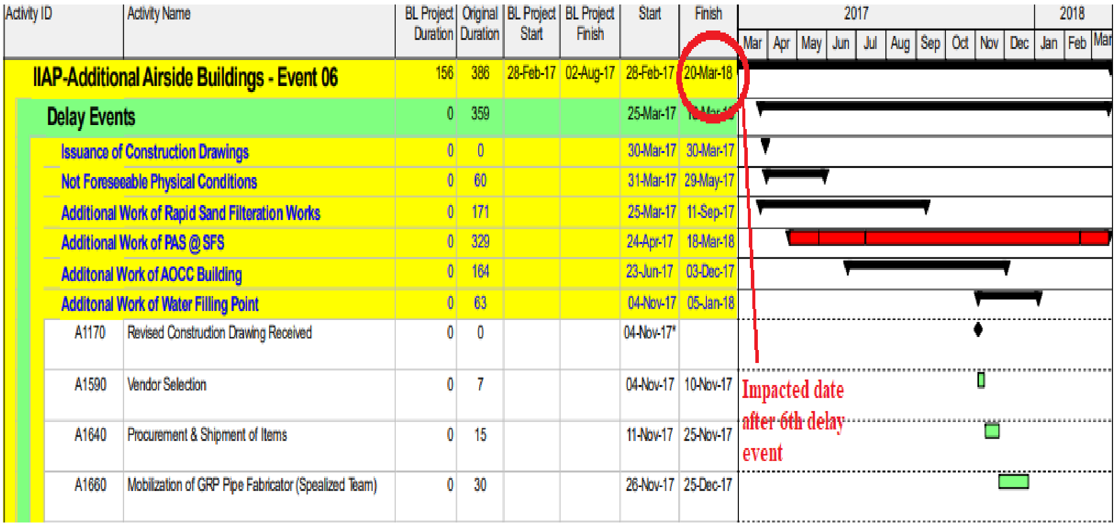
Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
	IIAP-Additional Airside Buildings - All Events	156	386	28-Feb-17	02-Aug-17	28-Feb-17	20-Mar-18
	Delay Events	0	359			25-Mar-17	[illegible]
	Issuance of Construction Drawings	0	0			30-Mar-17	30-Mar-17
	Not Foreseeable Physical Conditions	0	60			31-Mar-17	29-May-17
	Additional Work of Rapid Sand Filteration Works	0	171			25-Mar-17	11-Sep-17
	Additional Work of PAS @ SFS	0	329			24-Apr-17	18-Mar-18
A1090	Engineer's Instruction Received	0	0			24-Apr-17*	
A1100	Vendor Selection	0	30			24-Apr-17	23-May-17
A1110	Submission & Approval of Technical Submittal	0	48			24-May-17	10-Jul-17
A1120	Procurement & Shipment of Material	0	221			11-Jul-17	16-Feb-18
A1130	Conduiting, Wiring, Installation of PAS complete in all respect	0	30			17-Feb-18	18-Mar-18
	Project Milestones	156	386	28-Feb-17	02-Aug-17	28-Feb-17	20-Mar-18

Figure 4.4: IAP, Impact of delay event 4



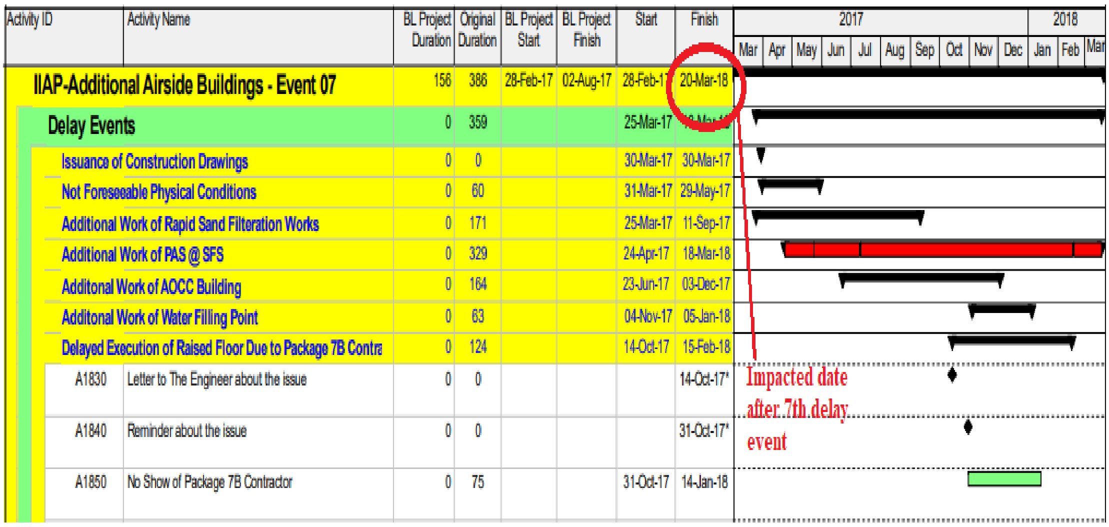
Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
	IIAP-Additional Airside Buildings - Event 05	156	386	28-Feb-17	02-Aug-17	28-Feb-17	20-Mar-18
	Delay Events	0	359			25-Mar-17	18-Mar-18
	Issuance of Construction Drawings	0	0			30-Mar-17	30-Mar-17
	Not Foreseeable Physical Conditions	0	60			31-Mar-17	29-May-17
	Additional Work of Rapid Sand Filteration Works	0	171			25-Mar-17	11-Sep-17
	Additional Work of PAS @ SFS	0	329			24-Apr-17	18-Mar-18
	Additonal Work of AOCC Building	0	164			23-Jun-17	03-Dec-17
A1150	Engineer's Instruction Received	0	0			23-Jun-17*	
A1330	Dismatling of Existing Cabinets	0	5			23-Jun-17	27-Jun-17
A1340	Removing of Existing Windows	0	1			28-Jun-17	28-Jun-17
A1350	RCC Shades over Windows	0	5			29-Jun-17	03-Jul-17

