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Original Research Article

Comparative Study of Prospective Delay Analysis Techniques (DATs)

Suroj Ghimire[1], Anjay Kumar Mishra[2*]

[1]NP Associates Pvt Ltd, Project controller, Nepal
[2]Associate Professor, Madan Bhandari Memorial Academy, Urlabari, Nepal

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***Corresponding author:** Anjay Kumar Mishra

Abstract

Delays are the major sources of disputes and adverse relationships between the stakeholders in construction industry. The existing delay analysis techniques (DATs), though helpful for decision-making, have not succeeded in properly addressing the high incidence of disputes associated with delay claims resolutions. This research has made a comparative study of limitation and capabilities of different 'Prospective' DATs i.e., Impacted as Planned method and Time Impact Analysis Method under the same baseline program and under similar circumstances of delay occurrence through the case study of under-Construction Hydroelectric Project and review of the relevant issues not addressed by the techniques. Oracle's Primavera (P6) software has been used for delay analysis. The Contractor has not followed any of the DATs to raise the claim for extension of time. Though the contractor has submitted its revised construction schedule as per the FIDIC conditions of contract and ask for time extension of 721 days, the revised construction schedule has no any linkage with the original approved baseline Schedule. The Impacted as planned technique confined the delay to 621 days. The actual site condition and the progress were not considered in this method. The concurrent delays and pacing delays were also not addressed. According to the Time Impact analysis technique, the contractor's caused delay was 101 days and the delay from Employer's side was 529 days. The actual site condition and the progress were considered in this method. However, none of the Delay analysis techniques is found to address all the delay occurring events. The concurrent delays and pacing delayswere also not addressed. Time impact analysis technique is more accurate method as the site progress is incorporated in this method and is recommended to be followed.

Keywords: Impacted as Planned, Time Impact, Actual site Condition.

INTRODUCTION
BACKGROUND

Construction delays are a main source of claims and disputes and have even been considered as the most common and costly cause of problems. Construction delays impart adverse impact on the success of the project in terms of time and cost. Its effect is confined not only to the construction industry alone, but also to the overall economy of a nation.

To substantiate the delay in Mega project is very complexin itself. The different methods that are used to provedelays, as explained in industry standards and handbooks, are theoretical and could be applied inthe small simple projects with few numbers of activities but the same methods cannot easily beapplied on mega/complex projects [1].

Barry [2], in his paper, presented on the international conference by the Society of Construction Law, mentioned that Impacted as-planned method, Time impact analysis method, Collapsed as-built or 'but-for' analysis method, Snapshot/windows/ time slice analysis method, As-planned versus as-built windows analysis methods are commonly used delay analysis techniques. Inspite of the availability of these techniques, the most appropriate way to analyze the delays and causes of delay is still arguable subject. Arditi and Pattanakitchamroon [3] claimed that that none of the identified delay analysis methodology can be universally used in all situations, although they noted that the Windows Analysis/Time Impact Analysis is the most acceptable method and provides the most reliable results. Researchers have identified multiple factors affecting the selection and the results of the delay analysis methodology.

The assessment to raise the claim for extension of time is one of the serious issue. The Baseline Schedule is an important tool whereby delays are impacted in a systematic approach to find out the overall delay occurred in projects. Basically, the DATs

needs to calculate the project delay to identify how much of it is attributable to each party (contractor or Employer) so that time and/or cost compensation can be decided. Delay analysis in sizable construction projects is complex and needs vigorous exercise. Especially concurrent delays are always the subject of discussion and/or argument between the concerned parties.

This study has reviewed the approved baseline construction schedule, the factors impacting the overall delay, the DATsusedby the contractor to claim for extension of time. The elaborated study has further been performed to find out the difference in project completion date using different industry standard DATs. The comparative discussion on the application of different techniques has thus helped to identify the capabilities and limitations of the different DATs

However, different DATs have got their unique application procedures and philosophies which may cause the different outcome for same delay causing events.

RESEARCH OBJECTIVES

The main purpose of this research is to make comparative study of the outcome of the different delay analysis techniques under the same baseline program and under similar circumstances of delay occurrence.

LITERATURE REVIEW

Prospective and Retrospective Analysis Techniques

Delay analysis techniques are either 'prospective' or 'retrospective'. Prospective analyses refer to the future, and seek to determine the likely impact of actual progress or a particular event(s) on project completion. Retrospective analyses refer to the historic, and usually seek to determine the actual impact of events upon progress and completion [2].

Project Scheduling

Bureau of Indian Standards [4] has defined Network Analysis and Scheduling as "the project network incorporating the activity durations and logical relationships with forward and backward pass schedule calculations to establish early and late start and finish time of activities with their available floats, critical activities, critical path and overall project duration." The project schedule needs to be prepared in terms of calendar dates of start and finish of activities with available floats. The network schedule is to be presented in the form of linked bar chart or in tabular format.

Society of Construction Law [5] has mentioned that the Contractor should submit and the Contract Administrator (CA) should accept a Programme (Using commercially available critical path method project planning Software) as early as possible showing the manner and Sequence in which the Contractor plans to carry out the Works. The accepted Programme (Which then becomes the updated Programme) should be the means by which actual against the planned progress is monitored, and can be used as a tool for determining EoT. If the CA disagrees with the amount of the progress the Contractor considers it has achieved, it should notify the Contractor, and the CA and Contractor should the attempt to reach the agreement. If they do not agree, the CA's view should prevail unless and until overturned under the Contract dispute resolution procedures, and the CA's view on progress should be reflected in the updated programme.

The Sub Clause 8.3 of the Federation Internationale Des Ingenieurs-Conseils (FIDIC) [6] as cited in Mishra and Bhandari [7] General Conditions of Contract is about the Programme of the Works which states that the Contractor has to submit a detailed time programme to the Engineer within 28 daysafter receiving the notice for Commencement of Works. Whenever the previous programmeis inconsistent with actual progress or with the Contractor's obligations, a revised programme has to be submitted. According to this clause, the programme shall include:

- The order in which the Contractor intends to carry out the Works, including theanticipated timing of each stage of design (if any), Contractor's Documents,procurement, manufacture of Plant, delivery to Site, construction, erection andtesting,
- Each of these stages for work by each nominated Subcontractor
- The sequence and timing of inspections and tests specified in the Contract, and
- A supporting report which includes:
  - A general description of the methods which the Contractor intends to adopt, and of the major stages, in the execution of the Works, and
  - Details showing the Contractor's reasonable estimate of the number ofeach class of Contractor's Personnel and of each type of Contractor's Equipment, required on the Site for each major stage.

The Section B of the General Conditions of Contract of the Bidding Document for the Procurement of the Works prepared by Public Procurement Monitoring Office of Nepal [8] is related to the time control in which sub clause 26 provides guidelines on the Project Schedule as stated that within the time stated in the SCC, after the date of the Letter of Acceptance, the Contractor has to submit to the Project Manager for approval a Program showing the general methods, arrangements, order, and timing for all the activities in the Works.

