Assess Effectiveness of TIA Method in Forensic Delay Analysis in Construction Projects

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Research

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DECLARATION

I confirm that, except where indicated through the proper use of citation and references, this is my own original work. I also confirm that my work include in this dissertation in part or whole has not been submitted for any other academic qualification at any institution. Further, I confirm that subject to final approval by the Board of Examiners of University of Moratuwa, a copy of this dissertation may be placed upon shelves of the library of the University of Moratuwa and may be circulated as required.

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M.S. Mendis

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ABSTACT

Results of delay analysis is the basis of many claims related to time and money of the construction projects. Results of delay analysis vary depending on the person how perform the analysis, delay analysis method, nature of data available, and many other subjective parameters associate with delay analysis. There is no delay analysis method specified in any standard condition of contracts. Therefore the selection of more suitable method is a liberty of person how preform the analysis. This inspire the background of this research.

Forensics delay analysis is the process which measure the impact of a delay event to the date of completion of the project based. This process called 'Forensic' because it is based on the past data. The planned sequence of activities of the project agreed by parties at the beginning of the project will be the basis of this process. Sequence of activities of a project or project programme, has many dependencies. Most of those dependencies are subjective. Therefore it is very difficult to develop a mathematical model to assess the impact of a delay event to the programme and its date of completion. There are many delay analysis methods. TIA is a one of the most accepted method even recommended by society of construction law. Assessment of the effectiveness of TIA method to analyze delays in construction projects is the objective of the research. Effective method shall be applicable, justifiable and scientific.

Assessing criteria to assess the effectiveness of a delay analysis method has been developed referring to basic requirements in analyzing project delays, provisions in contract law and experts views. The impact of few delay events would be analyze by TIA method and it could be assessed by the assessing criteria. Delay event and application of TIA method and results are the parameters which shall be assessed. This process have many subjective parameters. Impact of subjective parameters related to the delay analysis process, should be nullify to obtain more 'generalized' results. Therefore instead of obtaining results under few cases, it is planned to study the behavior of TIA results with the variability of its subjective parameters. Then these relationships are assessed by the developed criteria. Simulation followed by a case study is the selected methodology for the research. Simulation of the TIA has been done using a model developed based on critical path method. Simulation model should be capable of assemble each simulations together to observe the impact of one delay event on other. Results of simulations would be graphically illustrated.

Effectiveness of TIA method has been assessed in view of scientific method of measurement and applicability to the accepted industrial requirements and norms.

TIA cannot fulfill the requirements of effective delay analysis method, all the times. TIA shall be perform with proper understanding of behavior of its results. Interpretation of TIA results and final decision over the time extension claim shall be still a job, highly depend on expert judgment of professionals.

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Chapter 1 – Background

Construction project has 3 major phases in its life which are Planning, Implementation and Evaluation. Activities to be done, resource requirements and risks, which may occur while the implementation of the project, assess and foresee in the planning stage. Deliverables of the project are evaluated after the implementation stage, comparative to the assessments made in planning stage. Deliverables of the project can be assessed in budgetary aspects, quality aspects and schedule aspects. Construction programme is sequence of activities in a time line. When analyzing the impact of delay event, assessments done in planning stage regarding to the time, which included in the construction programme shall be taken as the base line.

Construction programme prepared in planning stage is not constant but very dynamic, shall change time to time and always pursuit the best path of working. Planner should have the liberty to change sequence; interrelationships of activities, level of breakdown of activities and resource allocation at any time to increase the efficiency of the project. Only the fixed parameters of the project are Cost, Quality and Time assumed in planning stage. (PMI, 1996)

Unplanned delays in construction projects are often regrettable but unavoidable. If the Contractor has been harmed by the effects of an event beyond his ability to foresee, when he would be preparing the bid, then the Employer should adjust the contact in a fair and equitable manner. The adjustment to the contract should be done quickly and with the least amount of effort as possible (Ron, 2004). Delays course number of changes to a construction contracts. The delay may course additional time or cost to the project. The party responsible for the delay should compensate to the impact of the delay. Calculating the impact of the delay is a complicated process. It involve mathematics and principals of contract law.

The global impact technology is the simplest way of calculating the delay impact; it treat all the delay event equally. It plot number of delays in a bar chart and sum the total duration. The simple summation of all delay events may not be the actual resultant impact due to all delay events. (David, 2006).The delay may be caused by the action of more than one party or delay may contribute to formation of another delay or few delays may impact concurrently. (David, 2006).

Delay analysis could be done;

1. Prospectively

   Analysis will be done by the time of delay event occur.

2. Retrospectively

   Analysis is performed after the delay event has occurred and when the actual impact is experienced.

Forensic delay analysis is retrospective analysis performs based on historical data. It is an investigation; objective of investigation is to find the extent of liability of the event to the total delay at the completion of the project. Forensic schedule analysis, like many other technical fields, is both a science and an art. As such, it relies upon professional judgment and expert opinion and requires many subjective decisions. Most important decisions shall be taken is, what technical approach should be used to measure the delay and identify the affected activities and extent of effect. How the analyst plans apply the chosen method is equally important (RPFSC 2011).

Efficient delay analysis method should minimize that impact of subjective parameters and obtain unique and reasonable results. Contractual conditions and technical constrains should only be the governing factors of results of delay analysis.

Though there are many techniques for delay analysis and all the standard forms of contract distinguish contractor liable delays events and employer liable events, none of them recommends a protocol of analyzing the net impact of delay events (Michael & Kenji, 2010). None of standard form of condition of contract restricts the freedom to revise construction programme in any time of project life. Therefore delay analysis in connection with the baseline construction programme eventually generates subjective results.

All techniques use to analyze the impact of delay event; are either simulate the delay event in computer model or perform comparison between as planed schedule and the as built schedule (Jhon, 2007).Time Impact Analysis (TIA) is a more analytical delay analysis method which simulate the impact of delay event in project time line.

TIA is widely accepted delay analysis method. This method has also been recommended by society of construction law and ACCE. TIA starts with construction programme and critical

path method. But in the procedure there are several steps to minimize the subjectivity and dependency of results on initial assumptions in construction programme and non-contractual constrains. (AACE, 2006)

All methods used to analyze a delay has many subjective parameters, the application of same technique by two opposing expert often produce varying and inconsistence conclusions (John Keane, 2008). This inspires the requirement of this research which assess the effectiveness of TIA as delay analysis methods.

1.2 Objectives of the Research

The objective of this research is to assess effectiveness of TIA method used in construction projects. Effectiveness of certain results implies that, the results are justifiable, results are useful to obtain required outputs to drive the project in positive way, results are obtained with minimum effort and time and results are comprehensive with detail required for the judgment in litigation process. The objective of assessment of effectiveness has been planned to obtain through following steps.

1. Develop a criteria to measure the effectiveness of a delay analysis method
2. Apply TIA method to deferent cases, obtain TIA results by varying subjective parameters which effect on TIA process and graphically illustrate the relationships.
3. Relationship between TIA results and variable parameters and other subjective parameters are graphically illustrated. Those results were evaluated in a criteria developed to assess the effectiveness.

Path to Reach the Research Objectives

Research planned in following procedure.

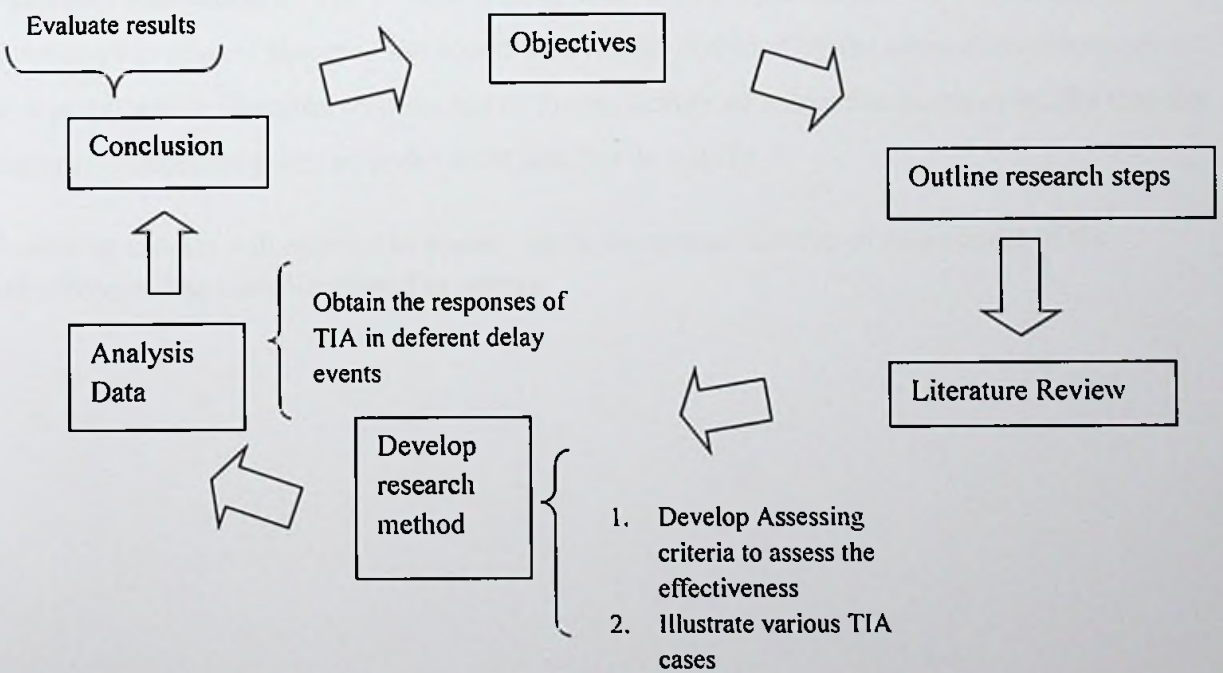


Figure 1 Reseach Flow

Precedence studies of research were focused on studying delay analysis methods and studying how to illustrate the delay analysis. The literature review developed deep understand particularly in the TIA method and develop background for an assessing criteria to measure the effectiveness of the method. In the analysis, TIA results are obtained with simulation of variable parameters.

Analysis of results focus on

1. Studying the impact of one delay event on other.
2. Applicability of TIA method on lengthy delay events.
3. Applicability of TIA method to concurrent delay events
4. Impact of the date in which the delay event occurred
5. Behavior of free float.
6. Liberty that planner has to drive the project on best path.
7. Separately identify the impacts of deferent delay events

This report has been structured to illustrate the effectiveness criteria of TIA method. Graphical illustration of TIA results varying with deferent parameters are very important. As mentioned in several places in the report TIA results obtained by the simulation always given as a graph which illustrate relationship to the variability of subjective parameters. By this the impact of subjectivity can be understood and can be nullify.

Assessing criteria will support to answer above questions. Results of assessment of the effectiveness has been illustrated in matrix.

Chapter 2 - Literature Review

2.1 Introduction

Precedence studies to the Literature Survey

Research brief was developed in the preliminary stage of literature review. At initial steps of the readings, it was understood that there is a gaps in previous studies relevant to TIA method which should be filled by a novel research.

Detail of use of delay analysis methods in pervious projects were studied as a primary data analysis. Major project with systematic approaches for planning and scheduling was studied/ Projects funded by reputed international agencies like World Bank, JICA, JABIC, ADB, and USAID follow systematic planning and progress monitoring methods. Experiences of southern highway were reviewed as major project to understand how delay claims were handled.

Secondly the detailed literature review was done. References of detail literature review are standards and recommendations published by reputed institutions, journal articles, researches, conference proceedings and text books.

2.2 Previous researches relevant to evaluation of TIA and delay analysis methods

Summarizing the studies on previous researches;

Research	Researcher	Objective of research	Methodology	Identified gap in the research
Schedule delay analysis in construction project: Time Impact Analysis Method	Songul Dayi	Detail Study in TIA method Study results under deferent conditions	Case Study	The conclusion cannot be generalize (paucity)
Delay analysis Methodology in UAE construction Projects:	Saad Hegazy	Analysis strength and weaknesses of delay analysis methods	Literature Survey	Not an analytical study
Selecting a delay analysis method in resolving construction claims	David Arditi and Thanat Tattanakitchamroon	Applicability of deferent delay analysis methods	Secondary data analysis	Analysis doesn't reveal how effectively apply delay analysis methods in deferent cases
Construction Delay analysis under multiple baseline update	Wail Menesi	Understand construction delay analysis with resource allocation	Case study – hypothetical	Results cannot be generalize All the possibilities are not studied
Construction Delay Analysis Techniques—A Review of Application Issues and Improvement Needs	Nuhu Braimah	Analysis the applicability of TIA method in construction delay analysis	Case study	The result cannot be generalize (paucity)

Table 1 Summary of Previous Researches

Following gaps were identified for a new research, when concluding the limitations of previous researches.