Figure 4.5: IAP, Impact of delay event 5



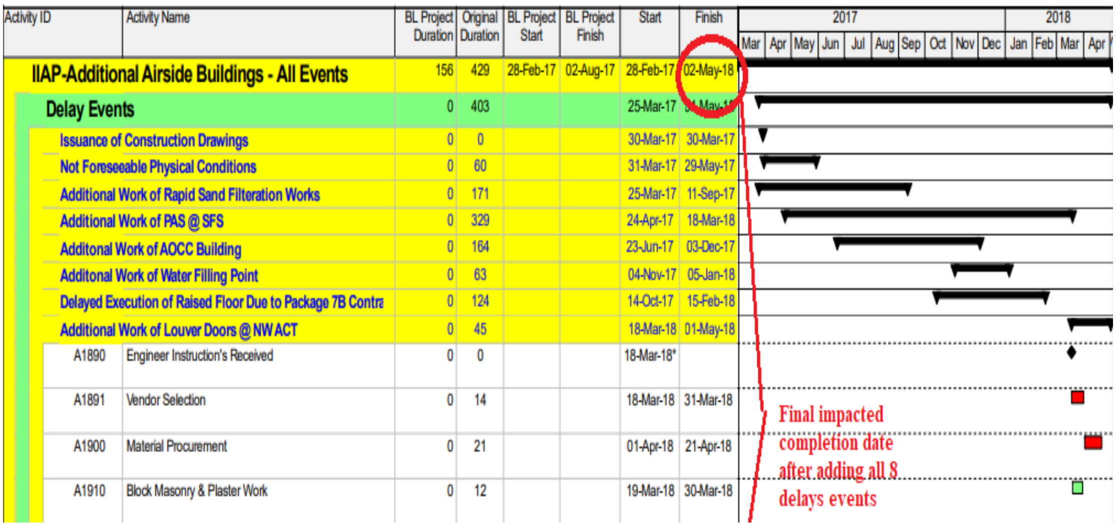
Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
	IIAP-Additional Airside Buildings - Event 06	156	386	28-Feb-17	02-Aug-17	28-Feb-17	20-Mar-18
	Delay Events	0	359			25-Mar-17	[illegible]
	Issuance of Construction Drawings	0	0			30-Mar-17	30-Mar-17
	Not Foreseeable Physical Conditions	0	60			31-Mar-17	29-May-17
	Additional Work of Rapid Sand Filteration Works	0	171			25-Mar-17	11-Sep-17
	Additional Work of PAS @ SFS	0	329			24-Apr-17	18-Mar-18
	Additonal Work of AOCC Building	0	164			23-Jun-17	03-Dec-17
	Additonal Work of Water Filling Point	0	63			04-Nov-17	05-Jan-18
A1170	Revised Construction Drawing Received	0	0			04-Nov-17*	
A1590	Vendor Selection	0	7			04-Nov-17	10-Nov-17
A1640	Procurement & Shipment of Items	0	15			11-Nov-17	25-Nov-17
A1660	Mobilization of GRP Pipe Fabricator (Spealized Team)	0	30			26-Nov-17	25-Dec-17

FIGURE 4.6: IAP, Impact of delay event 6



Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
	IIAP-Additional Airside Buildings - Event 07	156	386	28-Feb-17	02-Aug-17	28-Feb-17	20-Mar-18
	Delay Events	0	359			25-Mar-17	[illegible]
	Issuance of Construction Drawings	0	0			30-Mar-17	30-Mar-17
	Not Foreseeable Physical Conditions	0	60			31-Mar-17	29-May-17
	Additional Work of Rapid Sand Filteration Works	0	171			25-Mar-17	11-Sep-17
	Additional Work of PAS @ SFS	0	329			24-Apr-17	18-Mar-18
	Additonal Work of AOCC Building	0	164			23-Jun-17	03-Dec-17
	Additonal Work of Water Filling Point	0	63			04-Nov-17	05-Jan-18
	Delayed Execution of Raised Floor Due to Package 7B Contra	0	124			14-Oct-17	15-Feb-18
A1830	Letter to The Engineer about the issue	0	0				14-Oct-17*
A1840	Reminder about the issue	0	0				31-Oct-17*
A1850	No Show of Package 7B Contractor	0	75			31-Oct-17	14-Jan-18

FIGURE 4.7: IAP, Impact of delay event 7



Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
	IIAP-Additional Airside Buildings - All Events	156	429	28-Feb-17	02-Aug-17	28-Feb-17	02-May-18
	Delay Events	0	403			25-Mar-17	[illegible]
	Issuance of Construction Drawings	0	0			30-Mar-17	30-Mar-17
	Not Foreseeable Physical Conditions	0	60			31-Mar-17	29-May-17
	Additional Work of Rapid Sand Filteration Works	0	171			25-Mar-17	11-Sep-17
	Additional Work of PAS @ SFS	0	329			24-Apr-17	18-Mar-18
	Additonal Work of AOCC Building	0	164			23-Jun-17	03-Dec-17
	Additonal Work of Water Filling Point	0	63			04-Nov-17	05-Jan-18
	Delayed Execution of Raised Floor Due to Package 7B Contra	0	124			14-Oct-17	15-Feb-18
	Additional Work of Louver Doors @ NW ACT	0	45			18-Mar-18	01-May-18
A1890	Engineer Instruction's Received	0	0			18-Mar-18*	
A1891	Vendor Selection	0	14			18-Mar-18	31-Mar-18
A1900	Material Procurement	0	21			01-Apr-18	21-Apr-18
A1910	Block Masonry & Plaster Work	0	12			19-Mar-18	30-Mar-18

FIGURE 4.8: IAP, Impact of delay event 8

4.3 Time Impact Analysis

In this technique, the proper concentration was carried on the specific delaying event. Every time the project encounters a major delay scenario, a stop-action picture of the project is created. At this time, the schedule is revised, and the impact of the delay is examined to determine a new-found accomplishment date. The delay brought on by that specific impact is indicated by the time interval between the baseline duration and the original completion date before the exercise. The real-time critical path method was used to analyse the delays in this method.

As shown in Fig 4.9, first of all, the updated schedule, i.e., the schedule with the actual site progress, was updated. And then the delayed events and their activities were developed. A total of eight delay events were faced in this project. The delayed events model was developed, and the activities were inserted into the updated schedule. All the delayed activities were then linked with the impacted activities. The predecessor and successor were then carefully assigned to all the additional activities. The schedule was then recalculated. It can be shown in Fig 4.10 that the baseline duration of the project was 156 days, but when the delay model was added to the updated schedule, the original completion date was exceeded to 429 days, having 403 days of delay events. It can be seen in figure 4.10 that the baseline (BL) start date was 28 Feb 2017 and baseline (BL) finish date was 02 August 2017 making a total duration of 156 days. The project was started on time but due to delay events the progress wasn't done as actually planned. The delay events were inserted in the schedule which made the completion date extended to 02 May 2018. The following equation shows the delayed duration, which was calculated after employing the TIA on the selected project. The BL of the project was 156 days, and the project took a total of 429 days to complete.

$$\text{BL Duration} = 156 \text{ days}$$

$$\text{Original Duration after adding delays} = 429 \text{ days}$$

$$\text{Delayed Duration} = 429 - 156 \text{ days}$$

$$\text{Delayed Duration} = 273 \text{ days}$$

It has been noted from the above equation that the combined delay duration caused by these delays events was 273 days. And all the delay duration will be excusable and compensable to contractor.

The limitations which were observed during the process of analysis are stated as follows.

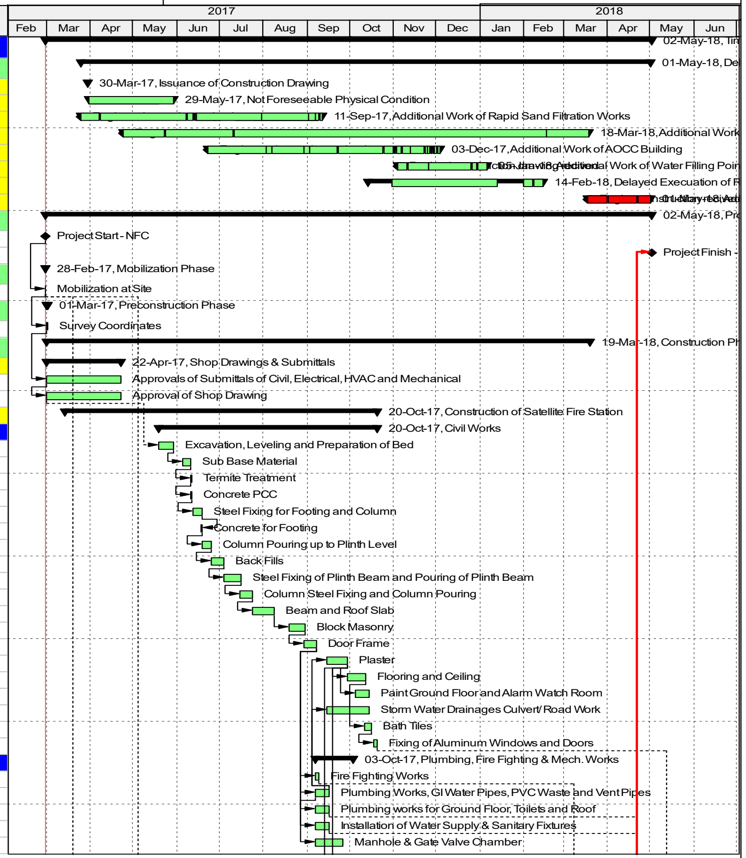
- Using it could not be feasible or reasonable if there are too many delay-causing events.
- Periodic updates might not exist, in which case the analyst would have to carry out extremely time-consuming analysis of project data to produce updates.
- The analysis is time-consuming and intensive.