Progress Monitoring

Bureau of Indian Standards [4] has defined the time monitoring as "processes implemented to collect, compile and analyze the status of project progress with

respect to its baseline." The objective of time monitoring is to evaluate a deviation from the estimations made during time planning and its impact on project status. Reports generated through time monitoring analysis serves as a decision-making tool which are then input for project time control. Timely discharge of all contractual obligations by every project-stakeholder is essential for the success of project. Time schedule for each of these obligations which are indicated as distinct activities in the baseline-schedule of time planning shall be monitored. Any variance is appropriately reported for effective contract-administration of the project.

The sub-clause 26.2 of the General Conditions of Contract of the Bidding Document for the Procurement of the Works prepared by Public Procurement Monitoring Office of Nepal [8] states that update of the program is a program showing the actual progress achieved on each activity and the effect of the progress achieved on the timing of the remaining work, including any changes to the sequence of the activities.

The sub-clause 26.3 states that the Contractor have to submit to the Project Manager for approval an updated Program at intervals no longer than the period stated in the SCC. If the Contractor does not submit an updated Program within this period, the Project Manager may withhold the amount stated in the SCC from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue Program has been submitted.

Delay Analysis Techniques

There are various types of delay analysis techniques available.The carrying out of a successful delay analysis requires the preparation of areliable as-planned programme and an accurate as-built programme. The effectivenessof delay analysis techniques can be greatly increased when it can bedemonstratedthat the as-planned programme was reasonable [9].

Williams [10] considers that the network based methods are generally powerful and reliable to access the impact of delay in construction Projects. He explains that the main purpose of the delay analysis is to determine the cause, effect, responsibility and damages. Arditi and Pattanakitchamroon [3] suggest that four methods are the most common in the construction industry which are the as planned vs. as built analysis, Impacted as planned, collapsed as built and the windows analysis methods.

Barry [2] explained following five commonly used in delay analysis techniques:

1. Impacted as-planned method;
2. Time impact analysis method;
3. Collapsed as-built or 'but-for' analysis method;
4. Snapshot/windows/time slice analysis method;
5. As-planned versus as-built windows analysis method

Keane and Caletka [9] claimed that there lies greater extent of dissimilarities between the existing delay analysis techniques. There is much discussion about the various approachesto delay analysis along with explanations as to why it should not be surprisingwhen two opposing programming experts can apply the same techniqueand produce widely varying and inconsistent conclusions. The commonly applied scientific delayAnalysistechniques according to Keane and Caletka (2015) areimpacted as-planned, collapsed as-built, as-planned versus as-built, andtimeimpact analysis.

Barry [2] stated in his paper that there are effectively four main criteria for selecting which delay analysis methodology to use. These are:

- What does the contract require?
- Which approach is appropriate, correct, and sustainable?
- Does a lack of information preclude the use of any of the approaches?
- Do time/cost constraints eliminate certain options?

One principle that Barry [2] firmly support is that when analyzing delay to a project, one should establish the effect first (i.e. the incidence and extent of delay) and only then move to establish the cause of that delay. In such a manner both accuracy and objectivity are ensured. He further stated in his paper that there is a really need of sophisticated Computer generated Schedule. A CPM schedule allows us to quantify time on a priority basis (i.e. float), and this can provide very valuable insight to a stretched and stressed management team. The CPM schedule allows us to record on screen and paper what otherwise might exist only within the head of a valuable and experienced colleague.

Brief Introduction of the Project under study

The Madhya Bhotekoshi Jalavidyut Company Ltd. (MBJCL), a subsidiary of Chilime Hydropower Company limited of Nepal, is a public limited company established in 2010 AD to develop the Middle Bhotekoshi Hydroelectric Project (MBKHEP) of installed capacity 102MW. The MBKHEP is located in Sindhupalchowk District of Bagmati Zone of the central development region. The project is accessible by Araniko Highway at a distance of 101 km towards north-east of Kathmandu which could be reached in 3 hours' drive to head-works site at Chaku from Kathmandu.

The Project is basically a run-of-river type scheme having the capacity of 102 MW with the design discharge of 50.8m3/sec and available gross head of 235m.

(Source: Project documents)

Major Contract Packages

The Construction work has been splitted in three main contract packages:

- Lot 1 civil and hydro-mechanical works on EPC contract model.
- Lot 2 Electromechanical works on PDB contract model.
- Lot 3 Transmission line and substation on PDB contract model.

In addition there are other several small Contract packages that are associated with the Project. However, those contract packages are not linked to the major Construction Works. Those Contract Packages are:

- Contract for construction of Staff Quarters, office and access roads.
- Contract packages for landscaping works of the staff Quarter and office.

LOT 1 –Civil and Hydro-mechanical Contract

The LOT 1 Contract was awarded through International Competitive bidding (ICB) to the Chinese contractor Guangxi Hydroelectric Construction Bureau (GHCB). The contract agreement with the GHCB has been done on January 1st 2014 and the Commencement date was set on 11th February 2014. The Contract is EPC Contract and has followed the FIDIC silver book. For Rock support and shotcrete Works BOQ system has been followed.

RESEARCH METHODOLOGY

Research approach

Qualitative analysis research approach has been adapted in this research.

As this research is a specific and requires certain level of experience, the Questionnaire has been provided to the claim expert of the consultant. Correspondences related to the events giving rise to claims and baseline Schedule of the project under study has been carefully reviewed and analyzed.

Study Area

This is a case study research in which on-going Project Middle Bhotekoshi Hydroelectric Project (MBKHEP) having capacity of 102 MW has been considered. The Consultant of the hydropower project under study has been selected as the respondent for this research. The approved baseline construction schedules, approved adjusted Schedules, delay impacted schedules at different stages of the project were also reviewed for further study.

Data collection

The primary data were used to find out the existing conditions of the project. The secondary data in the form of literature review sets the basis for using different prospective DATs under similar boundary conditions.

Following documents/components were studied in detail:

- The initial baseline program.
- Factors causing delays and its impact on the baseline Program.
- The delay analysis techniqueapplied in the revised program resubmitted by the Contractor asking for time extension for about two years after devastating earthquake occurred on April 2015 and the informal Blockade.
- The elaborated study has been performed to find out the difference in intended completion date using the
  - Impacted as planned technique for delay analysis, and
  - Time impact analysis technique for delay analysis.

Primary Data

Following are the data collected from the project:

1. Detailed Project Report (DPR) to find out the general information and Salient features of the Project.
2. FIDIC General Conditions of Contract and Particular conditions of Contract.
3. Approved Baseline Construction Schedule.
4. Series of correspondences between Employer, Consultant and the Contractor associated with the claims for extension of time, project change orders, variations etc.
5. Daily, weekly and monthly Progress reports.
6. Revised Schedule by the Contractor requesting for extension of time. The methods adapted has been reviewed and the redundant factors were identified.