1. Most of the researches are based on case studies in which results cannot be generalized. Generalize conclusion on the effectiveness of delay analysis method should be obtained by following new research methodology.

2. How delay analysis technique support to take progressive measures like mitigation of delay, should be done while analyzing the impact of delay event.

3. TIA process has many subjective and objective parameters, Impact of all the parameters shall be evaluated.

This research was developed based on above identified gaps in previous researches.

2.3 The Delay Analysis Methods

There are 2 divisions in delay analysis techniques.

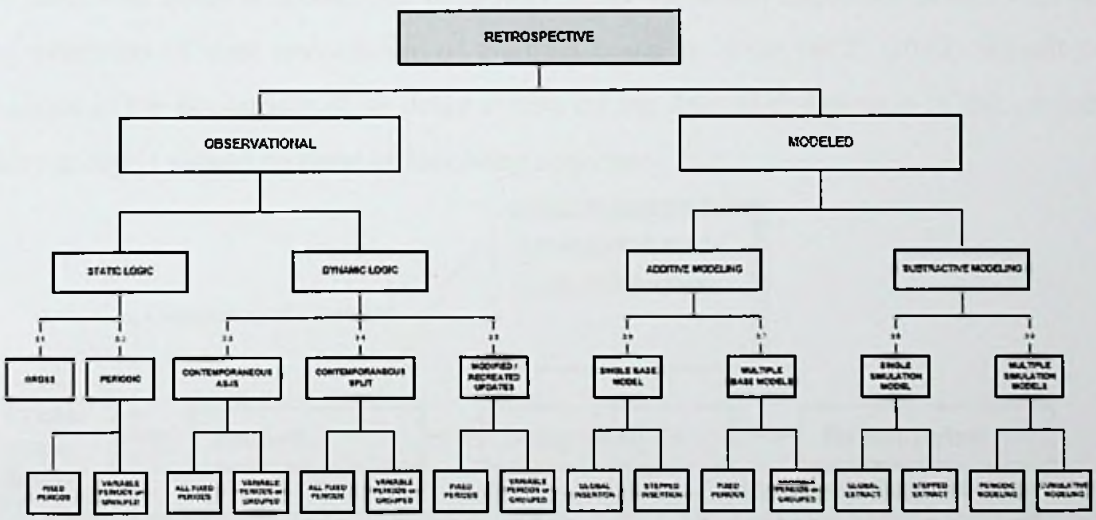


Figure 2 Methods of Delay Analysis

1. Observational

The observational method consists of examining a schedule, by itself or in comparison with another, without the analyst making any changes to the schedule to simulate delay event. (RPFSC 2011)

2. Modeled

The modeled method calls for intervention by the analyst beyond mere observation. In preparing a modeled analysis the analyst inserts or extracts activities representing delay events into or from a CPM network and compares the calculated results of the 'before' and 'after' states. (RPFSC 2011)

Common examples of the modeled method are the collapsed as-built, time impact analysis, and the impacted as-planned.

Delay analysis performs to foresee future delays or find out extent of liability of each event to the final total delay at completion of project. After the actual impact of delay event assessed, the extension of time and change of contract could be done (SCL, 2010). Result of delay analysis is the net impact of all delay events on the date of completion of the project. Any delay analysis should be done in following sequence.

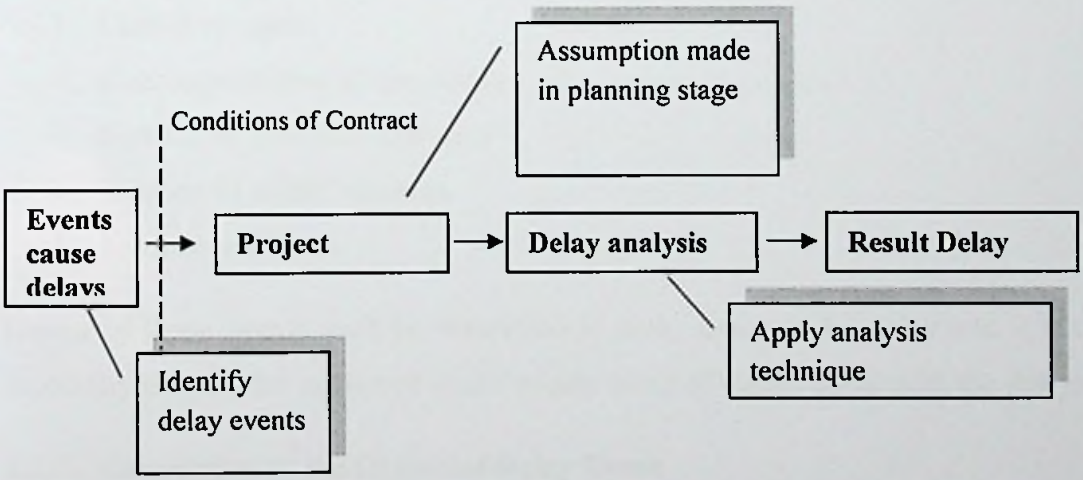


Figure 3 Delay analysis Protocol Common for all Methods

Either contractors or employers should be liable of the delay event. Liable party normally should compensate the damage to the other party.

There are some standards follow when perform a delay analysis. Those standards are governing rules of the delay analysis. Most of them are found in 'Delay and Disruption Protocol' published by United Kingdom Society of Construction Law. The Protocol has been designed as a code of good practices to be used before entered into a contract or during the administration of the contract or while assessing claims and resolving disputes (Robinson, 2002). But not a legal document which binds all parties. Delay and Disruption protocol used in this research to identify requirements in effective delay analysis method.

2.3.1 Identify Delay events and their ownership

Generally all the contract forms define following events as excusable events to the contractor;

1. Adverse weather condition
2. Change order/Variation
3. Force majeure
4. Delay in handing over of site (position of site)
5. Payment delay to the contractor
6. Design delay, instruction delay
7. Unforeseen physical condition

There are some common events cause delays but not excusable to the contractor

1. Cash flow issues
2. Poor organization of site works
3. Scarcest of specified resources
4. Scarcest of skilled workers
5. Logistic problems

Impact of those events shall be illustrated in delay analysis. In real world it is difficult to separately identify the impact of above events. Most of events occur with the link to another.

2.3.2 Calculation of the Impact of Delay Event

Irrespective the method of analysis, there are certain data available in a project which shall be used as basis for measuring the impact of delay event. Those are conditions of contract based to identify the liability of delay event, baseline programme (As plan Schedule), progress update records and notices of delays events.

Efficiency of the analysis depends on the *'quality of above data'*, strength of the method of delay analysis and assumptions made while analysis. Term quality of above data implies the accuracy, the actuality and the availability. Records of delay events and impact of them could be found in notices of delays issued to the employer.

2.4 Methods of Analyzing the Impact of Delay Event

	Method	Sub method
1	Time Impact Analysis ("TIA")	*1.* Properly Adjusted TIA
		2. Unadjusted TIA (Windows)
		3. Prospective TIA
		4. Windows (Wide Periods)
2	Collapsed As-built	*5.* Multiple Period Using Updates
		6. Collapsed Stepped Removal
		7. Remove Employer Delays
		8. Remove Contractor Delays
3	As-built Critical Path	*9.* Critical Path Using Updates
		10. As-built Path
4	Impacted As-planned	*11.* Stepped Insertion
		12. Global Insertion
		13. Compare Employer/Contractor
5	As-planned vs. As-built	*14.* As-planned vs. As-built

(Meagher & Robet, 2012)

Table 2 Further Sub Division of Delay Analysis Methods

2.4.1 As-Planned v As-Built

This method compares the duration of an As-planned activity (or the duration of all As-planned activities) on the original programme with the As-built duration for that same activity (or those same activities) in the As-built programme.

The difference in time between the duration in the As-built programme and the duration in the As-planned programme is taken as the period of delay to which a Contractor is entitled to an Extension of Time as a result of an excusable delay event (or delay events) (otherwise known as Employer delay events). (James, 2003)

The activity or activities impacted by delay event need to be clearly on the critical path. The delay event or events need to be clearly identified. There should be no other delay events to the activities in question that are non-excusable delay events (otherwise known as Contractor delay events). It is an inexpensive method to be used and simple to use and understand. Because no detailed analysis is possible it can only be used on the most of simple construction projects. It cannot deal with the issue of concurrent or parallel delays, the matter of consequential delay or re-sequencing of works, or the effects of mitigation and/or acceleration measures.

2.4.2 Impacted As-Planned

This method adds an identified excusable delay event (or events), either as a separate activity (or activities), or onto the duration of an existing activity (or activities), of the As-planned programme. The duration of the activity is derived (where possible) from the resource allowances on the As-planned programme. The As-planned programme with the delay event (or events) incorporated is then re-run, to show a resultant revised Completion Date on what is then called the Impacted As-planned programme.

The period between the Completion Date shown on the As-planned programme and that shown on the Impacted As-planned programme, is taken as being the period of delay to which a Contractor is entitled to an Extension of Time as a result of an excusable delay event (or events) (otherwise known as Employer delay events) (James, 2003). In a simple project or complex project, delay events that occur only over limited periods or where the As-planned programme has been affected by a limited number of delays only.

An accurate and realistic As-planned programme is required to obtain effective results from this method. Sufficient details on the As-planned programme to allow a reasonable estimate to be made of the resources necessary as allocated in as planed programme to assess the time to be added for the task resulting from the excusable delay event (or events). In this method As-built information is not needed at all and assume the contractor base line programme is accurate.

As the As-planned impacted programme rarely bears any relationship to what actually happened on site, it can be used to illustrate areas where the Contractor took acceleration measures (or conversely where the Contractor's actions were deleterious). It is a very

theoretical method. The practical aspect of work at the site is not considered. It relies heavily on the As-planned programme, and can show misleading results if the As-planned programme is incorrect (either in terms of durations for activities or in respect of logic linking).As the As-planned impacted programme rarely bears any relationship to what actually happened on site, it is difficult to use the results to ascertain a Contractor's actual extension of time entitlement. If records are available for an As-built programme, then it is unlikely that a tribunal would accept this theoretical method as being a basis for assessing a Contractor's Extension of Time entitlement

2.4.3 Collapsed As-Built (also known as 'As-Built But For' method)

Firstly the as planned programme shall be prepared. Then this method starts from removing identified excusable delays from the As-built programme to show what the Completion Date would have been if those delay events had not occurred.

The period between the Completion Date of the As-built programme and the Completion Date of the Collapsed As-built programme, is taken as the period of delay to which a Contractor is entitled to an Extension of Time as a result of an excusable delay event (or events) (otherwise known as Employer delay events) (James, 2003). An accurate As-built programme is required. Clear identification of delay events has to be done. As this method is based upon the As-built programme, there is certainty that the outcome coincides with the events on site. The analysis of this method is easy to understand.

The removal of sometimes arbitrarily established delays from the As-built programme can conceal the true effect of the Contractor's delays, and cannot allow for

a. The issue of concurrent or parallel delays,
b. The matter of the re-sequencing of the works,
c. The effects of mitigation and/or acceleration measures.
d. The re-creation of a critical path following the removal of delay events may not be the same as the critical path that actually existed at the time of the delay event since the process involves the re-construction of the as-built logic.

2.4.4 Introduction to the Time Impact Analysis

Time Impact Analysis is typically associated with the modeling of the effects of a single delay event at once. It requires a CPM schedule that is able to show the pure CPM calculation of differences between a schedule that does not include a delay and one that does include the delay. The difference for project completion between the non-impacted schedule and that of the schedule with the impact, is considered as the impact of the delay for the given time duration.

TIA is more useable as a forward-looking tool rather a backward-looking tool. It increases the ability of the Employer to respond to the results of the analysis and optimize the cost of a delay. Never the less, TIA is an acceptable and useable tool for the determination of the effects of a past delay. It is more accurate and reliable than other analysis techniques such as Impact as plan and As-Built Analysis in generally, but at the expense of more time.

Window analysis is a mode of TIA. Here the entire schedule divided in to time frames where the progress of that time period is known and called a window. Based on the analysis of the effects of delay events over the entire length of a project by looking at the events which have affected progress within 'windows' of the contract period sequentially.

The duration of each 'window' is not pre-determined, but is frequently taken as being one month. At the end of each 'window' the As-planned programme is updated to take account of any delaying inefficiency which is the Contractor's risk, any necessary logic or duration revisions because of mitigation measures undertaken, together with all excusable and/or compensable events during the period since the last update.