This approach clearly defines the delays caused by the contractor as well as the delays experienced by the client. As the selected study didn't face any delays caused by the contractor, only the delays caused by the client were clearly defined in the time impact analysis approach. This approach took into account the current site conditions as well as the progress update. The subnet was used for analysis in this technique, resulting in a more thorough and improved result. This strategy, however, necessitates regular progress updates from the site. It will be useless in the absence of progress statistics. Furthermore, the use of this strategy is relatively complicated and requires an experienced planner.

4.4 Collapsed As Built Analysis

This strategy, also known as “as-built but for,” is in essence a variant of “but for” that uses the as-built timetable as a BL schedule rather than the as-planned timeline. In this technique, the delay analysis is separately performed first for the analysis with contractor delays and then for the analysis with client delays, to get the individual impact of both the parties involved in the project. The selected case study was analysed by using this collapsed as-built method.

Thesis Project			**Time Impact Analysis**					**2017-2018**
#	Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
1	**Time Impact Analysis**		156	429	28-Feb-17	02-Aug-17	28-Feb-17	02-May-18
2	**Delay Events**		0	403			25-Mar-17	01-May-18
3	**Issuance of Construction Drawing**		0	0			30-Mar-17	30-Mar-17
4	**Not Foreseeable Physical Condition**		0	60			31-Mar-17	29-May-17
5	**Additional Work of Rapid Sand Filtration Works**		0	171			25-Mar-17	11-Sep-17
6	**Additional Work of PAS @ SFS**		0	329			24-Apr-17	18-Mar-18
7	**Additional Work of AOCC Building**		0	164			23-Jun-17	03-Dec-17
8	**Additional Work of Water Filling Point**		0	63			04-Nov-17	05-Jan-18
9	**Delayed Execution of Raised Floor Due to Packag**		0	124			14-Oct-17	14-Feb-18
10	**Additional Work of Louver Doors @ NW ACT**		0	45			18-Mar-18	01-May-18
11	**Project Milestones**		156	429	28-Feb-17	02-Aug-17	28-Feb-17	02-May-18
12	A1000	Project Start - NFC	0	0	28-Feb-17		28-Feb-17	
13	A1010	Project Finish - TOC	0	0		02-Aug-17		02-May-18
14	**Mobilization Phase**		1	1	28-Feb-17	28-Feb-17	28-Feb-17	28-Feb-17
15	AAB-0001	Mobilization at Site	1	1	28-Feb-17	28-Feb-17	28-Feb-17	28-Feb-17
16	**Preconstruction Phase**		1	1	01-Mar-17	01-Mar-17	01-Mar-17	01-Mar-17
17	AAB-0002	Survey Coordinates	1	1	01-Mar-17	01-Mar-17	01-Mar-17	01-Mar-17
18	**Construction Phase**		156	384	28-Feb-17	02-Aug-17	01-Mar-17	19-Mar-18
19	**Shop Drawings & Submittals**		53	53	01-Mar-17	22-Apr-17	01-Mar-17	22-Apr-17
20	AAB-0003	Approvals of Submittals of Civil, Electrica	53	53	01-Mar-17	22-Apr-17	01-Mar-17	22-Apr-17
21	AAB-0004	Approval of Shop Drawing	53	53	01-Mar-17	22-Apr-17	01-Mar-17	22-Apr-17
22	**Construction of Satellite Fire Station**		155	221	01-Mar-17	02-Aug-17	14-Mar-17	20-Oct-17
23	**Civil Works**		155	155	01-Mar-17	02-Aug-17	19-May-17	20-Oct-17
24	SFS-0001	Excavation, Leveling and Preparation of	11	11	01-Mar-17	11-Mar-17	19-May-17	29-May-17
25	SFS-0002	Sub Base Material	6	6	18-Mar-17	23-Mar-17	05-Jun-17	10-Jun-17
26	SFS-0003	Termite Treatment	1	1	24-Mar-17	24-Mar-17	11-Jun-17	11-Jun-17
27	SFS-0004	Concrete PCC	1	1	24-Mar-17	24-Mar-17	11-Jun-17	11-Jun-17
28	SFS-0005	Steel Fixing for Footing and Column	7	7	25-Mar-17	31-Mar-17	12-Jun-17	18-Jun-17
29	SFS-0006	Concrete for Footing	1	1	31-Mar-17	31-Mar-17	18-Jun-17	18-Jun-17
30	SFS-0007	Column Pouring up to Plinth Level	7	7	01-Apr-17	07-Apr-17	19-Jun-17	25-Jun-17
31	SFS-0008	Back Fills	10	10	07-Apr-17	16-Apr-17	25-Jun-17	04-Jul-17
32	SFS-0009	Steel Fixing of Plinth Beam and Pouring	13	13	16-Apr-17	28-Apr-17	04-Jul-17	16-Jul-17
33	SFS-0010	Column Steel Fixing and Column Pourir	10	10	27-Apr-17	06-May-17	15-Jul-17	24-Jul-17
34	SFS-0011	Beam and Roof Slab	16	16	06-May-17	21-May-17	24-Jul-17	08-Aug-17
35	SFS-0012	Block Masonry	12	12	01-Jun-17	12-Jun-17	19-Aug-17	30-Aug-17
36	SFS-0013	Door Frame	9	9	12-Jun-17	20-Jun-17	30-Aug-17	07-Sep-17
37	SFS-0015	Plaster	15	15	28-Jun-17	12-Jul-17	15-Sep-17	29-Sep-17
38	SFS-0016	Flooring and Ceiling	14	14	12-Jul-17	25-Jul-17	29-Sep-17	12-Oct-17
39	SFS-0019	Paint Ground Floor and Alarm Watch Rc	10	10	18-Jul-17	27-Jul-17	05-Oct-17	14-Oct-17
40	SFS-0020	Storm Water Drainages Culvert/ Road W	30	30	28-Jun-17	27-Jul-17	15-Sep-17	14-Oct-17
41	SFS-0017	Bath Tiles	6	6	24-Jul-17	29-Jul-17	11-Oct-17	16-Oct-17
42	SFS-0018	Fixing of Aluminum Windows and Doors	3	3	31-Jul-17	02-Aug-17	18-Oct-17	20-Oct-17
43	**Plumbing, Fire Fighting & Mech. Works**		27	27	20-Jun-17	16-Jul-17	07-Sep-17	03-Oct-17
44	SFS-0023	Fire Fighting Works	3	3	20-Jun-17	22-Jun-17	07-Sep-17	09-Sep-17
45	SFS-0014	Plumbing Works, GI Water Pipes, PVC V	10	10	20-Jun-17	29-Jun-17	07-Sep-17	16-Sep-17
46	SFS-0022	Plumbing works for Ground Floor, Toilets	10	10	20-Jun-17	29-Jun-17	07-Sep-17	16-Sep-17
47	SFS-0024	Installation of Water Supply & Sanitary F	10	10	20-Jun-17	29-Jun-17	07-Sep-17	16-Sep-17
48	SFS-0021	Manhole & Gate Valve Chamber	20	20	20-Jun-17	09-Jul-17	07-Sep-17	26-Sep-17