Isolated, Contemporaneous and the Concurrent delays were segregated by reviewing those correspondences.

The objective type of questionnaire as well as the subjective questionnaire were asked to the respondent. The starting question for interviewee was “Explain how you decided on the method to assess delays in this project?” Depending on the answer of interviewee, a group of follow up questions were asked to gather the information about the project.

Secondary Data

Published articles, papers and books were the main source of Secondary Data collection. Reports, contract documents, theses, FCAN article and the various standards /Guidelines published also formed the part of secondary data. Secondary data were collected through literature review. The industry standard DATswere reviewed from the literature and those methods has been implemented to impact the delay.

Since the project under study is on-going project, prospective methods of DATs were used.

The following DATs have been used in the approved baseline program under same boundary conditions and delays:

- Impacted as Planned Technique
- Time Impact Analysis Technique

Data Analysis

At first, correspondences related to the extension of time, schedules, differing site conditions, force majeure and the work stoppages was collected from the Project site office. Thus collected correspondences were reviewed thoroughly. Accordingly, the delays were classified as concurrent delay, contemporaneous delay and isolated delays. The employer's caused delays were tabulated and the impacted additional durations by those delays were calculated in the spreadsheet.

The FIDIC general conditions of Contract (GCC), Particular conditions of Contract (PCC) and the general specifications were observed thoroughly to find out the provisions made regarding construction time schedule and time extensions.

The progress reports were collected from the site office. The information obtained from completed questionnaires were also used during analysis of data.

The additional durations incurred due to isolated delay, concurrent delay and contemporaneous delay were impacted on the original baseline schedule by using impacted as-planned method and time impact analysis method.

The procedures applied in each method and the result of those methods were compared and discussed.

The project Planning Software Oracle's Primavera P6, Version 7 has been used for delay analysis.

RESULTS AND DISCUSSION

The delay analysis has further been done by using impacted as-planned method and Time Impact analysis technique under the same baseline program and under similar circumstances of delay occurrence. The comparative study of the limitations and capabilities of each method has been done in this chapter.

The case project under study is Middle Bhotekoshi Hydroelectric project having capacity of 102 MW.

Construction Time Schedule

The time allocated for this contract package is 1215 calendar days. The Commercial operation date of the Project was 9th July 2017 as per approved Schedule.

Construction schedule submitted by the contractor

The Contractor submitted the program in accordance with the conditions of contract and the general specifications.

The contractor submitted the program to cover the entire schedule within the stipulated time period. i.e., 1215 days from the work commencement. The commercial operation date (COD) date of the program is 9thJune 2017. The detailed construction schedule is presented in Appendix 1.

Features of the approved baseline construction Schedule

Formats and Settings

- The Program has been prepared in the Project Planning Software Primavera P3.
- The calendar provided for activities in head-works is 7 days' workweek with 8 hrs.' per day and June-July-August-September as non-working time.
- The calendar provided for activities in remaining works is 7 days' workweek with 8 hrs.' per day.
- Constraints were provided in the Site Handover activities of the Program.
- Critical path has been delineated in the Schedule.
- The activity coding has been done in the Program. Activities are grouped and sorted using activity codes rather than using WBS codes.

Contents of the Schedule

The Schedule has been prepared by using Critical Path method. The links has been provided in the activities.

Further to the conditions stated in the FIDIC Conditions of Contract, the activities for major stages of work, period for reviews, the timing for test and inspection as per the Contract has been delineated in the Program. Activities for Mobilization, Site access, equipment procurement, design submittals and approvals, major deliverables….etc. in addition to the major physical works has been shown in the Program.

The Project work has been divided into three separate construction areas, namely head-works, Water Conveyance System, and Powerhouse;

Activities for interfaces with the electromechanical works (by separate contractor) has been provided in the Program.

Resource loading has not been done in the Schedule.

Cost loading has not been done in the Schedule. The Construction program only provides the time sequence of the activities.Predecessors and

Successors has been provided in every activities to avoid the dangling errors.

Present Status of the Project

Further referring the questionnaire with claim expert of the project, Mr. Krishna Prasad Regmi, it is found that the project has undergone several delays and the submitted program is now no longer workable. Substantial changes occurs in the construction Schedule. Following are the causes of the major delays:

Delay caused from Employer side:

1. Late handing over of the Head-works Site in time stipulated in the approved Construction Schedule.
2. Social issues in the ADIT 1 site, Powerhouse site and the head-works site. The Social problems has caused the substantial stoppage of the Works. The Contractor has notified each stoppages in writing.

Delay caused from Contractor side:

1. Inefficiency of the Contractor to mobilize its equipment in site in time.
2. Inefficiency of the Contractor to construct the batching plant and Aggregate crushing plant in the stipulated time period.

Delay caused due to 'outside' factor:

1. Massive Landslide occurred in Jure, around 10 km downstream of the Powerhouse on August 02, 2014.
2. The devastating earthquake occurred in 25th April, 2015 and the series of aftershocks caused thereafter. This has caused the severe destruction and unrepairable elapse of time. The force majeure was declared in the project.
3. The "informal Blockade" by the India from September 2015. The shortage of the fuel due to the blockade caused the severe and significant loss in the Project.

The massive landslide in Jure blocked the entire transportation and hence the project work was literally closed. When the project was about to reinstate, the devastating earthquake occurred on 25th April 2015. Due to earthquake, the work stopped completely. The temporary structures like laboratory building, access road to Adit, contractor's labour camp were affected severely. The Contractor then demobilized from the site. When the site was about to restart, the "blockade" by the India again forced the project to postpone its activities due to the shortage of the supplies (material and fuel). From 15th March 2016, the Contractor resumes the regular work.

Major Delay events

The delay events from the employer's side were identified and tabulated hereunder. Coding of each events have been done (D1, D2…etc) so as to make it easy to incorporate in the Schedule to impact delay.