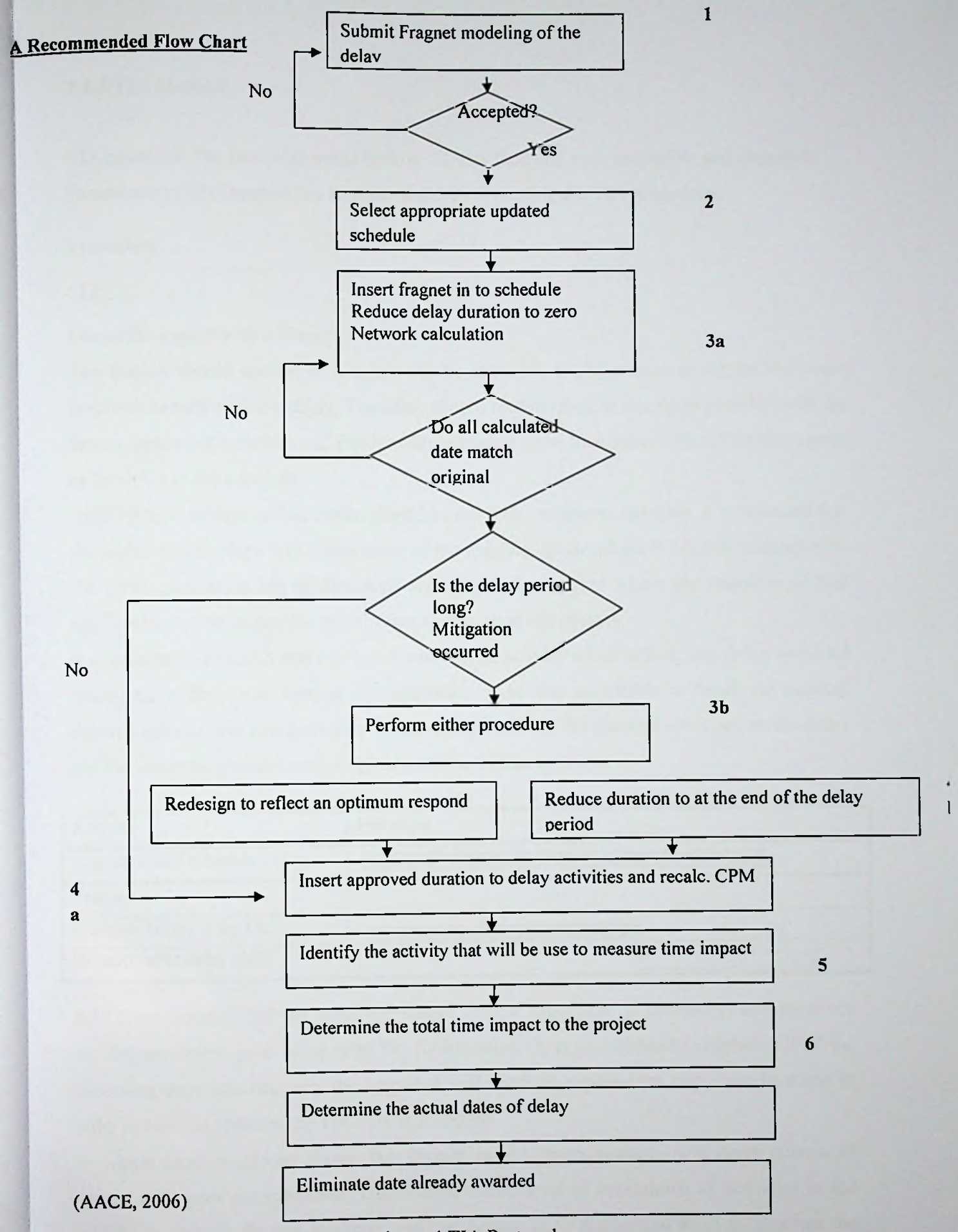
The closing of a window in this way forms an As-built programme at the end of that window which effectively becomes the As-planned programme for the next window in sequence. At the end of each window, projection is made to the Completion Date. At the end of the last window a final revised Completion Date is provided which, when compared to the original As-planned Completion Date, indicates the Extension of Time entitlement of the Contractor (James, 2003).

When being used retrospectively, accurate progress information at the time of the windows must be available. An accurate As-planned programme that reflects all of the activities that should have been included within the original programme. This method is the method

recommended by the Society of Construction Law Delay and Disruption Protocol. In each window there are relatively few activities to be analyzed (as compared to the over-all programme) and therefore the delay analysis is easier. It is the best technique for determining the amount of Extension of Time that the Contractor should have been granted at the time that an excusable risk occurred. Accurate progress information at the time of the windows must be available; otherwise the analysis cannot be properly or accurately completed.

The less accurate the programme and progress information available is, the more likely that results will be obtained that are clearly inaccurate, that will require to be amended by manipulating any obvious errors in the original As-planned programme.

A Recommended Flow Chart



(AACE, 2006)

Figure 4 TIA Protocol

2.4.5 TIA Method

TIA procedure has been elaborated bellow. TIA method and both subjective and objective Parameters of TIA method can be understood by reviewing the TIA procedure.

Procedure

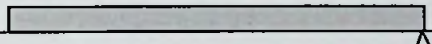
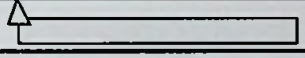
STEP 1:

Model the Impact with a Fragnet.

The fragnet should consist of a subset of the activities in the project schedules that were involved directly with the delay. The delay should be described as simply as possible with the fewest number of activities and relationships added in order to substantially reflect the impact of the delay to the schedule.

Existing relationships and activities should be left intact wherever passable. It is expected that the added relationships will cause some of the existing relationships to become redundant to the CPM calculation but relationships should only be deleted where the retention of that relationship would negate the actual work restraints on the project.

It is acceptable to add a delay as a successor to an activity when in fact, that delay occurred during the activity and delayed its completion. It is also acceptable to break the existing delayed activity into two activities, with one representing the planned work before the delay and the other the planned work original duration of that activity.

Activity	**Duration**
Activity initial schedule (A)	
Fragnet	
Duration before delay (A1)	
Duration after delay (A2)	

AACE recommend that the employer should review negotiates (if necessary) and approves the fragnet before proceeding with the further steps. It is acceptable to combine all of the following steps into one, buy the employer still needs to approve the step considerations in order in order to approve the TIA. (AACE, 2006)

In which basis employer accept the fragnet is not recommended. Analytical criteria of accepting fragnet are indefinite. This related to the level of breakdown of activities in the initial schedule; in fragnet activities shall be broken in to the bottom level to illustrate the impact of delay.

STEP 2:

Select the appropriate accepted schedule to impact. The appropriate schedule should be the last accepted schedule update prior to the date of the delay. The baseline schedule should be used if the delay began prior to the first schedule update.

If the date between the start of the delay and the last accepted schedule update is too large (or if significant deviation to the schedule were experienced between the last data date and the start of the delay,) the contractor may elect to first provide a new schedule update with a data date immediately prior to the start of the delay. If this new update schedule is to be used, it must first be submitted to the employer for review and acceptance just like any other schedule update for that project.

This happens when enough progress reports are not maintained at the site.

The schedule to be impacted will be called, "the original schedule update." The data date may not be altered from that used by the original schedule update and the impacted schedule.

Constraints not required by contract must not be included in the analysis. Any constraint that is required by contract must be the least restrictive one that still describes the contractual requirement. The list of constraints from least restrictive to most restrictive is as follows,

1. Zero free float
2. Zero total float
3. Start No Later than
4. Finish No Later Than
5. Start No Earlier Than
6. Finish No Earlier Than
7. Start On
8. Must Finish
9. Must Start

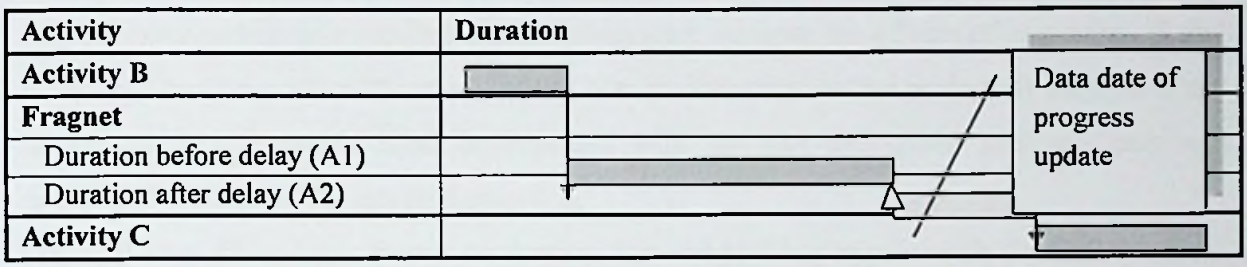
Non-contractual constraints must be removed and contractual constraints must be reduced to the least restrictive before proceeding to the next step. The resultant original schedule update will not be used for any purpose other than the TIA in question. (AACE, 2006)

STEP 3a:

Insert the fragnet into a copy of the appropriate schedule. Using the approved fragnet as a template, add the impact activities and make the existing activity adjustments as necessary to mirror the fragnet. With the duration of the delay activities set to zero, all computed and actual dates in the original schedule update must match that from the schedule which it was derived from. (AACE, 2006)

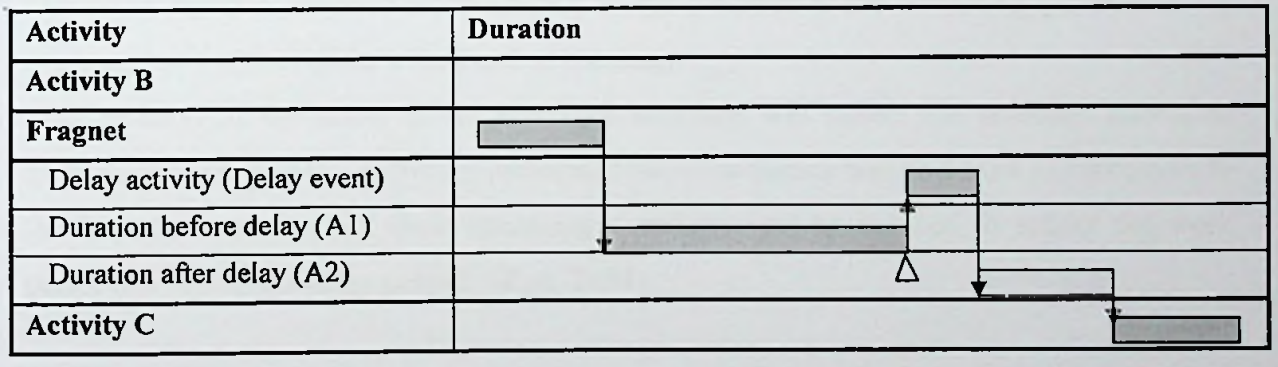
Inset fragnet in to appropriate schedule (last updated schedule before occurrence of delay event)

Schedule 1



Insert impacted activity in to fragnet

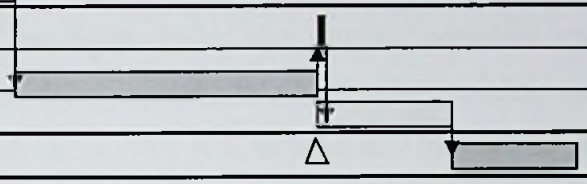
Schedule 2



Set impact of inserting the fragnet in appropriate schedule is zero. This ensures accurate progress update. Schedule 1 shall equal to Schedule 3.

Schedule 3

Activity	Duration
Activity B	
Fragnet	
Delay activity ('0' – Duration)	
Duration before delay (A1)	
Duration after delay (A2)	
Activity C	



OPTIONAL STEP 3b:

If the delay time period involved is long or if substantial mitigation of the delay has occurred, then an optional step may be made to consider the effects of mitigation.

Typical construction law requires that the contractor mitigate the effects of any delay, if that mitigation can be made without additional cost or disruption to the project. If Step 3b is not implemented, a statement must be provided with the TIA to explain why this step was unnecessary. Reasons for not implementing

Optional Step 3b includes frozen work plan, forward-looking impact analysis, and shortness of duration of the delay.

In lieu of actually redesigning the logic that was in effect when the delay occurred to that which was actually used after the delay occurred, the contractor may elect to revise the remaining duration status of every activity in the schedule to the remaining duration status evidenced at the time of the actual end of the delay.

This revision of the status to the impacted schedule will reflect the resultant effects of mitigation of the project. Activities performed out-of-sequence will still exist as successors to the impacted activity, but their remaining durations will be reduced to reflect the work performed during the delay period. (Ron, 2004)

STEP 4:

Recomputed the CPM and note a change in the project completion date.

This analysis is primarily interested in the estimated early completion of the last milestone prior to demobilization (usually substantial completion.) This is due to the consideration of Extended Field Overhead. The delay or acceleration effect to all contractual milestones still outstanding should be noted and documented.

STEP 5: Determine the amount of project delay. If the contract specifies work days, then this measurement is made in work days. If the contract specifies calendar days or lists an absolute date for completion, then the award is made in calendar days.