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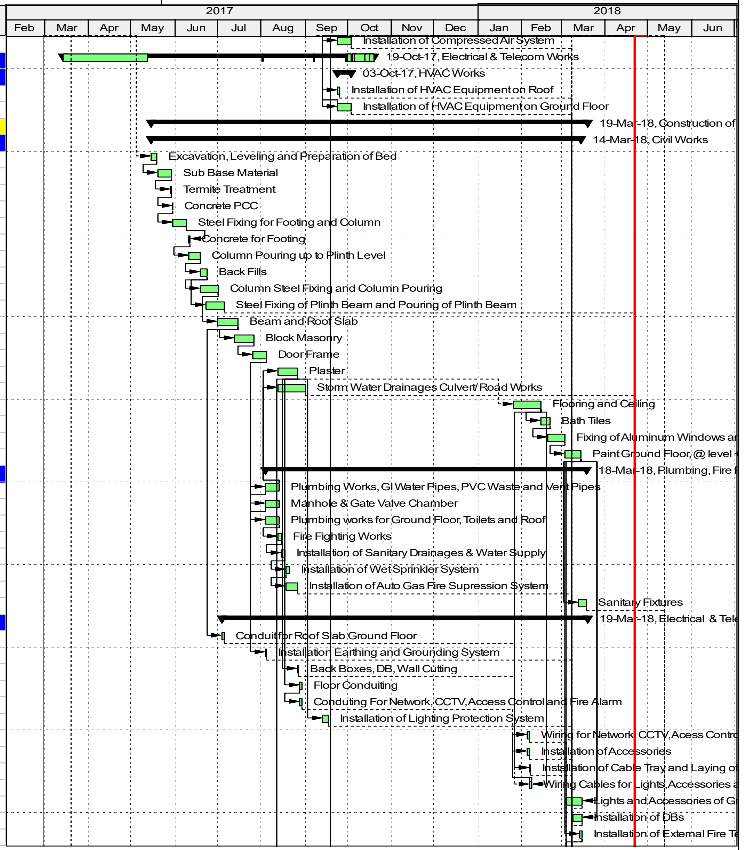
TASK filter: All Activities

FIGURE 4.9: Time Impact Analysis

Thesis Project	**Time Impact Analysis**	**2017-2018**

#	Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
49	SFS-0043	Installation of Compressed Air System	10	10	07-Jul-17	16-Jul-17	24-Sep-17	03-Oct-17
50		**Electrical & Telecom Works**	141	220	14-Mar-17	01-Aug-17	14-Mar-17	19-Oct-17
51		**HVAC Works**	10	10	07-Jul-17	16-Jul-17	24-Sep-17	03-Oct-17
52	SFS-0042	Installation of HVAC Equipment on Roof	2	2	07-Jul-17	08-Jul-17	24-Sep-17	25-Sep-17
53	SFS-0041	Installation of HVAC Equipment on Grou	10	10	07-Jul-17	16-Jul-17	24-Sep-17	03-Oct-17
54		**Construction of North West Apron Control Tower**	156	309	28-Feb-17	02-Aug-17	15-May-17	19-Mar-18
55		**Civil Works**	151	304	28-Feb-17	28-Jul-17	15-May-17	14-Mar-18
56	ACT-0001	Excavation, Leveling and Preparation of	5	5	28-Feb-17	04-Mar-17	15-May-17	19-May-17
57	ACT-0002	Sub Base Material	10	10	05-Mar-17	14-Mar-17	20-May-17	29-May-17
58	ACT-0003	Termite Treatment	1	1	14-Mar-17	14-Mar-17	29-May-17	29-May-17
59	ACT-0004	Concrete PCC	1	1	15-Mar-17	15-Mar-17	30-May-17	30-May-17
60	ACT-0005	Steel Fixing for Footing and Column	11	11	15-Mar-17	25-Mar-17	30-May-17	09-Jun-17
61	ACT-0006	Concrete for Footing	1	1	27-Mar-17	27-Mar-17	11-Jun-17	11-Jun-17
62	ACT-0007	Column Pouring up to Plinth Level	8	8	27-Mar-17	03-Apr-17	11-Jun-17	18-Jun-17
63	ACT-0008	Back Fills	5	5	04-Apr-17	08-Apr-17	19-Jun-17	23-Jun-17
64	ACT-0010	Column Steel Fixing and Column Pourir	13	13	04-Apr-17	16-Apr-17	19-Jun-17	01-Jul-17
65	ACT-0009	Steel Fixing of Plinth Beam and Pouring	13	13	08-Apr-17	20-Apr-17	23-Jun-17	05-Jul-17
66	ACT-0011	Beam and Roof Slab	15	15	16-Apr-17	30-Apr-17	01-Jul-17	15-Jul-17
67	ACT-0012	Block Masonry	14	14	28-Apr-17	11-May-17	13-Jul-17	26-Jul-17
68	ACT-0013	Door Frame	10	10	11-May-17	20-May-17	26-Jul-17	04-Aug-17
69	ACT-0015	Plaster	14	14	29-May-17	11-Jun-17	13-Aug-17	26-Aug-17
70	ACT-0021	Storm Water Drainages Culvert/ Road W	20	20	29-May-17	17-Jun-17	13-Aug-17	01-Sep-17
71	ACT-0016	Flooring and Ceiling	20	20	11-Jun-17	30-Jun-17	26-Jan-18	14-Feb-18
72	ACT-0017	Bath Tiles	7	7	30-Jun-17	06-Jul-17	14-Feb-18	20-Feb-18
73	ACT-0018	Fixing of Aluminum Windows and Doors	13	13	05-Jul-17	17-Jul-17	19-Feb-18	03-Mar-18
74	ACT-0019	Paint Ground Floor, @ level +4.20 and @	12	12	17-Jul-17	28-Jul-17	03-Mar-18	14-Mar-18
75		**Plumbing, Fire Fighting & Mech. Works**	74	227	20-May-17	01-Aug-17	04-Aug-17	18-Mar-18
76	ACT-0014	Plumbing Works, GI Water Pipes, PVC V	10	10	20-May-17	29-May-17	04-Aug-17	13-Aug-17
77	ACT-0022	Manhole & Gate Valve Chamber	10	10	20-May-17	29-May-17	04-Aug-17	13-Aug-17
78	ACT-0023	Plumbing works for Ground Floor, Toilets	10	10	20-May-17	29-May-17	04-Aug-17	13-Aug-17
79	ACT-0024	Fire Fighting Works	3	3	29-May-17	31-May-17	13-Aug-17	15-Aug-17
80	ACT-0025	Installation of Sanitary Drainages & Wate	3	3	31-May-17	02-Jun-17	15-Aug-17	17-Aug-17
81	ACT-0026	Installation of Wet Sprinkler System	3	3	03-Jun-17	05-Jun-17	18-Aug-17	20-Aug-17
82	ACT-0045	Installation of Auto Gas Fire Supression S	9	9	03-Jun-17	11-Jun-17	18-Aug-17	26-Aug-17
83	ACT-0020	Sanitary Fixtures	6	6	27-Jul-17	01-Aug-17	13-Mar-18	18-Mar-18
84		**Electrical & Telecom Works**	106	259	19-Apr-17	02-Aug-17	04-Jul-17	19-Mar-18
85	ACT-0027	Conduit for Roof Slab Ground Floor	2	2	19-Apr-17	20-Apr-17	04-Jul-17	05-Jul-17
86	ACT-0034	Installation Earthing and Grounding Sys	1	1	20-May-17	20-May-17	04-Aug-17	04-Aug-17
87	ACT-0028	Back Boxes, DB, Wall Cutting	2	2	11-Jun-17	12-Jun-17	26-Aug-17	27-Aug-17
88	ACT-0029	Floor Conduiting	2	2	13-Jun-17	14-Jun-17	28-Aug-17	29-Aug-17
89	ACT-0036	Conduting For Network, CCTV, Access C	2	2	13-Jun-17	14-Jun-17	28-Aug-17	29-Aug-17
90	ACT-0035	Installation of Lighting Protection System	5	5	29-Jun-17	03-Jul-17	13-Sep-17	17-Sep-17
91	ACT-0037	Wiring for Network, CCTV, Acess Control	2	2	21-Jun-17	22-Jun-17	05-Feb-18	06-Feb-18
92	ACT-0038	Installation of Accessories	2	2	21-Jun-17	22-Jun-17	05-Feb-18	06-Feb-18
93	ACT-0031	Installation of Cable Tray and Laying of L	2	2	22-Jun-17	23-Jun-17	06-Feb-18	07-Feb-18
94	ACT-0030	Wiring Cables for Lights, Accessories an	2	2	22-Jun-17	23-Jun-17	06-Feb-18	08-Feb-18
95	ACT-0032	Lights and Accessories of Ground, @ lev	12	12	18-Jul-17	29-Jul-17	04-Mar-18	15-Mar-18
96	ACT-0033	Installation of DBs	7	7	23-Jul-17	29-Jul-17	09-Mar-18	15-Mar-18
97	ACT-0040	Installation of External Fire Telephone Sy	2	2	28-Jul-17	29-Jul-17	14-Mar-18	15-Mar-18