Table-1: Delay type and description

Delay Code	Description of the Delay		Delay Duration (Days)	
D1	Employer asks for Counter Guarantee by "A" Class commercial Bank of Nepal. The provision for Advance payment guarantee was not in the Contract Agreement. The Contractor ask to shift the commencement date from January 15, 2014 to February 11, 2014. The Employer agreed to shift the Commencement date accordingly. The new commencement date was then February 11, 2014. Hence EOT granted is 28 days.		28	
D2				
	Area	Planned Handing over Date	Actually Handed over on	
D2.1	Delay on part	11 April 2014	19 May 2014	Site No. 3
D2.2		11 April 2014	7- May-2014	Site No.4
D2.3		11 April 2014	19-Mar-2014	Site No.5
D2.4		11 April 2014	7-May-2014	Site No.6
D2.5		11 April 2014	7-May-2014	Site No.7
D2.6		11 April 2014	19-Mar-2014	Site No.8
D2.7		11 April 2014	7-May-2014	Site No.9
D2.8		11 April 2014	6-May-2014	Site No.10
D2.9		11 April 2014	7-May-2014	Site No.11
D2.10		11 April 2014	6-May-2014	Site No.12
D2.11		11 April 2014	5-Jun-2014	Site No.13
D2.12		11 April 2014	5-Jun-2014	Site No.14
D2.13		11 April 2014	5-Jun-2014	Site No.15
D2.14		NA	6-May-2014	Site No.16
D2.15	Delay on part	NA	31-May-2014	Access Road to ADIT 1
D2.16	Delay on part	11 April 2014	Not yet handed over	Head-works site
D2.17	Delay on part	11 April 2014	02-Aug-2014	Power House site

D2.18	Spoil disposal area	11 April 2014	02-Aug-2014	
D3	Stoppage of Works at Access Roads to Adit 1 and Adit 2,			3
D4	Impact on Construction works due to interruption of Araniko Highway.			47
D5	Notice to claim by the contractor due to construction work stoppage by the villagers			10
D6	Stoppage of work due to private house locating at the middle of the road in November 03, 2014.			1
D7	Stoppage of gabion work @ access road to Adit 1 by Local villager in November 10, 2014.			1
D8	The work stopped entirely at access road to Adit 1 from October 30, 2014 to November 21, 2014			21
D9	The Work was stopped from 1st December 2014 to 4th December 2014.			4
D10	The Work at Adit 1 stopped from December 04, 2014 to December 08, 2014.			5
D11	Work Stopped at Site no.14 from 10 December 2014 to 12 December 2014.			3
D12	Work Stopped at ADIT 1 from December 11 2014 to December 12,2014			2
D13	The Work at Adit 1 stopped from March 12, 2015 to March 15, 2014.			4
D14	The work on the whole site stopped due to massive Earthquake occurred on April 25, 2015.The Force majeure was declared and the Contractor demobilized their entire set up from the work station.			(174+151)

Source: Regmi, 2016, personal Communication based on project documents [11]

Contractors claim for Extension of time

It was found that the contract document has made a provision to prepare revised construction schedule if the substantial changes occurs. In this regard, the contractor submit the revised construction schedule effective from the 15th March 2016 asking for the time extension for about 2 years. According to the new construction schedule, the intended completion date was 17th May 2019. The following table provides a clear comparison:

Table-2: Comparison of Approved and Contractor's proposed completion date

	As per approved Baseline Program	As per Proposed Revised Program
Project Completion	9thJune 2017	31stMay 2019
Project Duration	1215 days	1936 days (From original Commencement date)
Additional days proposed: (1936-1215) =721 days		

Source: Regmi, 2016, personal Communication [11]

The program was prepared by using the software Primavera Project Planner (P3).

The contractor has not used any of the established DATs. The Durations provided for the critical activitieswere not found consistent with the approved baseline Schedule. There were no any linkage between the original approved base schedule and the revised schedule.

Delay Analysis by using impacted as-Planned method

The overall delay in the project was further analyzed by using impacted as-planned method.It is 'prospective' and 'dynamic' method of delay analysis. The delays that are caused from the employer's side, delays caused due to the factors which were beyond the control of the employer and the contractor and the concurrent delays are considered for further analysis. The total float of the activities has been considered in this analysis.

The approved original Schedule is kept as baseline Schedule. It is to be noted here that the Primavera P6 has provided the option to manage multiple baseline projects as well.

The delay events were introduced into the schedule, and linked to the activities affected by those delay events.

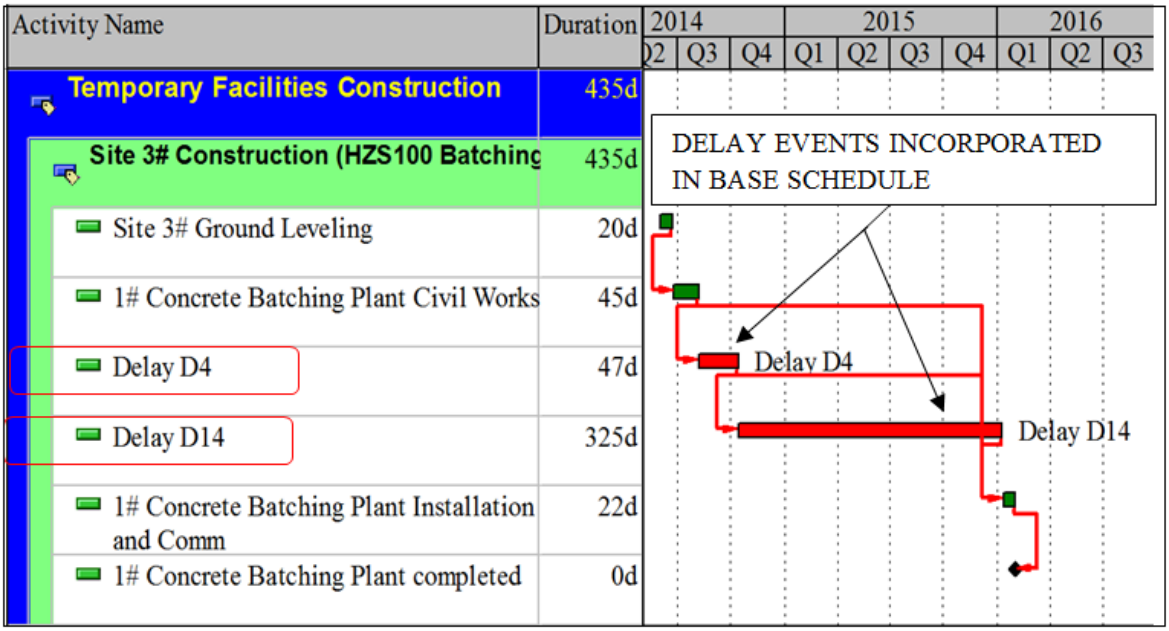


Fig-1: Illustration-Insertion of Delay Activities

Referring series of correspondences between the employer and the contractor, the delay events (D1 to D14), the effected duration and the area impacted by those delays were identified which is presented in Table-1 above.

In case of milestones like handing over of site, right of access to the site, partial completion …etc, delays are impacted by putting constraints over those activities.