STEP 6: Determine the actual dates of the delay. Using the original schedule update, determine when the successor activity to the delay impact actually became a project critical activity. On schedules without negative float, the activity will be predicted to become project critical on the computed late start date. The first date of delay due to this impact will be the next day after the activity late start date. Every day after this start of delay will be labeled a delay day (counting work days or calendar days as appropriate) until the number of delay days is exhausted (Ron, 2004)(AACE, 2006)

TIA shall be applied to a project case by case. Bellow time line show how to apply deferent events in analysis.

Time line (Forensic Delay analysis)

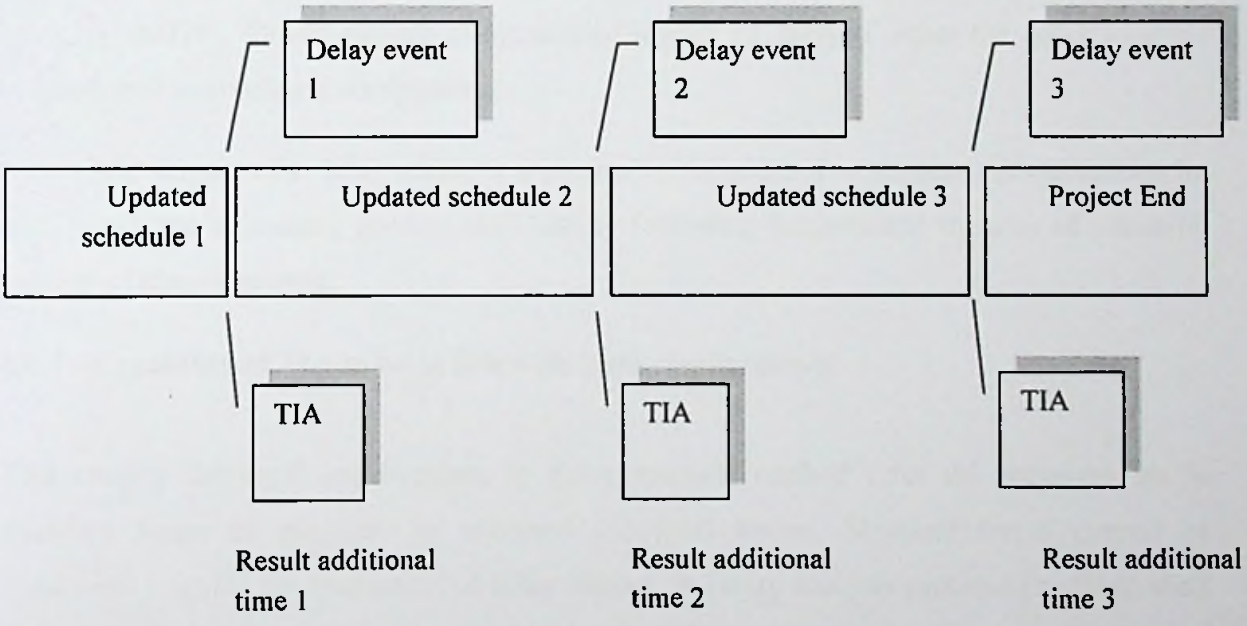


Figure 5 Time Line of TIA Method

2.5 Evaluation Criteria of Effectiveness of Delay Analysis method

Evaluation criteria of effectiveness of a delay analysis method developed based on following principals. Results of TIA method should be used in litigation process. Therefore the TIA process should satisfy, fundamental legal principals used to evaluate a time claim. In other hand TIA process has been discussed as a method of measurement of impact of delay event. Therefore it shall satisfy the principals of scientific method of measurements.

Legal context the contract law is very vague subject. As a principal of contract law, Contract should obey the party autonomy in contracting. Parties can freely come in to contracts with any type of conditions other than the conditions impact public interest or illegal substance. Therefore in principally parties could decide and agree how they consider a time claim, in their agreement. But commonly contracts follow standard form of contract. The contract should protect the other party from unjust claims and expenses. With regard to the time claim, the delay analysis method should distinguish the real impact of a justifiable claim. As example that how delay analysis method should be in line with legal requirement; the method of delay analysis should support mitigation of impact of delay. Further the delay analysis method shall encourage the mitigation.

When 'the impact of a delay event to a project' is considered as a measured parameter by TIA (tool), the measuring process shall satisfy following fundamental theories of scientific method of measurements.

2.5.1 Capability of TIA to be in line with legal requirements

This chapter the legal requirements in delay analysis method refer the requirements in Standard forms of contracts or accepted industrial norms. Standard forms consist of conditions to guide the evaluation of delay impact. A Delay analysis protocol (method) shall satisfy requirement of those standards. This research limits the industrial norms and standards which given in CSL Delay and Disruption Protocol 2002 and FIDIC condition of contract. Delay and Disruption Protocol of Construction Law is widely accepted document states many standard in analyzing the delay.

Evaluation criteria of effectiveness of delay analysis method refer to condition of contract.

Event	Principal of construction law	Reference	Relation to the Effective delay analysis
Mitigation of Delay	Contractor shall take all possible steps to mitigate delay (without increasing resources). This avoids risk of having unnecessary advantage to the contractor	SCL 11	Effective delay analysis method shall guide analyst (planner) in following way; Contractor shall revise his work programme to pursuit the best path of completion of works. Revised programme shall not exaggerate the impact of employer risk
Float	Case 1. Contractor plan all activities, all the times contractor can consume the float. Case 2. Float owns to the project, either party first delay the activity can get use of the float 2 cases depend on the nature of the contract	SCL	Effective delay analysis method shall have a capability of analyzing delay in both ways.
Compensation of Damage due to Delay	Liquidated damage is only way to recover the direct cost incur due to the delay of the project	FIDIC or ICTAD	Effective delay analysis method shall separately identify the impact of contractor liable events, employer liable event and neutral events shall

Concurrent delays	Concurrent delay will not reduce EOT Either part cannot compensate Concurrent delay	SCL 9 SCL 10	Effective delay analysis method shall calculate total delay impact Impact of separate delay events shall be differentiate Impact of concurrent delays or part of delay event which occur concurrently to other parties responsible delays shall be differentiate
Neutral events	Either part cannot compensate neutral events	SCL	Effective delay analysis method shall differentiate effect of all delay events separately
Purpose of EOT	New date of completion of project shall be established	SCL	Effective delay analysis method shall have a capacity of establishing realistic date of completion of project
Float as related to time Float as related to compensation	impact to the all paths of activities shall be identified	SCL 7 ,8	
Time of analysis	Analysis could be performed after, before or while the impact of delay event imposed	SCL	
Global claims	Global claims are discouraged		Impact of delay events shall be identified separately
Acceleration		SCL 1.18	Effective delay analysis method shall separately identified If Acceleration done contractor
Disruption	Even without total delay to the completion it reduce the efficiency	SCL 1.19	Effective delay analysis method shall identify the effect of disruption
Resource Allocation	Contractors obligation to mitigate	FIDIC or ICTAD	Effective delay analysis method shall result the resource

	delay is limited to his resources original allocation		requirement after revised schedule

Figure 6 Evaluation Criteria of Effectiveness if Delay Analysis Method Refer to the Satisfactory of Condition of Contract

The contracting parties have the certainty of knowing, the financial impact of the delay in advance and how that risk is allocated. The non-defaulting party benefits from making a recovery of damages without the difficulty and expense of proving actual loss (usually to the client's benefit) (Turner, 2009)

2.5.2 Scientific Method of Measurement

This discussion maps the *method of analysis of impact of delay event*, to the principals in scientific method of measurement. The research base is 'measurement of delay in construction project'. Project objective can be elaborate as evaluation of the effectiveness of '*method of measurement of delay in a construction project*'. Delay analysis method as a method of measurement, shall be satisfied fundamentals of scientific method.

Conclusions of the analysis of impact of delay events, should be based on observation after insertion of real world data in to the analysis. Analysis can be performed in mathematical model.

Measurement shall be invariance. In connection with any measured property of an object, or set of objects, unique number shall be assigned to measure the property. (Suppes, 1962) Mapping this scinario to the delay analysis; results of delay analysis shall be unique to the project and the delay event. Analysis shall give same unique results after any number of times it performed.

The extent to which data are affected by the factors, that idiosyncratic to the tool or person performing the measurement is denoted in part by the data order. The closer the data to the life event, the less they may be affected by the measurement process. (Krebs, 1987). In any case measurement is not 100% independent form the measuring tool or the person who is taking measurements. But results shall be reasonably independent. Further the measurement shall also be independent from the inherent properties of the measuring protocol or measuring tool as far as possible. Mapping this to our research, results of TIA method shall not be depend on subjective decisions, those planer take while analyze the impact of delay. When 2 experts perform analysis it shall give unique results.

Measuring process should not be influence or change measured object. For example, if diameter of apple is measured, the measuring tool shall not change the shape of the apple. Mapping this to the delay analysis, basic properties of the project as we identify (time, budget or quality) shall not be influenced by the delay analysis process. Those basic properties are illustrated in base line programme, baseline budget and specifications and standards of the project.

Procedures followed in delay analysis process should not results new construction methodologies which additional cost to the project which vary the budget. The delay analysis process give revised construction programme as a result, to satisfy above fundamental rule, the resulting revised programme shall only be impacted by the effect of delay event or the procedure of delay analysis. The project programme shall not be changed while delay analysis. If any change need to be done to the project programme (baseline programme), that has to be done before applying baseline programme to the delay analysis process.

The Primary concerns of a construction projects are completion task on time and on budget. Planning and Scheduling are initial activities of project life cycle, which anticipate and control above time and cost factors. It generates construction programs, baseline budgets, and milestones.

Outcomes in planning and scheduling are later become basic input parameters of TIA protocol. In philosophy of scientific method of measurement, TIA it shelf shall not influence planning and scheduling out comes. Time and budget frequently fluctuate while implementation of project task. Therefore construction programme could be changed to mitigate delays or enhance the efficiency, but not as result of internal procedure of delay analysis method.

Evaluation criteria effectiveness of delay analysis method refer to the Scientific method of measurements

Item	Principal in scientific method	Relation to the Effective delay analysis
1	Results shall not be idiosyncratic to person (subjective)	Effective delay analysis method shall give results independent from the person how perform the delay analysis
2	Results shall not be idiosyncratic to sequence (subjective)	Effective delay analysis method shall give results independent from, any number of time the TIA perform, it shall give unique results
3	Measuring process shall not change the measuring object	Effective delay analysis method shall not change budget, resource requirements
4	Measuring process shall not influence the results	Results of effective delay analysis method shall not depend on internal properties of delay analysis process.
5	Measurement of one event shall not impact of value of other event	Results one event of analysis of effective delay analysis method shall be independent form other event of analysis

Figure 7 Evaluation Criteria Refer to the Scientific Method of Measurements

2.6 Delays and Delay Events

Delay events are incidents occurs within the process of implementation of project which cause delay to the schedule. Parties are the stakeholders of the project. The impact of delay events on the project schedule is born by above parties. Delay event can be a defect of a party involved in the project or a neutral event. In view of employer the delay event can be excusable or inexcusable.

Neutral events are mostly act of god; neither party could be responsible.

Critical events are delay event which impact on the critical path of the project and cause delay to the completion of the project. Non Critical events are delay activities which not impact on the completion of the schedule.

Concurrent delay includes a combination of two or more independent causes of delay occurring within the same time frame.

Concurrent delays may be generated by the contractor or by the Employer, but if it happens that both parties are responsible, and these delays overlap then neither party can be able to retrieve damages.

2.7 Concurrent Delays

Impact of two or more delay events liable to employer and contractor can be effect on a project concurrently. In other word impact of delay event can be intercepted. As per the most of standards conditions applied in projects are not recommended to pay compensation for the intercepted portion of delay to neither party (SCL, 2010). Therefore TIA shall have the capacity to separately identify the concurrent impact and individual impact of total delay.

2.8 Technical and Contractual Constrains

There are constrains in construction schedules which based on technical aspects of activities, requirements agreed contractually and constrains limited by resource availability.

Contractual constrains

1. Date of commencement
2. Date of completion
3. Milestones set by the contract

Technical constrains

1. Curing time
2. Setting time
3. Lead time to delivery of special material or equipment
4. Availability of resources
5. Availability of specialized subcontractors

Other constrains set in the schedule are non-contractual constrains. Impact of those constrains shall be nullify while analysis the resultant impact of the delay. Technical constrains all the operations involved in construction process can be determined by simulation of construction activities. Simulation of construction operation results pure technical and resource constrains of operation. Simulation of operation always limited to one or few activities of contraction programme.

Example:

Transporting and Placing of bridge beams using mobile crane

2.9 Variable parameters (Source input data) of delay analysis

Source input data are schedules, data, facts, agreed conditions which depend on time and project. That forms the foundation for the various forensic delay analysis methodologies. Deferent scenarios in projects developed subjective to the variance of those parameters.