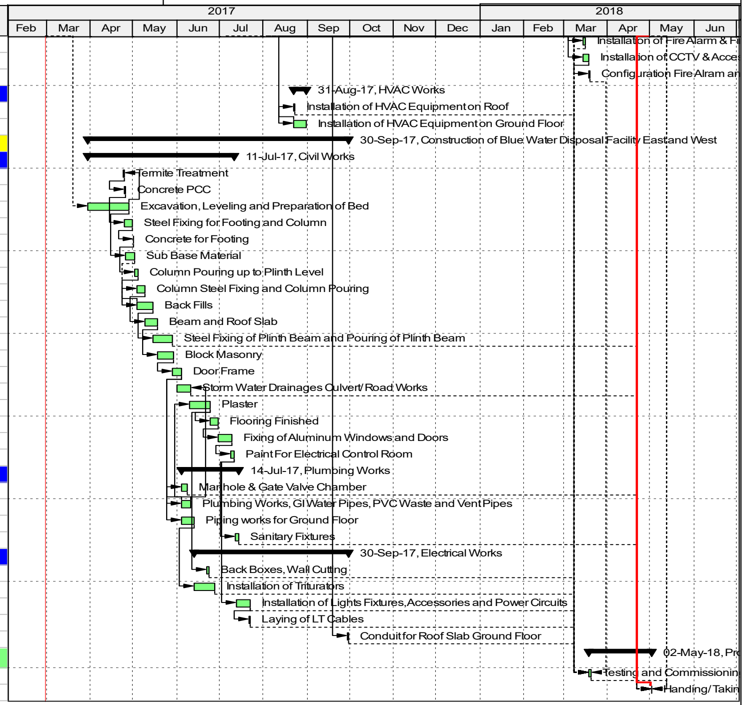


	Page 2 of 3	TASK filter: All Activities © Oracle Corporation

Continued Fig 4.10 Time Impact Analysis

Thesis Project | **Time Impact Analysis** | **2017-2018**

#	Activity ID	Activity Name	BL Project Duration	Original Duration	BL Project Start	BL Project Finish	Start	Finish
98	ACT-0039	Installation of Fire Alarm & Fire Telephon	2	2	29-Jul-17	30-Jul-17	15-Mar-18	16-Mar-18
99	ACT-0041	Installation of CCTV & Access Control Pa	4	4	29-Jul-17	01-Aug-17	15-Mar-18	18-Mar-18
100	ACT-0042	Configuration Fire Alram and CCTV with	1	1	02-Aug-17	02-Aug-17	19-Mar-18	19-Mar-18
101	**HVAC Works**		10	10	07-Jun-17	16-Jun-17	22-Aug-17	31-Aug-17
102	ACT-0044	Installation of HVAC Equipment on Roof	2	2	07-Jun-17	08-Jun-17	22-Aug-17	23-Aug-17
103	ACT-0043	Installation of HVAC Equipment on Grou	10	10	07-Jun-17	16-Jun-17	22-Aug-17	31-Aug-17
104	**Construction of Blue Water Disposal Facility East a**		136	185	28-Feb-17	13-Jul-17	30-Mar-17	30-Sep-17
105	**Civil Works**		104	104	28-Feb-17	11-Jun-17	30-Mar-17	11-Jul-17
106	BWDF-000	Termite Treatment	1	1	25-Mar-17	25-Mar-17	24-Apr-17	25-Apr-17
107	BWDF-000	Concrete PCC	1	1	26-Mar-17	26-Mar-17	25-Apr-17	25-Apr-17
108	BWDF-000	Excavation, Leveling and Preparation o	30	30	28-Feb-17	29-Mar-17	30-Mar-17	28-Apr-17
109	BWDF-000	Steel Fixing for Footing and Column	6	6	26-Mar-17	31-Mar-17	25-Apr-17	30-Apr-17
110	BWDF-000	Concrete for Footing	1	1	01-Apr-17	01-Apr-17	01-May-17	01-May-17
111	BWDF-000	Sub Base Material	7	7	27-Mar-17	02-Apr-17	26-Apr-17	02-May-17
112	BWDF-000	Column Pouring up to Plinth Level	3	3	02-Apr-17	04-Apr-17	02-May-17	04-May-17
113	BWDF-001	Column Steel Fixing and Column Pourir	6	6	04-Apr-17	09-Apr-17	04-May-17	09-May-17
114	BWDF-000	Back Fills	12	12	04-Apr-17	15-Apr-17	04-May-17	15-May-17
115	BWDF-001	Beam and Roof Slab	10	10	09-Apr-17	18-Apr-17	09-May-17	18-May-17
116	BWDF-000	Steel Fixing of Plinth Beam and Pouring	14	14	15-Apr-17	28-Apr-17	15-May-17	28-May-17
117	BWDF-001	Block Masonry	12	12	18-Apr-17	29-Apr-17	18-May-17	29-May-17
118	BWDF-001	Door Frame	7	7	29-Apr-17	05-May-17	29-May-17	04-Jun-17
119	BWDF-002	Storm Water Drainages Culvert/ Road W	10	10	02-May-17	11-May-17	01-Jun-17	10-Jun-17
120	BWDF-001	Plaster	15	15	11-May-17	25-May-17	10-Jun-17	24-Jun-17
121	BWDF-001	Flooring Finished	7	7	25-May-17	31-May-17	24-Jun-17	30-Jun-17
122	BWDF-001	Fixing of Aluminum Windows and Doors	10	10	31-May-17	09-Jun-17	30-Jun-17	09-Jul-17
123	BWDF-001	Paint For Electrical Control Room	3	3	09-Jun-17	11-Jun-17	09-Jul-17	11-Jul-17
124	**Plumbing Works**		41	41	05-May-17	14-Jun-17	04-Jun-17	14-Jul-17
125	BWDF-002	Manhole & Gate Valve Chamber	5	5	05-May-17	09-May-17	04-Jun-17	08-Jun-17
126	BWDF-001	Plumbing Works, GI Water Pipes, PVC V	7	7	05-May-17	11-May-17	04-Jun-17	10-Jun-17
127	BWDF-002	Piping works for Ground Floor	10	10	05-May-17	14-May-17	04-Jun-17	13-Jun-17