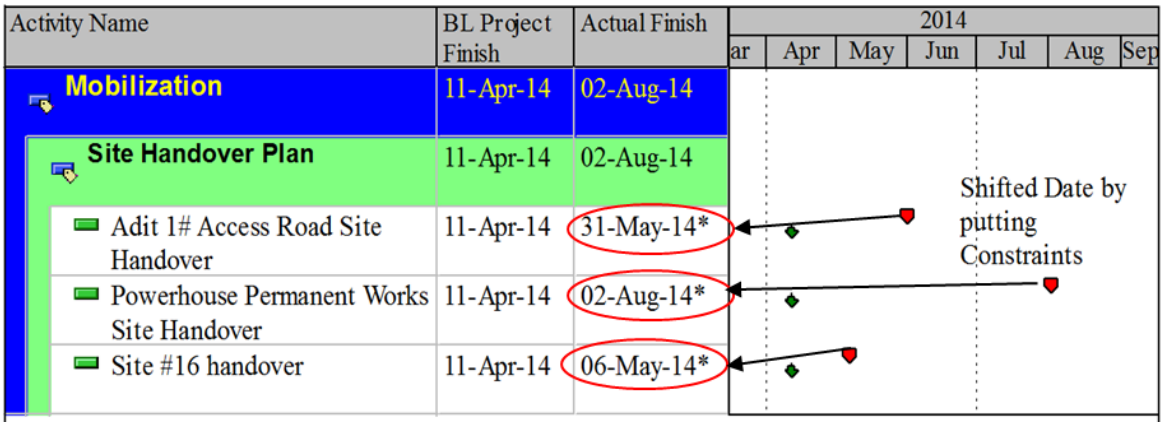


Fig-2: Illustration-Insertion of constraints on the activities

Changes made in the original baseline Program

The Delays mentioned in Table-1 above (D1 to D14) and the delay in Handover of the sites (In the form of Constraints) were all incorporated in the baseline program as shown in the table:

Table-3: List of Delayed events –Impacted as planned method

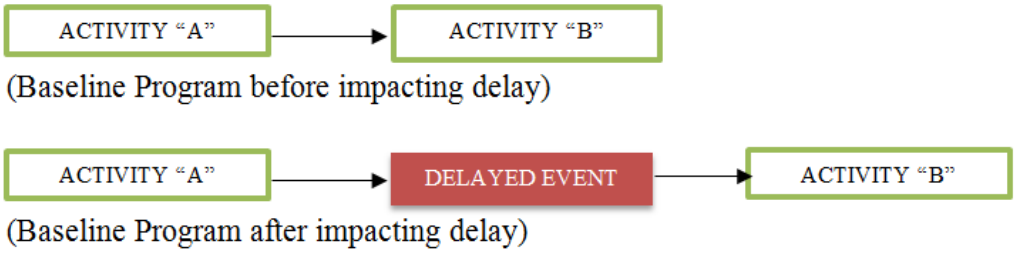
Activity ID	Activity Name	Duration	(Baseline) Start	(Baseline) Finish	Impacted Start	Impacted Finish	Variance - BL Project Finish
Mobilization		796d	11-Feb-14	11-Apr-14	11-Feb-14	16-Apr-16	-736d
Equipment Mobilization Plan		0d	11-Feb-14	11-Feb-14	11-Feb-14	11-Feb-14	0d
A01010100	Commencement (After Incorporating Delay D1)	0d	11-Feb-14		11-Feb-14		0d
Site Handover Plan		796d	11-Feb-14	11-Apr-14	11-Feb-14	16-Apr-16	-736d
A02010300	Site #3 handover (Handed over on 19 may 2014)	0d		11-Apr-14		19-May-14*	-38d
A02010400	Site #4 handover (Handed over on 19 may 2014)	0d		11-Apr-14		07-May-14*	-26d
A02010500	Site #5 handover (Handed over on 19 mar 2014)	0d		11-Apr-14		19-Mar-14*	23d
A02010600	Site #6 Handover (Handed over on 07 may 2014)	0d		11-Apr-14		07-May-14*	-26d
A02010700	Site #7 handover (Handed over on 07 may 2014)	0d		11-Apr-14		07-May-14*	-26d
A02010800	Site #8 handover (Handed over on 19 mar 2014)	0d		11-Apr-14		19-Mar-14*	23d
A02010900	Site #9 handover (Handed over on 07 may 2014)	0d		11-Apr-14		07-May-14*	-26d
A02011000	Site #10 handover (Handed over on 06 may 2014)	0d		11-Apr-14		06-May-14*	-25d
A02011100	Site #11handover (Handed over on 07 may 2014)	0d		11-Apr-14		07-May-14*	-26d
A02011200	Site #12 handover (Handed over on 06 may 2014)	0d		11-Apr-14		06-May-14*	-25d
A02011300	Site #13 handover	0d		11-Apr-14		05-Jun-14*	-55d
A02011400	Site #14 handover	0d		11-Apr-14		11-Apr-14*	0d
A02011500	Site #15 handover	0d		11-Apr-14		05-Jun-14*	-55d
A02011600	Site #16 handover	0d		11-Apr-14		06-May-14*	-25d
A02011700	Handover of Geological Survey and Mobilization	0d		11-Feb-14		11-Feb-14*	0d
A02011800	Adit 1# Access Road Site Handover	0d		11-Apr-14		31-May-14*	-50d
A02011900	Adit 2# and Accesss Road Site Handover	0d		11-Apr-14		11-Apr-14*	0d
A02012000	Adit 3# Site Handover	0d		11-Apr-14		11-Apr-14*	0d
A02012100	Powerhouse Traffic Detour Site Handover	0d		11-Apr-14		11-Apr-14*	0d
A02020100	Headworks Permanent Works Site Handover	0d		11-Apr-14		16-Apr-16*	-736d
A02020200	Pressure Conduit Permanent Works Site Handover	0d		11-Apr-14		11-Apr-14*	0d
A02020300	Powerhouse Permanent Works Site Handover	0d		11-Apr-14		02-Aug-14*	-112d
A02020400	spoil disposal area handover	0d		11-Apr-14		02-Aug-14*	-112d
Temporary Facilities Construction		447d	27-Apr-14	23-Jun-14	27-Apr-14	12-Jan-16	-406d
Site 3# Construction (HZS100 Batching Plant)		372d			08-Aug-14	11-Jan-16	
B03010310	Delay D4	47d			08-Aug-14	13-Oct-14	
B03010320	Delay D14	325d			14-Oct-14	11-Jan-16	
Site 6# Construction (Laboratory)		372d			16-Jun-14	17-Nov-15	
B06010210	Delay D4	47d			16-Jun-14	19-Aug-14	
B06010220	Delay D14	325d			20-Aug-14	17-Nov-15	
Site 9# Construction (Contrator's Main Camp)		3d			27-Oct-14	29-Oct-14	
B09010310	Delay D3	3d			27-Oct-14	29-Oct-14	
Site 10# Aggregate Processing Plant&HZS75)		397d			07-Jul-14	12-Jan-16	
B10010210	Delay D4	47d			07-Jul-14	09-Sep-14	
B10010220	Delay D14	325d			10-Sep-14	08-Dec-15	
B10020110	Delay D3	3d			08-Jan-16	12-Jan-16	
Site 12# Construction (Equipment Parking Lot)		4d			11-Sep-14	16-Sep-14	
B0120102	Delay D3	3d			11-Sep-14	15-Sep-14	
B0120102	Delay D4	1d			16-Sep-14	16-Sep-14	
Site 14# Construction (HM Storage Yard)		3d			26-May-14	28-May-14	
B14010210	Delay D11	3d			26-May-14	28-May-14	
Other Temp Facilities		58d	27-Apr-14	23-Jun-14	27-Apr-14	23-Jun-14	0d
Design and Approval		120d	12-Apr-14	09-Aug-14	12-Apr-14	09-Aug-14	0d
HM Making, Procurement and Delivery		325d			13-Feb-15	12-May-16	
The Hydromechanical equipment for the headrwo		325d			13-Feb-15	12-May-16	
D02010000	Delay D14	325d			13-Feb-15	12-May-16	
Hydromechanical equipment for headrace tunnel		325d			13-Feb-15	12-May-16	
D03010000	Delay D14	325d			13-Feb-15	12-May-16	
The Hydromechanical equipment for the Powerho		325d			13-Feb-15	12-May-16	