1. Subjective Parameters which depend on analyst of delay or other persons involved in the process of planning or delay analysis
2. Objective Parameters which are depend on the project or nature of the delay event or condition of contract

Though the variance of above parameters are subjective, reasonability of them can be assessed by following validation procedure. Both subjective and objective parameters are based on statergies of the employer, contractor or other stakeholders of the project, to achive project deleverables. Thoes stratergies set in the planning stage of the project. Planning has defined as 'trying to anticipate what will happen devising ways of achieving the set of objectives and targets' (Arkan & I, 2004).

Objective of project planning is achieving following tasks (Meagher & Robet, 2012).

1. To complete the construction within the specified time (duration)
2. To complete it within the budget, (with a profit)
3. To complete it in compliance with technical and administrative specifications.

Source inputs generally found in any delay analysis method

2.9.1 Construction programme (Baseline programme)

Construction programme prepare after determines sequence of activities of the project. Construction programme includes time duration, relationships and constrains which result the total time taken for the completion. Above factors determine in planning stage are assumptions which come through expert judgments.

Contractor has freedom to schedule his activities within employer milestones. Baseline construction programme is the accepted construction programme agreed by all parties.

Logical construction programme of same project can vary depending on level of breakdown of activities, assumed construction methodologies, level of dependencies. Construction programme is very dynamic (Songul, 2010)

1. More elaborated programme and less elaborated programme (brief programme)
   More elaborated programme has lower level of work breakdown; with this lowest level of breakdown we can exactly identify impacted part of the project.

2. Relationship between activities – Some planners illustrate all relationships between activities even they are not critical. (In case of delay in a activity noncritical relationship might become critical)

Frequent revisions to the construction programme shall be done to maintain it in live stage. Live programme accepted by parties shall always be at the project.

Construction programme to be successfully used in delay analysis as baseline programme, following validation shall be done.

How to validate the of baseline programme

1. Ensure that all activities have at least one predecessor, except for the start milestone, and one successor, except for the finish milestone.
2. Ensure that the full scope of the project/contract is represented in the schedule.
3. Ensure that the calendars used for schedule calculations reflect actual working day constraints and restrictions actually existing at the time when the baseline schedule was prepared.
4. The level of detail is such that no single schedule activity (other than a milestone activity created solely for the purpose of payment) carries a contract payment value of more than one half of one percent (½%) of total contract payment value per unit of activity duration, and no more than five percent (5%) of total contract payment value per schedule activity.
5. Create separate activities for each responsible party.
6. All controlling and non-controlling constraints shall be logically established.
7. If the description of the schedule activity is too general or vague to properly ascertain the scope, the schedule activity should be subdivided into detailed components using other progress records.

(RPFSC 2011)

2.9.2 Progress Update

Progress update always refers to a data date. In delay analysis data date shall be a nearest date to a date of occurrence of the delay event. Accuracy and reliability of progress update data is very important though it never be perfect.

Keeping records on progress updates throughout the project are very important data in Delay analysis. Those details can obtain from daily, weekly or monthly progress reports.

Progress update data can be validated in following procedure.

1. Ensure that the data date is set equal to or later than the events and impacts that are to be evaluated in the analysis.
2. Ensure that all activities to the left of the data date have actual start and completion dates.
3. Ensure that all activities to the right of the data date do not have actual start or finish dates.
4. Contractual dates such as notice-to-proceed, milestones, and completion dates should be accurate to the exact date. Should those dates be subject to dispute, the justification for the selection of the dates should be clearly stated.
5. If the description of the schedule activity is too general or vague to properly ascertain the scope, the schedule activity should be subdivided into detailed components using other progress records.
   (RPFSC 2011)

2.9.3 Condition of Contract

Conditions in the Condition of contract shall govern the delay analysis process. Therefore in view of scientific analysis it is a source data.

There are required outputs from the delay analysis, to make decisions in line with clauses in deferent conditions of contract as agreed by parties. When some decisions are taken while the delay analysis process, clauses of condition of contract agreed by parties shall be referred.

Example; when a particular condition of contract state concurrent delays as neutral events, the delay analysis method shall give distinguish results of impact of delay events concurrently implied by parties. Standard forms of contracts used in Sri Lanka are generally published by FIDIC and ICTAD. There are many versions like FIDIC 1985, FIDIC 1994, FIDIC Harmonized edition, SBD2 2003, SBD2 2007 etc. All of those documents have Extension of Time clauses and in some other clauses give right to claim additional time.

2.9.4 Source input data specifically applied in TIA Method

Following parameters specifically apply in TIA method are subjective to the person perform the analysis or the situation. The planner shall have a liberty to take decisions based on his expert judgments and experiences.

2.9.5 Nature of fragnet

Parties involved in the project shall agree upon fragnet. Fragnet is set of activities linked to the delay event, which can be broken in to the lower level as the impact of delay event can illustrate. Relationship between fragnet activities indefinite but when we insert the impacted event act of fragnet highly depends upon those relationships.

2.9.6 Appropriate Schedule

Accuracy of appropriate schedule depends on sequence of progress update at the site and record keeping. Depending on the situation at the site, appropriate updated schedule may be ahead the schedule or behind the schedule. TIA shall assess impact of both conditions.

2.9.7 Time of analysis been done

Delay analysis can perform with the occurrence of delay or some time later. Term forensic analysis refer the analysis perform after the impact. Availability of progress update by the occurrence of delay event is difficult.

2.9.8 Level of mitigation of delays

Contractor is fundamentally liable to mitigate employer delay. Many standard contract documents says contractor shall take all necessary measure to mitigate delays unless it is financially impact contractor. The financial impact may be either cost to the contactor of impact on the cash flow.

2.9.9 Selection of best path of working

This is also relevant to the level of mitigation. Question raise here is whether the planer (contractor) has selected the best sequence of activities to pursuit the completion. Best path of working is most economical, fastest and low risk work methodology.

2.10 Effective Cases of TIA

TIA gave deferent results when analyzing deferent incidents of the project. Those incidents occur with the variance and deferent combination of above parameters. Resulting possible combination with the variance of above parameters are infinite.

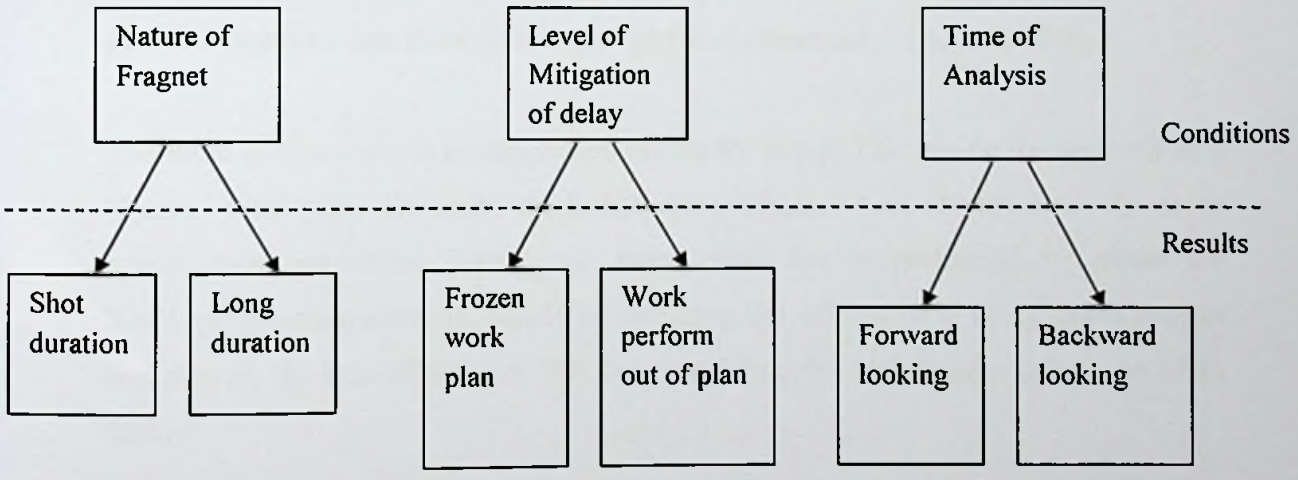


Figure 8 Different Parameters of Delay Analysis Process

In some cases TIA can be easily perform depending on condition agreed by parties.

1. Short duration of delay. In general, TIAs are intended to model delays of less than one month. If longer periods are considered, then Optional Step 3b in the procedure must be considered. (AACE, 2006)

2. Frozen work plan. If the Contractor has not been given remediation direction and is not able to redeploy his work force in order to keep it in readiness for resumption of work, then the work plan is said to be 'frozen 'and the assumptions inherent in a TIA remain valid. (AACE, 2006)

3. Forward looking. Delays planned to occur or occurring at the present time are better subjects for a TIA than those that have already finished. (AACE, 2006)

But in following nature performing TIA is difficult.

1. The less linear (or serial in nature) the work plan. Work plans based upon resource considerations are more easily adjusted without detriment to the project completion or planned expenses than those based upon physical constraints. (AACE, 2006)

2. The more mitigation was accomplished during the delay. This can be the opposite of a 'frozen' work plan. The more work that was performed 'out of-sequence', the more construction restrictions waved, the more effort that is performed by either the Employer or contractor on behalf of reducing the effects of a delay upon project completion, the less effective a TIA is in modeling the effects of a delay. (AACE, 2006)

3. The longer the time period between the schedule update and the start of the delay, the more conditions will have changed between the planned work schedule and the actual work schedule before the time of the delay. (AACE, 2006)

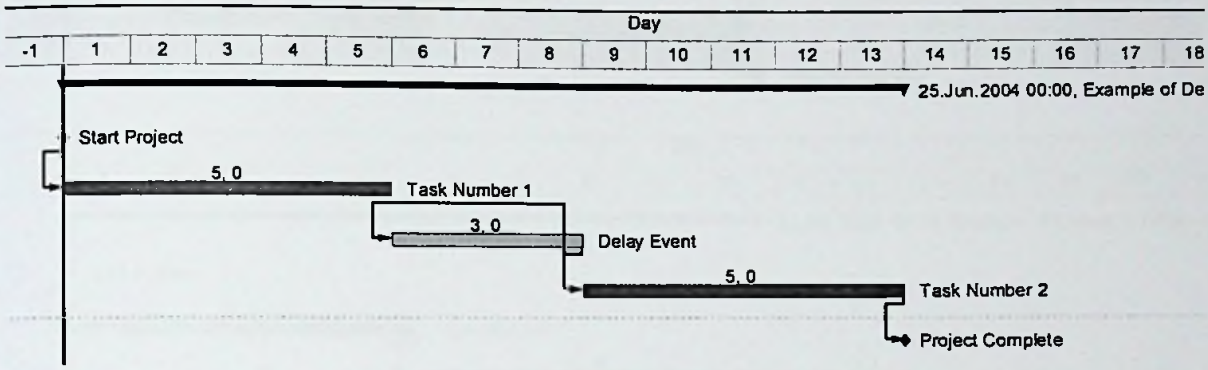
Focus of the research is to find out how effectively TIA responds above cases. To assess the respond, the respond shall be visualized in from of comparable.

2.11 Illustrate TIA

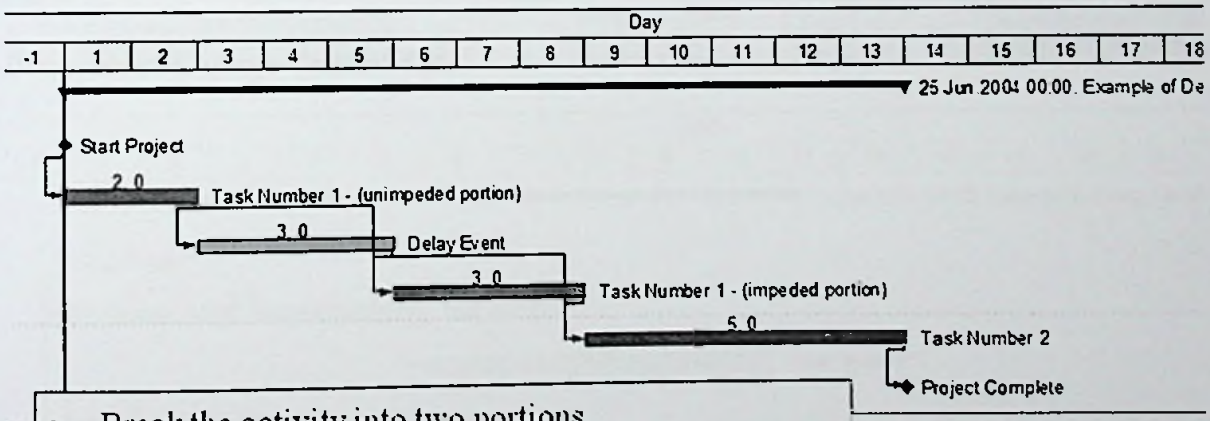
2.12.1 Illustrated in Gant Chart

In view of contractor or the employer the presentation of claim or presentation of rejection of claim is important as much as the procedure of the analysis. Bar Charts are common method of illustrating activities their relationships and actions in schedule.