128	BWDF-001	Sanitary Fixtures	3	3	12-Jun-17	14-Jun-17	12-Jul-17	14-Jul-17
129	**Electrical Works**		61	110	14-May-17	13-Jul-17	13-Jun-17	30-Sep-17
130	BWDF-002	Back Boxes, Wall Cutting	2	2	23-May-17	24-May-17	22-Jun-17	23-Jun-17
131	BWDF-002	Installation of Triturators	15	15	14-May-17	28-May-17	13-Jun-17	27-Jun-17
132	BWDF-002	Installation of Lights Fixtures, Accessorie	10	10	13-Jun-17	22-Jun-17	13-Jul-17	22-Jul-17
133	BWDF-002	Laying of LT Cables	1	1	22-Jun-17	22-Jun-17	22-Jul-17	22-Jul-17
134	BWDF-002	Conduit for Roof Slab Ground Floor	2	2	12-Jul-17	13-Jul-17	29-Sep-17	30-Sep-17
135	**Project Completion Phase**		2	45	01-Aug-17	02-Aug-17	19-Mar-18	02-May-18
136	BWDF-0028	Testing and Commissioning	2	2	01-Aug-17	02-Aug-17	19-Mar-18	20-Mar-18
137	BWDF-0029	Handing/ Taking Over	1	1	02-Aug-17	02-Aug-17	02-May-18	02-May-18



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Continued Fig 4.10 Time Impact Analysis

Analysis with contractor delays:

Due to the nature of the selected project, all the delays were caused by the owner. Not a single delay was caused by the contractor, as shown in Table 3.1. This technique basically works by subtracting the relevant party's delays from the As-Built schedule. That's why the analysis wasn't performed because of the delay incurred by the contractor.

Analysis with client delays:

For this method, the As-Built schedule was developed first. In this process, the analysis was carried out from the owner's perspective. All the delays and events caused by the contractor will have to removed from the As-Built schedule. But due to the nature of the project, as it only contained the client delays, the As-Built schedule remained the same. As mentioned above, and also shown in Table 4.1, there was not even a single delay event caused by the contractor. That's why no delay event was deducted from the As-Built schedule. The data is then recomputed, and it gave the completion date of May 02, 2018, causing the 403 days delays, with a total duration of 429 days as shown in Fig 4.10.

$$\text{Client caused delays} = \text{Total Duration} - \text{BL Duration}$$

$$\text{Client caused delays} = 429 - 156 \text{ days}$$

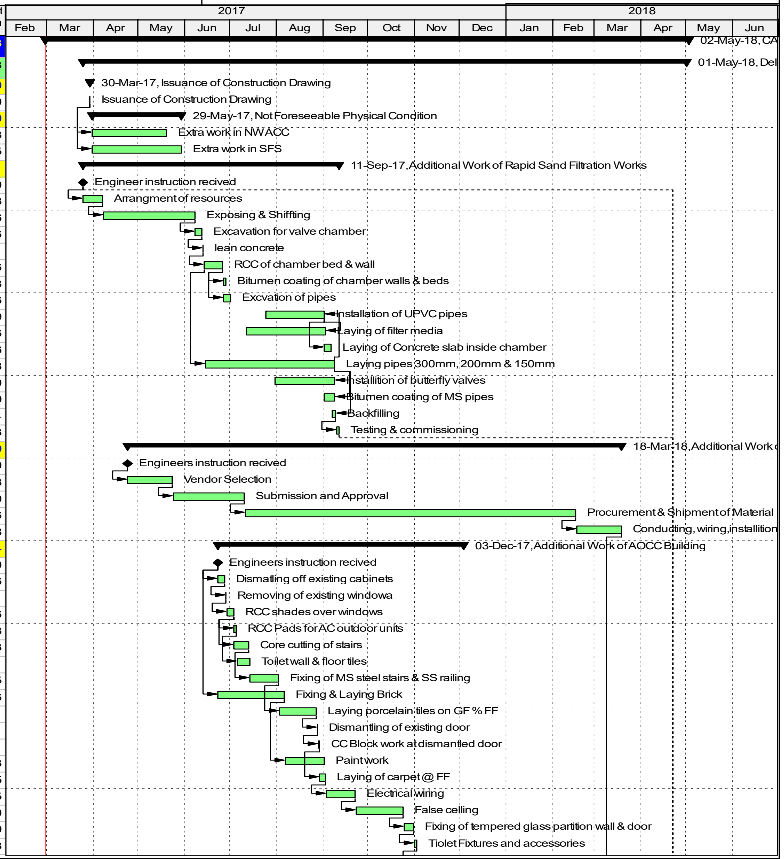
$$\text{Client caused delays} = 273 \text{ days}$$

It can be concluded from the above equation that the client is responsible for all of the 273 delays. And with the original completion duration of 429 days, the contractor wasn't even responsible for a single day. This result shows that all the delays that occurred should be excusable and compensable to the contractor. However, these are some of its limitations:

- When the plan sequence has been so greatly altered by the delays, removing them from the schedule could leave it with an unreasonable as-built but-for schedule.