Constraints added in the Program

Activities for delay added with proper linking

Activity ID	Activity Name	Duration	(Baseline) Start	(Baseline) Finish	Impacted Start	Impacted Finish	Variance - BL Project Finish
D04010000	Delay D14	325d			13-Feb-15	12-May-16	
Headworks Construction		918d	31-May-14	19-May-16	31-May-14	06-Dec-17	-404d
Construction Preparation		0d	31-May-14	31-May-14	31-May-14	31-May-14	0d
E01020000	Diversion Tunnel Workfront Handover Begin	0d	31-May-14		31-May-14*		0d
Diversion Tunnel and Cofferdam		325d			19-Nov-14	16-Feb-16	
E02010410	Delay D14	325d			19-Nov-14	16-Feb-16	
Spillway Construction		108d	11-Feb-15	29-May-15	11-Dec-16	28-Mar-17	-425d
E03030100	Left Wing Wall Concrete Placement	108d	11-Feb-15	29-May-15	11-Dec-16	28-Mar-17*	-425d
Desander Construction		410d	31-Jan-15	27-Apr-16	01-Oct-16	14-Nov-17	-566d
E04010500	Intake and Diversion Canal Excavation	45d	01-Nov-15	15-Dec-15	20-May-17*	03-Jul-17	-566d
E04020250	Desander (ch1+31~1+51) Construction below EL1144	121d	31-Jan-15	31-May-15	01-Oct-16	29-Jan-17*	-609d
E04020300	Outlet&Forebay Construction1+51~2+00 above 1144m	121d	31-Jan-15	31-May-15	01-Oct-16	29-Jan-17*	-609d
E04020420	Diversion Canal (Ch0+08~0+37) Construction	134d	16-Dec-15	27-Apr-16	04-Jul-17	14-Nov-17*	-566d
The HM for the headwork installed and tested		30d	20-Apr-16	19-May-16	07-Nov-17	06-Dec-17	-322d
E05040100	Intake Trashrack Embedded Part&secondary concrete	30d	20-Apr-16	19-May-16	07-Nov-17	06-Dec-17*	-322d
Reinforcied cement conerete Pressure cornduit		325d			26-Mar-15	22-Jun-16	
Construction Preparation		325d			26-Mar-15	22-Jun-16	
F01010310	Delay D14	325d			26-Mar-15	22-Jun-16	
Headrace tunnel(HRT) Construction		446d	02-May-14	02-May-14	02-May-14	15-Jan-16	-446d
Construction Preparation		0d	02-May-14	02-May-14	02-May-14	02-May-14	0d
G01010100	Adit 1# Access Road Plan Submittal	0d	02-May-14		02-May-14*		0d
Adit 1# Access Road		39d			01-Jul-14	22-Aug-14	
G02010120	Delay D1	3d			01-Jul-14	03-Jul-14	
G02010122	Delay D9	4d			04-Jul-14	09-Jul-14	
G02010123	Delay D10	5d			10-Jul-14	16-Jul-14	
G02010124	Delay 12	2d			17-Jul-14	18-Jul-14	
G02010125	Delay D13	4d			21-Jul-14	24-Jul-14	
G02010127	Delay D5, D6, D7, D8	21d			25-Jul-14	22-Aug-14	
Adit 2# and Access Road		3d			21-Jul-14	23-Jul-14	
G03010210	Delay D3	3d			21-Jul-14	23-Jul-14	
Tunnel 1 Construction		325d			20-Oct-14	15-Jan-16	
G05010010	Delay D14	325d			20-Oct-14	15-Jan-16	
Powerhouse Construction		1041d	15-Jun-14	10-Feb-16	15-Jun-14	21-Apr-17	-436d
Temp Facilities and Preparation		0d	15-Jun-14	15-Jun-14	15-Jun-14	15-Jun-14	0d
H01020200	Traffic Diversion Approval and Government Permit	0d		15-Jun-14		15-Jun-14*	0d
Milestone of works		0d	10-Feb-16	10-Feb-16	21-Apr-17	21-Apr-17	-436d
H06015000	MS-50Handover to LOT2 for install Overhead crane	0d		10-Feb-16		21-Apr-17*	-436d

The delay events as shown above were then linked with the respective activities which are affected by those delay. The illustrationbelow will make it clearer:



Theprogram is then scheduled/recalculated and the scheduled program is compared with the base schedule. The difference in the completion date is observed. After impacting the delay as mentioned above it was observed that the new completion date became 19th February 2019.

Table-4: Project Completion date comparison; impacted as-planned v/s approved baseline Schedule

	As per approved Baseline Program	As per Impacted as planned Program
Project Completion	9th June 2017	19th February 2019
Project Duration	1215 days	1834 days (From original Commencement date)
Additional days proposed: (1936-1215) =620 days		

Advantages

In this method, there is a linkage between previous approved baseline schedule and the newly delay Impacted Program. Delays which are incurred from employers side has been incorporated in the schedule. Delay caused by the contractor were not introduced in the new revised schedule since those delays are non-excusable in nature. In general, the contractor have to accelerate the pace of the work to meet the intended completion target if the delays happened solely from their side only. The program is relatively easy to prepare and understand. Actual site progress and updated program is not required. The total float has been considered when impacting the delay. This type of DAT is preferred if the regular progress updates are not available.

Disadvantages/Limitation

The major limitationobserved in this method is that the concurrent delays were not addressed. In our case study, for instance, at one hand, the employer was unable to hand over the head-works site to the contractor while in other hand, due to the financial crisis and improper internal management, the contractor was not able to mobilize its manpower and machinery to the head-works site particularly. So it seems that both party are liable for this delay. Concurrent delay is excusable and non-compensable in general. However, it requires subjective judgment to some degree and has to be sort out by proper negotiations. If such delays are impacted in the program, it simply either tends to drag the final completion date or use the float if available which means that this method assumes that the time extension must be granted to the Contractor in case of concurrent delay.