Delay between activities

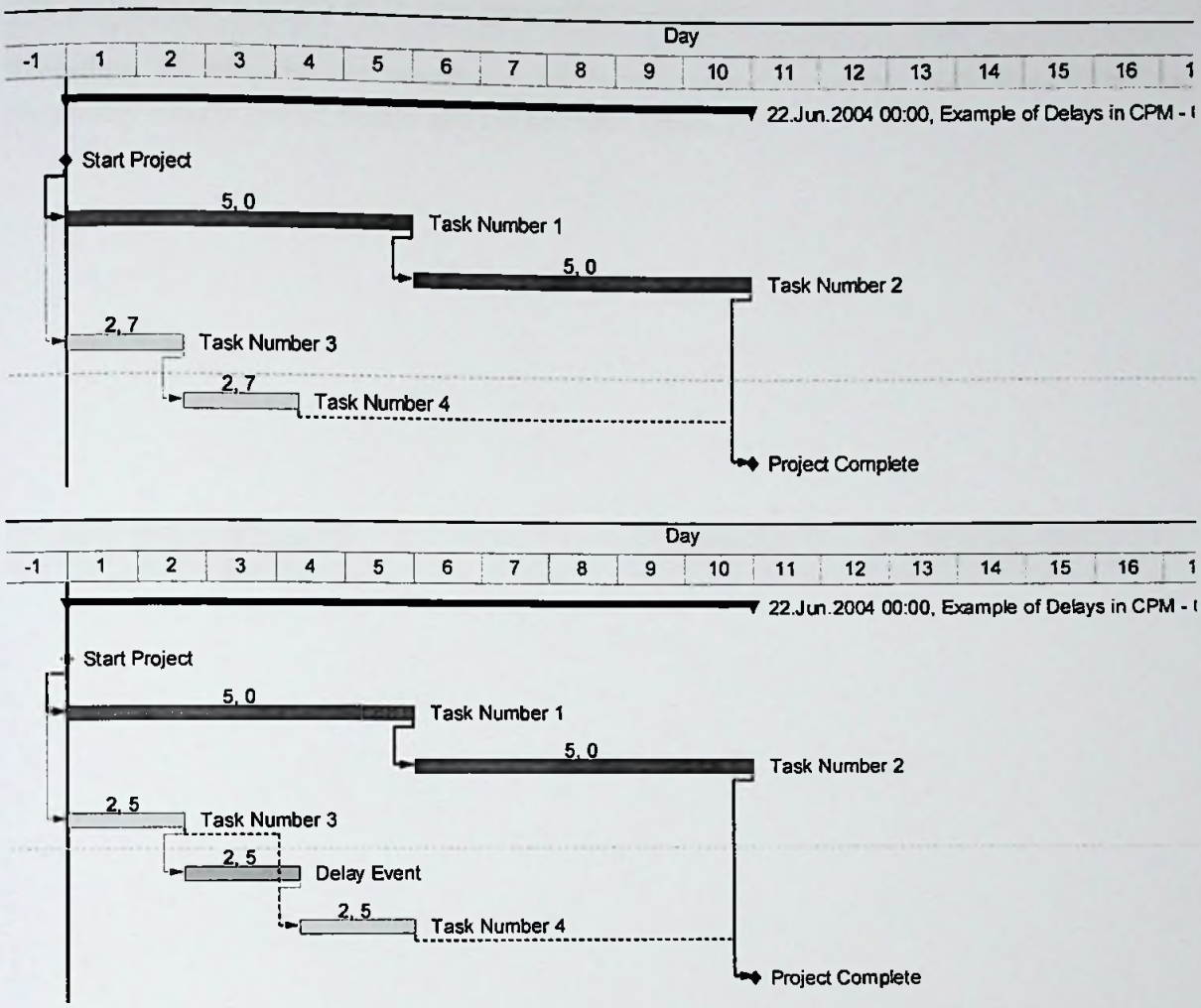


Activities delayed in progress

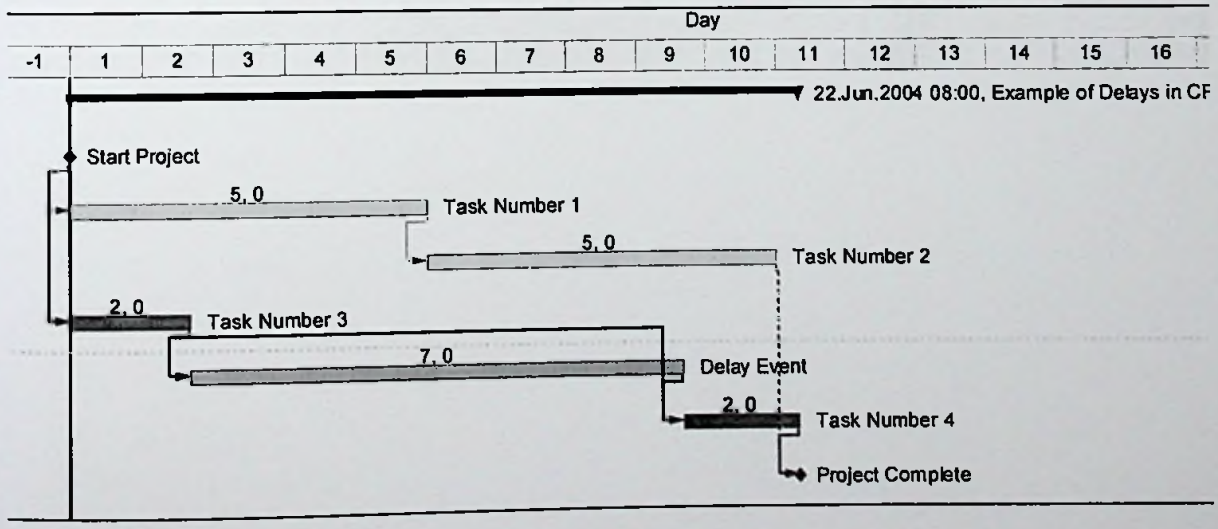


- Break the activity into two portions
  - Unimpeded & impeded portion
  - Total duration should be the same as the original
- Insert the delay event between the two portions

Delays and Floats



Delay event Change Critical Path



(Michael, 2004)

Figure 9 TIA Method (Example)

There are some modern methods to illustrate schedule like 4D model. But they are not established in the industry as famous gang chart method.

Recording of delay by the occurrence of delay is very important. Following forms are commonly used to record delays and initiate time claim.

2.12.2 Time Impact Evaluation Forms

Delay analysis which preform with the occurrence of delay event can be analyze in following format.

TIME IMPACT EVALUATION

PROJECT: JOHN DOE TIE #: 2

PREPARED BY: J. J. O'BRIEN DATE: 1/31/95

DESCRIPTION: STRUCTURAL STEEL DELIVERED IN 123 WORK DAYS RATHER THAN SCHEDULED 80

ACTIVITIES AFFECTED:

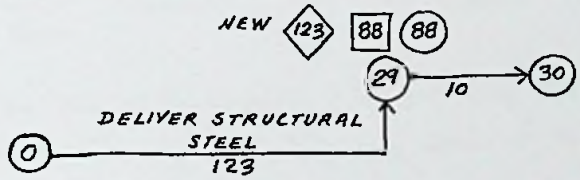
29-30 "ERECT STRUCTURAL STEEL"

TYPE OF IMPACT:

INCREASED DURATION: 43 AMOUNT: _____

DELAYED DATE/SUSPENSION OF WORK: DELIVERED @ DAY 123

FRAGNET:



EVALUATION/RESPONSIBILITY:

STEEL DELIVERY HAD 8 DAYS FLOAT.
THEREFORE DELAY IS (123 - 88) = 35

OWNER REQUIRED CHANGES. RESPONSIBILITY AS FOLLOWS: DESIGN CHANGES 15 DAYS
FABRICATION CHANGES 15 "
OWNER 30
FABRICATOR 5

Time Impact Analysis Form
Michael E. Stone PMP

Project: Beltway 8 Overpass TIA No 3

Prepared by: Mike Stone Date 11/3/03

Description of Time Impact Encountered: (When did delay begin? What happened? When did delay end?)

Shop drawings for pre-cast beams was not returned promptly delaying fabrication & delivery of beams.

Activities Affected: (list activities impacted)

1020	Prep Shop Dwgs	10 day O.D.	Ø T.F.
1030	Review Shop Dwgs	10 day O.D. → 35	Ø T.F.
1040	Fab & Deliver Beams	30 day O.D. → 28	Ø T.F.
1050	Set Beams	10 day O.D. → 10	Ø T.F.
9900	Project Completion	01 May 05 → 25 may 05	

Type of Impact:

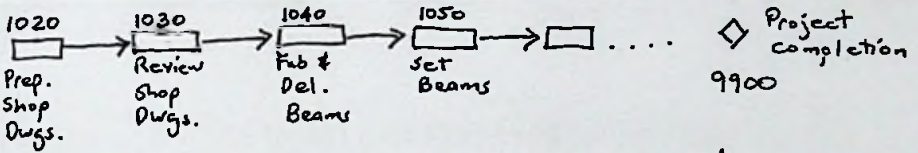
Days of Delay 25 Project Completion Delayed (Y/N)

Cost of Impact # 106,250.- New Project Completion Date 25 May 05

25 days extended O.H. cost ($1,500/day)

25 days standby time for beam crew ($2,750/day)

Fragnet: (sketch logic of portion of schedule impacted)



All activities on the critical path. Delay of shop drawings delayed setting beams thereby impacting end date of the project.

Evaluation / Responsibility: (describe who is responsible)

Per contract & schedule, engineer was to return shop drawings within 10 days of submittal. Shop drawings for bridge beams took 35 days to go through engineers office therefore 25 days of delay is attributable to late shop drawing approval.

Responsibility: Engineer - failed to review submittals promptly.

(Michael, 2004)

Figure 10 Illustration of TIA Calculation at Site Level

2.12.3 Illustrated in 4D model

4D modeling is graphical model to illustrate activity schedule which enable to handle more complex situations.

Project schedules alone are not detailed enough for performing certain process analyses. Some parameters used for planning are lost once a schedule is created and some schedules are not conducive to considering "what-if" scenarios (Kevin, 2008).

4D modeling solves many of these problems by enabling project teams to simulate the virtual construction of a project.

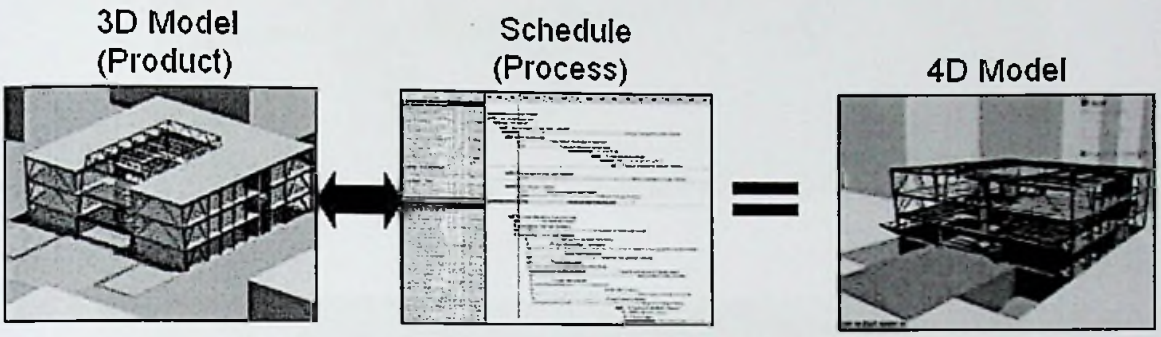


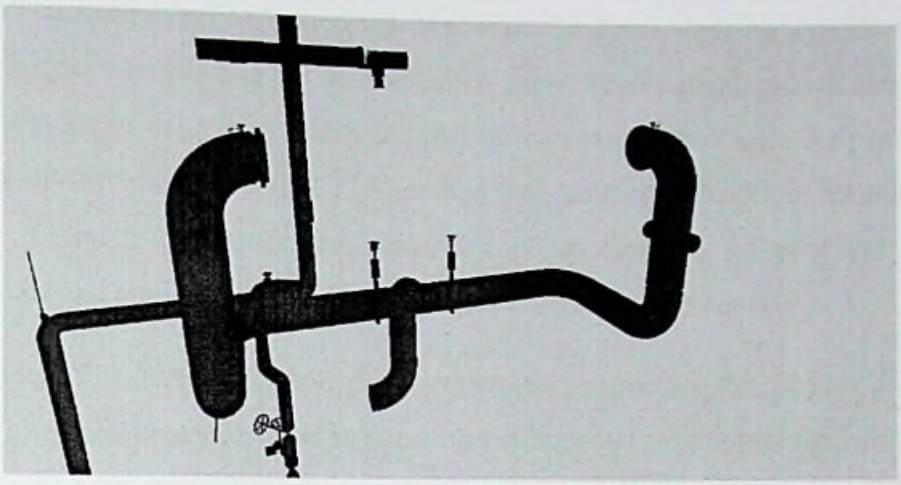
Figure 11 4D Model to Illustrate Delay Analysis

4D modeling has been used on a myriad of project types, including transportation, general commercial, office and retail complexes, biotechnology, new and retrofitted hospitals, theaters and museums, industrial, manufacturing, heavy civil, and financial facility asset modeling. 4D modeling has been used during all project phases, from pre-construction through post construction.