Thesis Project | **CAB with Client Delays** | **2017-2018**

#	Activity ID	Activity Name	BL Project Duration	Original Duration	Start	Finish	Variance - BL Project Duration
1	**CAB with Client delays**		156	429	28-Feb-17	02-May-18	-273
2	**Delay Events**		0	403	25-Mar-17	01-May-18	-403
3	**Issuance of Construction Drawing**		0	0	30-Mar-17	30-Mar-17	0
4	A1020	Issuance of Construction Drawing	0	0	30-Mar-17*	30-Mar-17	0
5	**Not Foreseeable Physical Condition**		0	60	31-Mar-17	29-May-17	-60
6	A1030	Extra work in NW ACC	0	50	31-Mar-17	19-May-17	-63
7	A1040	Extra work in SFS	0	60	31-Mar-17	29-May-17	-75
8	**Additional Work of Rapid Sand Filtration Works**		0	171	25-Mar-17	11-Sep-17	-171
9	A1050	Engineer instruction recived	0	0	25-Mar-17*		0
10	A1060	Arrangment of resources	0	14	25-Mar-17	07-Apr-17	-18
11	A1070	Exposing & Shiffting	0	61	08-Apr-17	07-Jun-17	-76
12	A1080	Excavation for valve chamber	0	5	08-Jun-17	12-Jun-17	-6
13	A1090	lean concrete	0	1	13-Jun-17	13-Jun-17	-1
14	A1100	RCC of chamber bed & wall	0	13	14-Jun-17	26-Jun-17	-16
15	A1180	Bitumen coating of chamber walls & bec	0	2	27-Jun-17	28-Jun-17	-3
16	A1110	Excvation of pipes	0	5	27-Jun-17	01-Jul-17	-6
17	A1130	Installation of UPVC pipes	0	39	25-Jul-17	02-Sep-17	-49
18	A1150	Laying of filter media	0	53	12-Jul-17	02-Sep-17	-66
19	A1140	Laying of Concrete slab inside chambei	0	5	02-Sep-17	06-Sep-17	-6
20	A1120	Laying pipes 300mm, 200mm & 150mr	0	86	15-Jun-17	08-Sep-17	-108
21	A1160	Installition of butterfly valves	0	40	31-Jul-17	08-Sep-17	-50
22	A1170	Bitumen coating of MS pipes	0	7	02-Sep-17	08-Sep-17	-9
23	A1190	Backfilling	0	3	07-Sep-17	09-Sep-17	-4
24	A1200	Testing & commissioning	0	2	10-Sep-17	11-Sep-17	-3
25	**Additional Work of PAS @ SFS**		0	329	24-Apr-17	18-Mar-18	-329
26	A1210	Engineers instruction recived	0	0	24-Apr-17*		0
27	A1220	Vendor Selection	0	30	24-Apr-17	23-May-17	-38
28	A1230	Submission and Approval	0	48	24-May-17	10-Jul-17	-60
29	A1240	Procurement & Shipment of Material	0	221	11-Jul-17	16-Feb-18	-276
30	A1250	Conducting, wiring,installition of PAS	0	30	17-Feb-18	18-Mar-18	-38
31	**Additional Work of AOCC Building**		0	164	23-Jun-17	03-Dec-17	-164
32	A1260	Engineers instruction recived	0	0	23-Jun-17*		0
33	A1270	Dismatling off existing cabinets	0	5	23-Jun-17	27-Jun-17	-6
34	A1280	Removing of existing windowa	0	1	28-Jun-17	28-Jun-17	-1
35	A1290	RCC shades over windows	0	5	29-Jun-17	03-Jul-17	-6
36	A1330	RCC Pads for AC outdoor units	0	2	04-Jul-17	05-Jul-17	-3
37	A1300	Core cutting of stairs	0	10	04-Jul-17	13-Jul-17	-13
38	A1340	Toilet wall & floor tiles	0	9	06-Jul-17	14-Jul-17	-11
39	A1345	Fixing of MS steel stairs & SS railing	0	20	14-Jul-17	02-Aug-17	-25
40	A1310	Fixing & Laying Brick	0	45	23-Jun-17	06-Aug-17	-56
41	A1350	Laying porcelain tiles on GF % FF	0	25	03-Aug-17	27-Aug-17	-31
42	A1360	Dismantling of existing door	0	1	28-Aug-17	28-Aug-17	-1
43	A1370	CC Block work at dismantled door	0	1	29-Aug-17	29-Aug-17	-1
44	A1320	Paint work	0	26	07-Aug-17	01-Sep-17	-33
45	A1380	Laying of carpet @ FF	0	4	30-Aug-17	02-Sep-17	-5
46	A1390	Electrical wiring	0	20	03-Sep-17	22-Sep-17	-25
47	A1400	False celling	0	32	23-Sep-17	24-Oct-17	-40
48	A1410	Fixing of tempered glass partition wall &	0	7	25-Oct-17	31-Oct-17	-9
49	A1420	Tiolet Fixtures and accessories	0	2	01-Nov-17	02-Nov-17	-3