Similarly, if there are multiple delays occurred in the site or if only portion of any site is disturbed, it is very difficult to show it in program. In our case study, the access road to Adit 1 has been disturbed several times. Sometime the full section has been stopped while in most of the cases, work stopped in certain chainages only. To incorporate or not to incorporate the stoppage/delays occurred in the portion of the site is also subjective.

The actual site condition and the real progress is not incorporated in the program so the schedule after incorporating delays did not reflect the actual site condition. The links in the approved baseline program must be very accurate and realistic. Otherwise the result will be misleading.

Delay Analysis by using Time Impact Analysis method

Correspondences related to the schedules and the periodic progress reports were used as primary data for the analysis purpose.The delays that are caused from the employer's side, delays caused due to the factors which were beyond the control of the employer and the contractor and the concurrent delays are considered for further analysis. Referring the correspondence between the employer and the contractor, the delay events, the effected duration and the area impacted by those delays were extracted which is presented in table 1above.

The approved original Schedule is kept as baseline Schedule for the first fragnet. The 'networked' baseline schedule was first updated with progress to a point in time just before the delay event arose. For the succeeding fragnets, the preceding delay impacted and updated schedules were used as baseline schedule. For instance, original baseline schedule has been considered as a baseline schedule for fragnet 1; updated and delay impacted schedule uptofragnet 1 has been considered as a baseline schedule for fragnet 2 and so on.

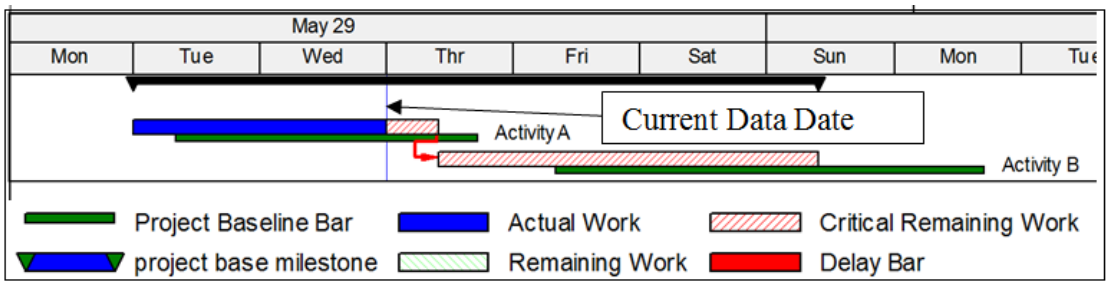


Fig-3: Illustration of progress updates before Impacting Delay

The delay events are then introduced into the schedule to establishthe likely impact on completion date, given the status of the works at the timethe delay event arose. In other word, the as-built status of the project, incorporating actual start/finish dates, changes, delays and impacts, is established up to the impact date and the schedule is recalculated. The as-planned or uncompleted portion of the schedule then forecasts the

work remaining to be completed. The estimated impact of any delay-causing event can then be assessed by comparing the newly established completion date to the previous as-planned completion date.

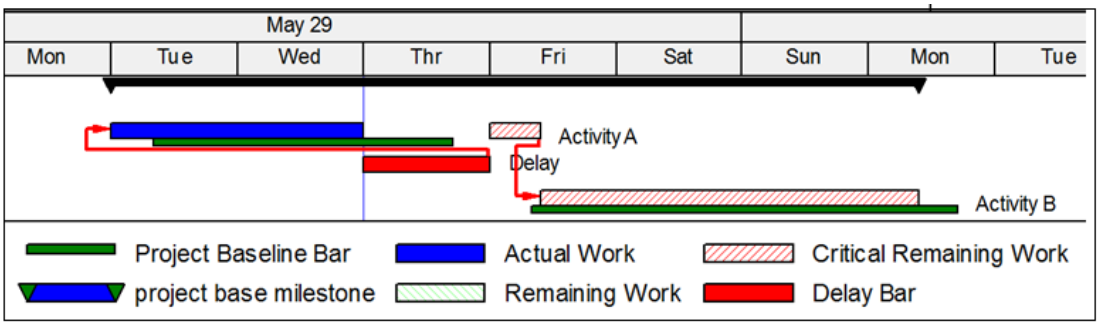


Fig-4: Illustration of progress updates after Impacting Delay

This is an iterative process repeated for each and everydelay causing event mentioned in Table-1 and finally the total delay attributable to the employer and the contractor is calculated.

Delay Due to D1 and D2

The delay D1 and D2 has already been incorporated in original approved schedule. The commencement date, 11th February 2014, was considered after incorporating D1.

Fragnet 1 – Delay D3 (11th Feb 2014 to 22nd July 2014)

Table 4.7: Fragnet 1 – Delay D3

(A)	Project Completion date as per approved original baseline program	09 June 2017
(B)	As per progress updated program (upto 22nd July 2014) before impacting delay	06 July 2017
(C)	As per progress updated program (upto 22nd July 2014) after impacting delay	06 July 2017
(D)**	Delay occurred due to the Owner	=(A)-(B) =27 days

**After updating the program and impacting the delay, it is observed that the non-handing over of the site no#13 (Temporary site) to the contractor in time has changed the critical path and has shifted the completion date of the project. Hence the delay occurred is due to owner's delay in handing over of the site.

Fragnet 2- Delay D4 (22nd July 2014 to 02nd August 2014)

Table 4.8: Fragnet 2-Delay D4

(A)	Project Completion date as per updated program upto 22nd July 2014	06 Jul 2017
(B)	As per progress updated program (upto 02nd August 2014) before impacting delay D4	18 July 2017
(C)	Delay occurred due to the Contractor	=(A)-(B) =12 days
(D)	As per progress updated program (upto 02nd August 2014) after impacting delay D4	17 Oct 2017
(E)	Total Delay	=(D)-(A) =83 days
(F)	Delay to Owner's causeupto the end of Fragnet 1	(E)-(C) =71 days

The stoppage of whole of the works occurred from 02 August due to devastating landslide at Jure (Delay D4). However, after the completion of the Bailey bridge (Activity ID E020102000 of the original approved schedule) in 19 Jul 2014, which was in the critical path, the contractor failed to further expedite the work for diversion tunnel excavation which is shown below in snapshot of the updated program