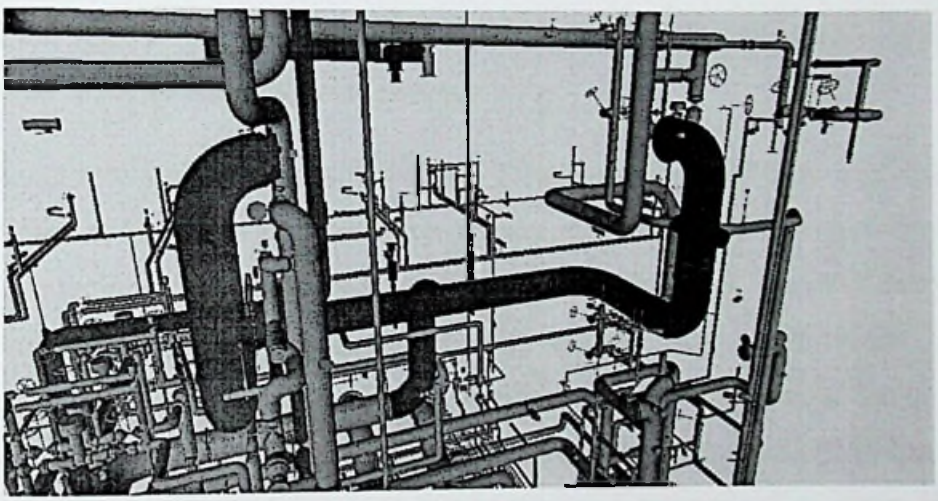
Illustrate TIA in 4D model

Integration of 4D Modeling Tools

This section details the steps from the above list that can benefit from the integration of 4D modeling.



(3D Fragnet)



(Insert 3D fragnet in to 4D model)

Figure 12 Illustrate Fragnet in 4D Model

2.12 Summary of Literature Review

A Project has a defined scope, a time line and a budget. Schedules or the critical path analyze is a tool developed to plan how to achieve those tasks. Occurrence of delay events are unavoidable. When such event happened the impact of the event shall be identify either to mitigate the impact or compensate the non-defaulted party. Few methods which can be used to analysis the impact of delay was briefly studied in literature review with their merits and demerits. Literature review understood TIA method as a protocol which can formulate in a flow diagram. Research objectives are evaluation of applicability in practical context, accuracy of results and compatibility with standards and legal requirements.

This research identifies TIA as method of measurement to measure the impact of a delay event. Method of measurement shall be in line with fundamental principles of measurements. Relationships among the elements within the various delay analysis methods and their inputs and their results are revealed in the literature review. Parameters impact on results of analysis, Data use in Delay analysis, Delay analysis methods with their strengths and weaknesses were reviewed in literature review.

Then the focus was on Time impact analysis. Detail procedure of TIA was discussed. In detail procedure of TIA, the steps were taken to minimize the impact of as non-contractual or technical assumptions in planning stage on its results. Illustration of impact of delay events is also important. Capability to illustrate all delay events gives good results. There are innovative techniques in illustrating activity schedule. Construction programme or schedules are commonly illustrated in mathematical and data base environment like MS Project, Open Workbench or Primavera. Delay events were found and categorized as given in standard condition of contracts and relevant documents. Delay event can be illustrated as fragnet (small segment with activities and relationship).

Most of pervious researches done in this context are based on case studies and secondary data analysis. Therefore those conclusions cannot be generalize. When variable parameters of the delay analysis process is considered there are infinite number of combinations. Those combinations generate deferent incidents in the project. Therefore case study research or secondary data analysis research cannot give reasonable justification on effectiveness of delay analysis technique.

Chapter 3 - Research Methodology

3.1 Overview

Methodology is a framework of tools and procedures which use to inquire the problem in the research. (Jeniffer, 2011)

Selection of methodology for a research shall be initiated with following discussion. (Burton, 2002).

1. Why the study was designed by the researcher in that way?
2. What were the questions the researcher was asking?
3. How the researcher ensured that confidence could be felt in the data gathered?
4. How analysis of those data to be done?

As stated in objectives, This reseach has been designed to eveluate the effectivenes of TIA method through following criteria.

3.2 Outline of the Research

Following figure brief, how this report illustrate the development of research and findings of research.

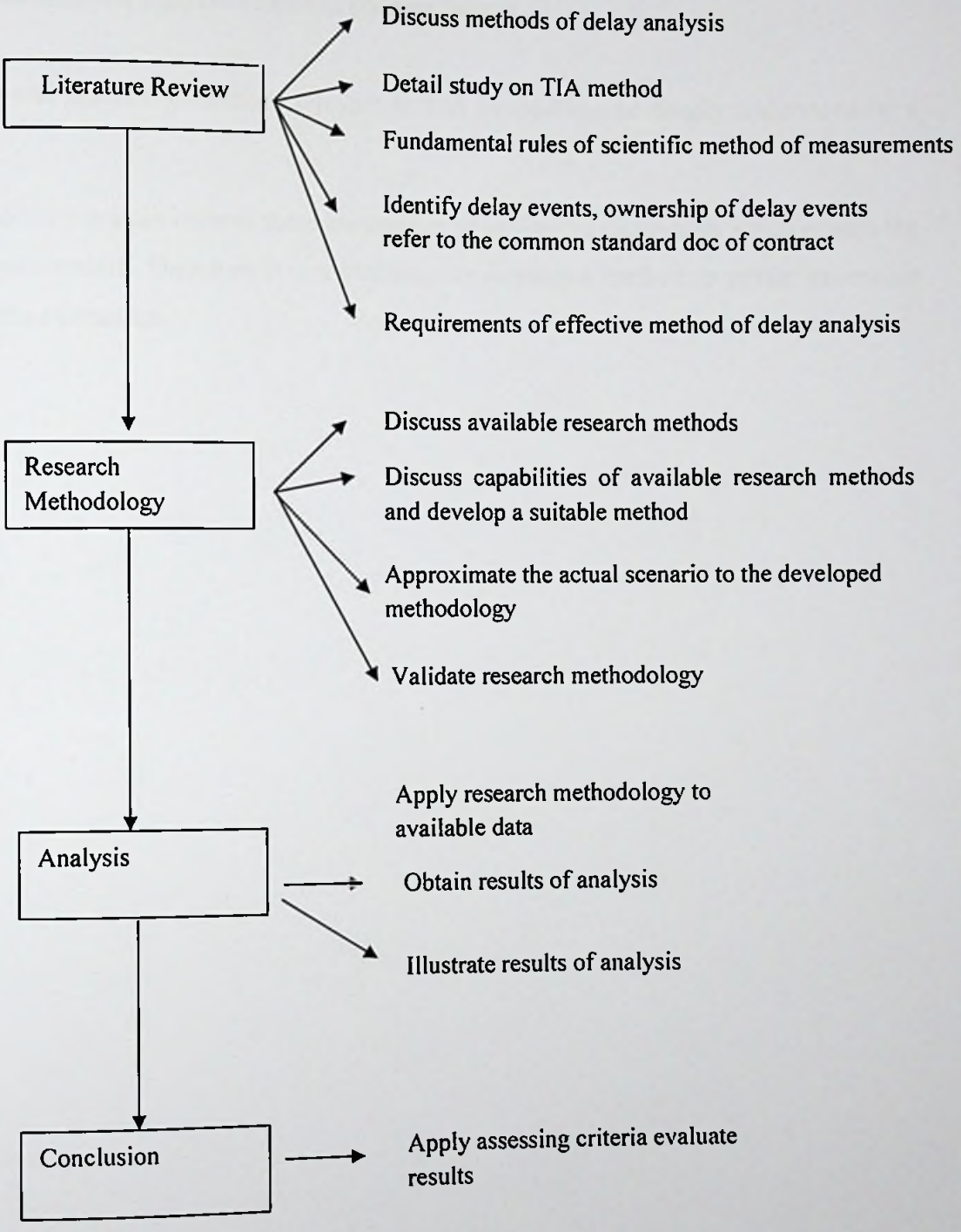


Figure 13 Research Flow Diagram

TIA resullts, which can be generalized (resonable for every case) for deferent conditions in projects shall be obtained. Compatibility of thoes results with the eveluation criteria shall be assessed.

Eveluation criteria has been developed in litrature review.

Parameters and deferent conditions relevant to TIA method can be deeply understood by a case study.

As discussed in literature review, there are number of subjective parameters which govern the delay analysis results. Therefore it is a challenge to develop a method to obtain generalize results for the evaluation.

3.3 Research Strategy

Research plan is to assess the effectiveness of TIA reference to assessing criteria developed in literature survey. Assessing criteria developed on 3 fundamentals.

1. Principals of scientific method of measurements
2. Compatibility of TIA method with fundamentals in contracts law and capability of method to obtain answers required to take decision when evaluating a time claim
3. Compatibility of TIA method with good practices in the industry

Development of research strategy starts with the given task and information available to drive to the research objectives.

The analysis of the research will have 3 major phases.

1. Obtaining results of TIA under Different circumstance
2. Analyze those results with developed assessing criteria of effectiveness
3. Ilustrate the results

TIA results under different parameters

Assessing criteria of effectiveness

Illustration of responds of results to assessing criteria

Figure 14 Research Methodology

Case study or simulation can be performed to obtain results under different delay events of a project. Deferent circumstance represent by different input parameters to the TIA method as

described in literature review. A methodology with a combination of simulation and case study is planned to use in the research. This research deal with complex protocol (TIA method) generally applied in highly volatile project environment. Results of delay analysis method are highly dependent (subjective).

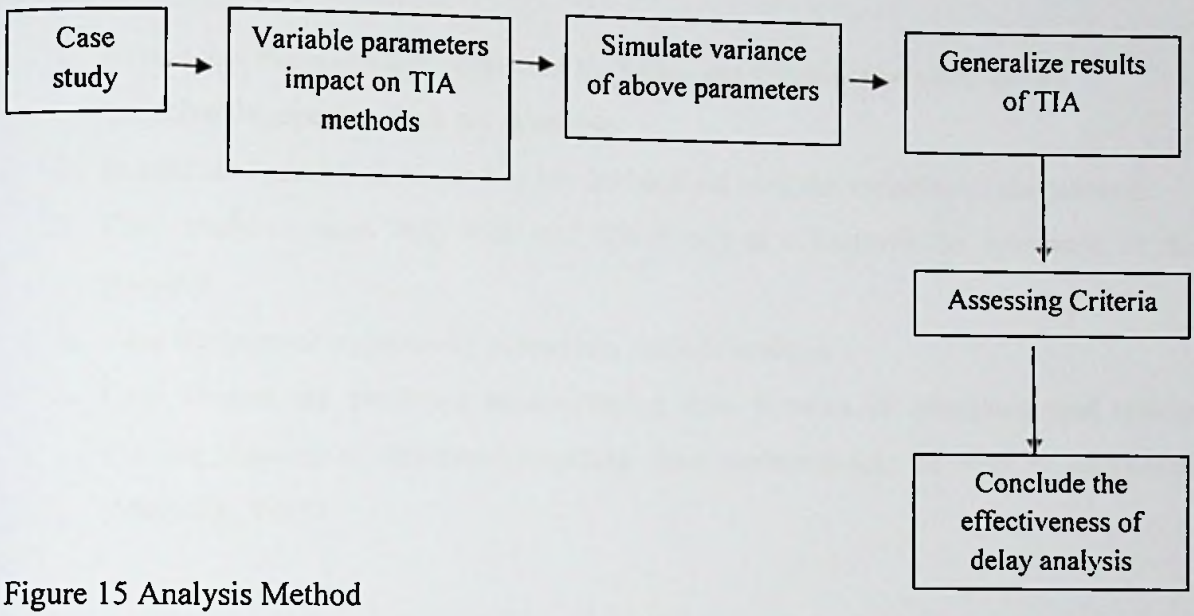


Figure 15 Analysis Method

Therefore results obtained by a case study is not reasonable for generalize conclusion.