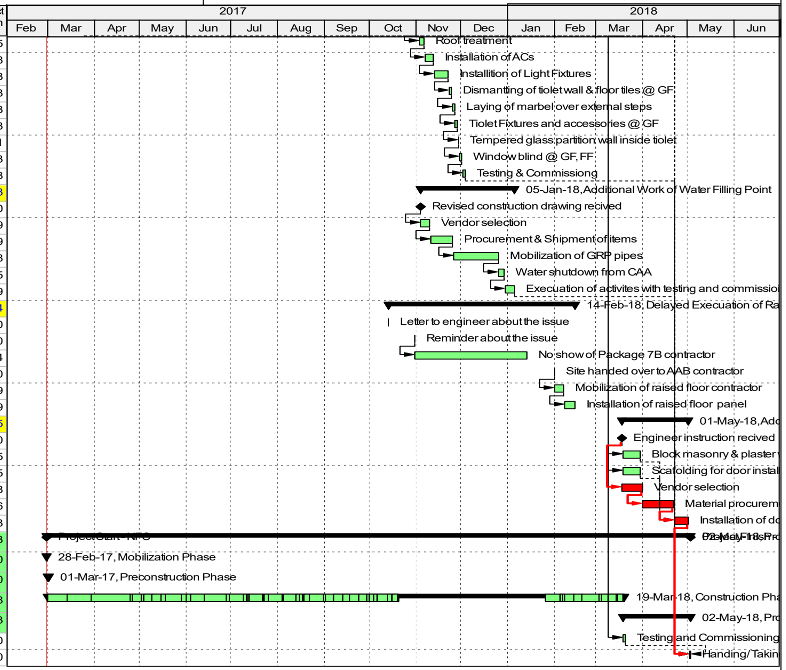


Page 1 of 2 | TASK filter: All Activities

FIGURE 4.10: CAB with client delays

Thesis Project | **CAB with Client Delays** | **2017-2018**

#	Activity ID	Activity Name	BL Project Duration	Original Duration	Start	Finish	Variance - BL Project Duration
50	A1430	Roof treatment	0	4	03-Nov-17	06-Nov-17	-5
51	A1440	Installation of ACs	0	6	07-Nov-17	12-Nov-17	-8
52	A1450	Installition of Light Fixtures	0	10	13-Nov-17	22-Nov-17	-13
53	A1460	Dismantling of tiolet wall & floor tiles @ G	0	2	23-Nov-17	24-Nov-17	-3
54	A1470	Laying of marbel over external steps	0	2	25-Nov-17	26-Nov-17	-3
55	A1480	Tiolet Fixtures and accessories @ GF	0	2	27-Nov-17	28-Nov-17	-3
56	A1490	Tempered glass partition wall inside tiole	0	1	29-Nov-17	29-Nov-17	-1
57	A1500	Window blind @ GF, FF	0	2	30-Nov-17	01-Dec-17	-3
58	A1510	Testing & Commissiong	0	2	02-Dec-17	03-Dec-17	-3
59	**Additional Work of Water Filling Point**		0	63	04-Nov-17	05-Jan-18	-63
60	A1520	Revised construction drawing recived	0	0	04-Nov-17*		0
61	A1530	Vendor selection	0	7	04-Nov-17	10-Nov-17	-9
62	A1540	Procurement & Shipment of items	0	15	11-Nov-17	25-Nov-17	-19
63	A1550	Mobilization of GRP pipes	0	30	26-Nov-17	25-Dec-17	-38
64	A1560	Water shutdown from CAA	0	4	26-Dec-17	29-Dec-17	-5
65	A1570	Execuation of activites with testing and c	0	7	30-Dec-17	05-Jan-18	-9
66	**Delayed Execuation of Raised Floor Due to Packag**		0	124	14-Oct-17	14-Feb-18	-124
67	A1580	Letter to engineer about the issue	0	0	14-Oct-17*	14-Oct-17	0
68	A1590	Reminder about the issue	0	0	31-Oct-17*	31-Oct-17	0
69	A1600	No show of Package 7B contractor	0	75	31-Oct-17	13-Jan-18	-94
70	A1610	Site handed over to AAB contractor	0	0	01-Feb-18*	01-Feb-18	0
71	A1620	Mobilization of raised floor contractor	0	7	01-Feb-18	07-Feb-18	-9
72	A1630	Installation of raised floor panel	0	7	08-Feb-18	14-Feb-18	-9
73	**Additional Work of Louver Doors @ NW ACT**		0	45	18-Mar-18	01-May-18	-45
74	A1640	Engineer instruction recived	0	0	18-Mar-18*		0
75	A1670	Block masonry & plaster work	0	12	19-Mar-18	30-Mar-18	-15
76	A1680	Scafolding for door installation	0	12	19-Mar-18	30-Mar-18	-15
77	A1650	Vendor selection	0	14	18-Mar-18	31-Mar-18	-18
78	A1660	Material procurement	0	21	01-Apr-18	21-Apr-18	-26
79	A1690	Installation of doors	0	10	22-Apr-18	01-May-18	-13
80	**Project Milestones**		156	429	28-Feb-17	02-May-18	-273
81	**Mobilization Phase**		1	1	28-Feb-17	28-Feb-17	0
82	**Preconstruction Phase**		1	1	01-Mar-17	01-Mar-17	0
83	**Construction Phase**		156	384	01-Mar-17	19-Mar-18	-228
84	**Project Completion Phase**		2	45	19-Mar-18	02-May-18	-43
85	BWDF-0028	Testing and Commissioning	2	2	19-Mar-18	20-Mar-18	0
86	BWDF-0029	Handing/Taking Over	1	1	02-May-18	02-May-18	0



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TASK filter: All Activities

Continued Fig 4.11 CAB with client delays

- The as-built timetable is prepared using as-built information, which is arbitrary and highly manipulable.
- The analyst is generally obliged to add after-the-fact logic ties when compressing the schedule, that may not resemble the thinking of the schedule executor during real performance.
- The as-built critical path must be identified, which takes a lot of judgement and scheduling manipulation.
- It disregards both the critical path's dynamic character and the circumstances present at the moment of the delay.
- The ability of most analysts to adapt the collapsed timetable to match what the contractor is likely to follow takes expertise and strong judgement.

It is concluded that the collapsed as-built can determine the impact of delays when there isn't enough time and resources available. This approach will be helpful if the owner and the contractor both have access to the specific as-built records and can reasonably agree on how to interpret the data used to build the as-built schedule. This technique presented the delays caused by contractors and clients separately. It was discovered that collapsed as built easily established the amount of delays that could be caused by a specific party's action simply by removing the particular delay from the schedule. The results of the collapsed as-built method have been found to be easily traceable in an as-built schedule.

4.5 Comparative Analysis of DAT's

A comparative analysis of delay assessment techniques (DAT's) was carried out and it was observed that each technique gave the same results. i.e., 273 days. This happened because of the reason that the selected project only faced the client caused delays thus all subsequent activities were delayed due to client. And all the activities performed by the contractor were according to the planned duration. That's the reason each technique gave the same results. The delayed duration was

Table 4.1: Comparative Analysis of DAT's

Sr No.	DAT's	Impacted Completion Date	Total Delay	Delay Caused by Client	Delay Caused by Contractor	Discussion
1	Impact As-Planned	02-May-18	273 days	273 days	Not mentioned	Baseline schedule was considered. Individual impact of each delay was observed potentially.
2	Time Impact Analysis	02-May-18	273 days	273 days	No delay was caused by the contractor.	Actual progress was considered. Time to time impact of delays were observed.
3	Collapse As-Built with Client	02-May-18	273 days	273 days	Nil	As-built data was considered. Delays caused by client was observed only.

found excusable and compensable to contractor, because all the delays were caused by the client. But due to the factors and parameters which were considered during the analysis process it was found that Time Impact Analysis (TIA) is the better approach to evaluate the delays as it used the actual site progress and the sub net for each delay occurring events is analyzed. Table 4.1 illustrates the comparative analysis of delay assessment techniques employed on the selected project.

4.6 Summary

In this chapter, to evaluate and analyse the impact of delays on the progress of the project, first of all, the main sources of delays were identified, and information was gathered regarding these delays. The schedule was then developed by using Primavera P6 and delayed events were added to the schedule according to the requirements of the DAT's. In the Impact As-Planned (IAP) technique, the individual impact of each delayed event was examined on the completion date by using an As-Planned schedule. Time Impact Analysis (TIA) accessed the delays by using actual site implementation dates. While Collapsed As-Built (CAB) provided the separate impact of delay events caused by the contractor and the client by subtracting the relevant party delay events. Among these, Time Impact Analysis was found to be comparatively better due to its capability of considering the regular progress and actual site implementation. The selected case study didn't have any delays from the contractor's side. Thus, due to the nature of the project, all the DAT's provided the same delayed duration.

Chapter 5

Conclusions and Recommendations

5.1 Conclusion

Delays are a global trend in the construction industry. No matter how challenging the project is, delays are typical in the construction sector. Construction delays relate to projects that take longer to complete than expected. And it affects the progress of the project in terms of triple constraint i.e. time, cost and quality. This causes disputes among the different parties in the project. That's why it is very important to assign the responsibility of the delay to the particular party to avoid the disputes. In this study, real time building case study is selected and then the main sourses of delays events are identified. Three main DAT's are selected i.e. IAP, TIA and CAB (recommended by SCL Protocol), are used to investigate the impact of delays events on the completion date of the project. Primavera P6 is used for the analysis . From this research, the following conclusions have been made:

- Among three techniques employed for the current case-study, Impact As-Planned is relatively easy and simple. Client shortcoming are pointed to be the reason of delay for the considered project.

- Out of three employed techniques on project, Time Impact Analysis is found to be complicated and it needs proficient and experienced planner.
- Results provided by Collapsed As-Built can be easily traceable to the actual case in an as-built schedule.
- Each technique gave the same results. i.e., 273 days, which are excusable and compensable to contractor, because all the delays were caused by the client.
  - By comparing all the DAT's used, it is found that the Time Impact Analysis approach is comparatively better since it considers the actual site progress and analyses each delay-causing event's sub-net.

On overall basis, the Time Impact Analysis (TIA) is a better and reliable approach among all frequently used delay analysis techniques (DAT's) to claim the Extension of Time (EOT) in developing countries like Pakistan.

5.2 Recommendations

- The claims for increment in costs and time value of money should also be studied.
- Future research can also be conducted on a study having both, contractor and client delays.

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