Activity ID	Activity Name	Duration	(Baseline) Start	(Baseline) Finish	Actual Start	Actual Finish
Diversion Tunnel and Cofferdam		930d	31-May-14	21-Dec-16	31-May-14 A	16-Feb-17
E02010100	Diversion Tunnel Workfront and Site Handover	15d	31-May-14	14-Jun-14	31-May-14 A	14-Jun-14 A
E02010200	Diversion Tunnel Bailey Bridges Up/Downstream	50d	31-May-14	19-Jul-14	31-May-14 A	19-Jul-14 A
E02010210	Delay D4	47d			02-Aug-14	17-Sep-14
E02010300	Diversion Tunnel Excavation and Support	15d	20-Jul-14	03-Aug-14	18-Sep-14	02-Oct-14

The Contractor's delay in this regard has been considered and therefore the delay due to Owner was:
71 days – (02 Aug 2017-19 July 2014)
= (71-14) days
=57 days

Fragnet 3- Delay D5 and D8 (11th August 2014 to 31st October 2015)

Table 4.9: Fragnet 3-Delay D5 and D8

(A)	Project Completion date as per updated program upto 02nd August 2014	17 October 2017
(B)	As per updated program (upto31st October 2014) before impacting delay	29 November 2017
(C)	Delay occurred due to the Contractor	=(A)-(B) =43 days
(D)	As per updated program (upto31st October 2014) after impacting delay	29 November 2017
(E)	Total Delay	=(D)-(A) =43 days
(F)	Delay to Owner's cause	(E)-(C) =0 days

The delay D5 and D8 consumed the available float and they did not lie in critical path. The critical path was same as in previous fragnet. The delay caused in excavation of diversion tunnel was the driving factor to shift the completion date. In this fragnet, the shifting of completion date was due to inefficiency of the contractor only.

Delay Due to D6 and D7

Both D6 and D7 are contemporaneous delay and has already been included in delay fragnet 2.

Fragnet4- Delay due to D9 and D10 (31st October to 01st December 2014)

No substantial delay occurred during this fragnet except minor stoppage of the works in the ADIT 1 area.

(A)	Project Completion date as per updated program upto 02nd August 2014	29 November 2017
(B)	As per updated program (upto 1st December 2014) before impacting delay	30 December 2017
(C)	As per updated program (upto 1st December 2014) after impacting delay	30 December 2017
(E)	Total Delay	=(D)-(A) =32 days

In this fragnet, Diversion tunnel construction is the driving activity for project completion. This delay is therefore attributable to the contractor.

Fragnet5- Delay due to D14 (31st October to 24th April 2015)

The project passed under several delays. Devastating Earthquake with magnitude 7.9 Richter scale and numerous aftershocks caused thereafter has substantially impacted the Work Progress. In addition the blockade by India in between this period has also impart the substantial delay in the Project. The Schedule has beenanalyzed during this interval. The observations made is presented in the table below:

Table-4.10: Fragnet4-Delay due to D14

(A)	Project Completion date as per updated program upto 1st December 2014	30 December 2017
(B)	As per updated program (upto25th April 2015) before impacting delay	31 March 2018
(C)	Delay occurred before impacting Delay D14	=(A)-(B) =90 days
(D)	As per updated program (upto25th April 2015) after impacting delay	19 February 2019
(E)	Total Delay	=(D)-(A) =415days
(F)	Delay to Delay D 14 (Earthquake and blockade in border)	(E)-(C) =325 days

During Progress update upto 25th April 2015, it was observed that the critical path changed. The head-works activities were in the critical path due to delayed handover of the head-works site. In addition the Delay D14 (the impact of devastating Earthquake and the blockade in the border) further pushed the project completion date to 20 February 2019. It is to be noted here that the head-works site was still not handed over

to the Contractor till the collection of these data and information. The project management team was therefore inquired about the probable date of the handover of the head-works site. It was predicted that probably the site hand over will occur on 1st May 2017. Thus putting constraint in the head-works handing over activity (Activity ID: A02020100) on1st May 2017, the project completion date shifted to 20 February 2019.

Hence the delay occurred due to Employer in this sub net is
((C) + (F)) of table 4.8
=90 days + 325 days
=415 days

Total Delay Calculation

Overall delay (OD)
$\sum EC_{od}$= Difference of the project completion of the last Fragnet and that of approved baseline schedule= (20 Feb 2019-9 Jun 2017) = 621 days

Net delay occurred from Employer's side (EC) is:
$\sum EC_{net}$= $\sum$ (EC's of all fragnet) =27+57+0+415=**499 days.**

Again,

Due to the devastating Earthquake, the Contractor literally demobilized all its resources from the site. After the resumption of work from 15th March, the period for remobilization and restoration of temporary structure had to be provided to the contractor. Upon discussion with the project management officials, allocating 30 days for remobilization and restoration was recommended.

Therefore the contractor is liable for 529 days of time extension using this method.

Comparative Summary

Following table provides quick comparative review on the outcomes from the application of Different DATs:

Table 4.11: Delayed Duration comparison by using various DATs

S. No	Description	Impacted Completion date	Delay due to Employer	Delay due to Contractor	Total Delay
1	Contractors' proposed Extension of time from the revised Schedule	31 May 2019	721 days	Not mentioned	Not applicable: the revised program only asks the time for intended completion date.
2	Delay analysis using Impacted as planned method	19 Feb 2019	621 days	Not mentioned; the delays caused from Employers side has only been impacted	Not applicable
3	Delay Analysis using Time Impact analysis Method	20 Feb 2019	529 days	90 days	621 days

Three different results were obtained by using three different techniques on a case study.

CONCLUSION

In this case study, the Contractor has not followed any of the DATs to claim for extension of time. The contractor has submitted its revised construction schedule as per the FIDIC conditions of contract and ask for time extension of 721 days. The revised construction schedule has no any link with the original approved base Schedule.

The use of Impacted as planned method shows the delay to 620.This method is conventional method and relatively easy. The major delays incurred due to employer's deficiencies and outside factors were all taken into consideration in this method. Total Floats were considered in this method. The delay incurred by the Contractor has not been incorporated in the impacted Schedule. Actual site condition and the progress were not considered in this method. Concurrent delay has also not been addressed.

In Time Impact Analysis method, the delays from the Contractor's side as well as delay incurred due to the Employer were distinctly defined. The actual site conditions and the progress update were considered in this method. In this method, analysis has been done using the subnet and hence getting more detailed and

refined result. However, this method demands regular progress updates from the site. In the absence of progress data, it will be of no use. Furthermore, application of this method is relatively complicated and needs experienced planner.

None of the DATs is found to address all the delay occurrence events. It is found that the Time Impact analysis method is relatively more elaborate as it uses the actual site progress and the sub net for each delay occurring events were analyzed. However, pacing delays and the concurrent delays were not addressed by any of the Prospective method used above.

Limitation of the Study

- The claims for time extension have only been considered in this study. The other consequences occurred due to delay like increment in overhead costs and other intangible costs, time value of money and opportunity cost are not included in this study.
- There are multiple Contract packages in the project under study. Only the Contract package comprising of Civil and Hydro-mechanical Works has been considered in this study.

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