Case study can be used to identify deferent parameters of TIA method.

TIA results are obtained by simulation for variable parameters.

Then results of TIA can be illustrate with the variability of parameters.

Though a single generalize result is not obtained, the behavior of TIA results with the variability of TIA parameters can be obtained.

That illustration can be assess by the developed assessing criteria.

Conclude more generalized conclusion over the effectiveness of delay analysis method.

3.4 Research Methods

3.4.1 Case study Method

Case study is research method with overall objective of gaining deep understanding of chosen research phenomena (Daniel Hellströma, 2006). Case Study research is suitable under following circumstance.

1. Researcher focus towards numerous variables and relationships covering all conceivable aspects which are available.
2. In case study research researcher has less control over the variables of the research
3. Case study research deal with real life data and it improve the relevance of the research
4. Case study gives opportunity to analysis real life settings.
5. Case studies are preferred in developing new theories or extending and testing existing theories in situations requiring deep understanding of what is happening (Meredith, 1998)

Case study research has following criticisms.

1. Paucity – insufficient data to generalize
2. Ambiguous of what case study designs was chosen, what protocol was used, how cases were selected, how data was collected and analyzed and how results were validated

Complexity of TIA method requires an in-depth study since there may be numerous interpretations and explanations for the observed outcome.

3.4.2 Simulation Method

Simulation develops an analytical approximation to model a system to measure performance (Settles, 1997). Simulation can provide superior insight into complex theoretical relationships among constructs, especially when challenging empirical data limitations exist (Davis, et al., 2007). Simulation is also defined as a method for using computer software to model the operation of 'real world' processes, systems or events (Law & Kelton, 1991). Computer software model is faster to analysis.

Recall the findings of literature review over the delay analysis methodology; the TIA method was categorized as model method, which approximately models the actual delay event and the impact of delay event to the project. Development of simulation model step of the research will combine the formulated model for TIA in flow chart and model developed simulate delay event.

3.4.3 Combine research Methodology

Combine method with the case study and the simulation will be developed to proceed with the research. Simulation will be followed by a case study.
Research objectives are achieved through the combine method in following steps.

- Case study
  - Get insight in the TIA method
  - Discuss how TIA method comply with condition of contract and other industrial requirement
  - Identify various conditions found in the TIA method which impact the results
  - Derive variable parameters other than technical and contractual constrains governed above situations

- Simulation
  - Simulation will measure TIA results under variability of TIA method parameters established in the case study
  - Understand the situations which raised the variability of above parameters and discuss the applicability of method in deferent situations.
  - Assess results reference to assessing criteria

3.5 Development of Case study Approach

Case selected for the case study will be a project with various delay events.

1. Availability of records of delay events and progress
2. Submission and analysis of delay claims
3. Systematic evaluation of delay claims

Actual delay event analyzed based on TIA method was very few in Sri Lankan experiences; Deferent conditions of contract draft based on different procurement guide lines of local and foreign institutions were taken in to consideration. Very few institutions as the employer of the projects has been included the delay analysis criteria in to their conditions of contract.

1. USAID – Condition of contract draft by USAID in collaboration with CH2Mhill has included basic critical path analysis method. Delay analyze has to be done in prospectively and submit with each interim claims.
    a. Development of Vocational Training College in Tsunami affected areas

2. JICA – Conditions of contract draft based on procurement guidelines of JICA has record keeping system, records could be used for the base of delay analysis
    a. PRDA road development projects

3. World Bank - Conditions of contract draft based on procurement guidelines of JICA has record keeping system, records could be used for the base of delay analysis
    a. PRDA road development project

4. American Red cross – Contract management system of American Redcross and Cardno international systematically evaluate delay claims
    a. Sewerage collection and disposal project in Republic of Maldives

JICA funded road development project (CP1NE1) in Nuwara-eliya district.

This project was selected for the case study. It has experienced various types of delay events which implied deferent end results. The contractor based on TIA method in his submissions of time claims.

3.6 Development of simulation for the impact of delay event

Approximate model shall be developed to simulate the project, TIA procedure and the impact of delay event. Basic formula of TIA method illustrated by a flow diagram was developed in literature review.

The project programme shall be inserted in to the TIA formula. The program has set of data with interrelationships required to process the TIA formula.

1. Time line
2. Construction activities
3. Logical relationships between Activities
4. Represent the impact by the delay events

The project programme developed base on critical path programme like MS Project or Primavera.

CP analysis software shall have following facilities.

1. Updated programme
2. Insert delay event as fragnet
3. Reschedule balance work (See Annex case study)

Formulate the TIA illustration

Then the problem raised is whether the actual illustration of delay analysis can be used as the model in simulation.

3.6.1 Model TIA in with multiple variables

TIA procedure formulated is very complicated and has both objective and subjective variables. Simulation shall be done iteratively to measure the response of results to the variability of input parameters.

Actual illustration of results of delay analysis shall have followings;

Programme has number of activities

Activities have complicated inter relationships

Activities have number of dependencies

Activities have multiple variable parameters like progress levels, constrains, time of occurrence (whether act simultaneously).

Simulation need to assess the response of CP to variable parameters.

Insert input parameters iteratively in to the system and analyze the response is not possible in complicated system in above nature. The complexity of illustration of analysis can be study in case study.

Therefore it is required to develop a model comprise with simple data set which can simulate in the TIA formula.

3.6.2 Model TIA in a Critical Path Programme

TIA is forward looking analysis which shall be started analyzing the impact from the past event to the more recent event.

Formula developed based on MS Project in case study shall also be irreversible. Operation Reschedule Activities in MS project cannot be use iterate input parameter and observe results. Liner method shall be developed to update the progress and reschedule balance work which can be tested iteratively.

3.7 Match critical path programme to develop TIA simulation model

Refer to the 3.5.1 and 3.5.2 to simulation shall be developed to model the TIA method and estimate the response of the simulation with the variability of input parameters. TIA model with number of activities and interrelationships shall be simplified to make suitable to perform simulation.

Simplification of Simulation model shall satisfy flowing requirements.

1. The number of input parameters shall be controlled (number of variables shall not be increased up to indeterminate level).
2. Behavior of activities inside the system should be seen
3. Simulation models representing the impact of deferent delay events could be combines to illustrate the combined effect of delay events
4. CP Programme based on critical path computer package can be used for simulation model but irreversible operations which shall not be applied to reschedule balance work. (Reschedule balance work in MS Project is irreversible and it cannot applied for simulation).

Those advantages of finite element method principals are perfectly match with expected requirements in simplification of TIA method.

3.8 Development of Model

When a project plan updated for a particular date, activities behind the data date is constant. Activities lies ahead the data date is variable. Based on this principal following model was developed. Entire Programme as updated on particular date can be simplified in to several paths which are critical, nearly critical and non-critical.

- Delayed Path has a delay event. An element represent a line of activities completed before occurrence of delay event and an element represent a line of activities after the effect of delay event was defined.
- Above model is unique for a 'date of occurrence of delay' or the 'date of progress update in TIA'. If progress update on another date is considered the line of activities can follow another path (see CP analysis)
- Either other path or delay path can be the critical path

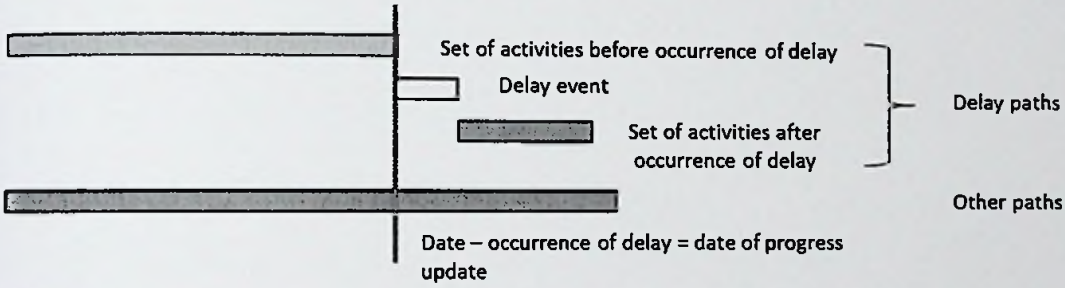


Figure 16 Simplification of Delay Analysis Method

Delay Event

- Delay event can be neutral, contractor responsible or Excusable in simulation it is possible to model three types of delay event and analyze their impact concurrently

Progress Update

- Line of balance activities are set reference to the progress

Assemble paths

- Paths can be simply assembled as sub projects in MS Project environment.
- When 2 or more path assemble only 1 path shall be variable other paths shall be remain constant.
- Multivariable analysis can be done changing parameters of sub project and measuring impact of assembled system. But two paths cannot vary simultaneously because path is valid only for a particular date

- One path shall keep constant when other path changing

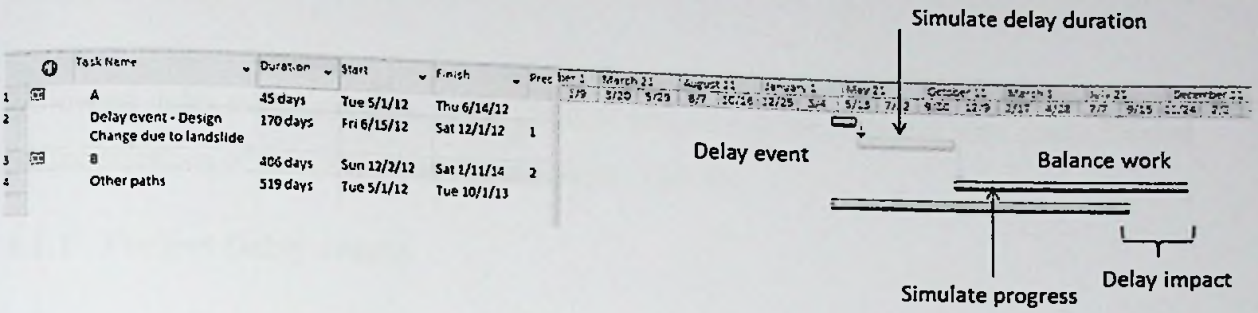


Figure 17 Model Simplification of TIA Method in MS Project for Simulation

Chapter 4 - Analysis

4.1 Case Study

Following delay event impacted to the CP1NE1 project was considered in case study. Reason for the selection of this project has been described above.

4.1.1 Project Delay events

Both Contractor and Employer agreed to consider following events as acceptable delay event liable to offer legitimate extension of time to the project

1. Landslides happened at 6+000km to 6+400km work stopped that area until employer give a new design on 14/06/2012
   30/11/2012 employer instructed to omit construction of that particular stretch

2. Hard rock found at culvert construction locations. There was no time allocated for rock blasting in original programme. Rock blasting is not variation to the contract.
   Pertaining to the condition of contract, contractor instructed to revised the programme without changing original date of completion including rock blasting in the programme
   Additional quantity beyond the limit of BOQ shall be treated as variation to the contract.
   Contractor informed 23/10/2012 BOQ Quantities for rock blasting completed
   Quantity of rock blasting varied 250% from the original BOQ amount

3. Rain adversely affect to the project.

   Analyzing with last 10year rainfall data following dates are agreed as adverse weather

Start	No of days	No of days impact
1/6/2012	2	3
10/6/2012	1	2
11/7/2012	1.5	2
20/7/2012	3	5
5/8/2012	2	3
8/10/2012	2	2
12/10/2012	1	1

4. Flood experienced from 15/05/13 to 20/05/13. Land slide occur on 1km – 2+200km. 500m asphalt laying damaged.

Asphalt damage	500m
Base Washout	800m including asphalt damage area
Sub base damage	300km

Figure 18 Case Study

5. Landslide 25/05/13 and 5 days to remove landslide and 10 days to repair
6. 11/11/13 work stopped for 2 days due to public protest
7. 15/10/13 to 25/11/13 work temporary suspended due to public protest
8. 26/11/13 to 15/12/13 work suspended in 5km to 10km stretch
9. 50% work delayed from 20/12/13 to 15/01/14 due to delay in payment
10. 100% work suspended from 15/01/14 to 10/02/14 due to non-payment
11. 10/02/14 to 15/02/14 resume work

4.1.2 Delay Analysis

TIA is modeling method which approximately models the impact of delay event. The MS Project environment is used to model the impact of delay event. Results of delay analysis process has been summarized below.

Event 1

Design change land slide

Inputs

1. Original date of completion 1/10/2013
2. Appropriate progress update up to 31/5/2012
3. Reschedule activates new date of completion 1/10/2013 not changed due to delay of activities
4. Fragnet

Activity	Start	Finish	Predecessor	Successors
Work hold due to land sliding in section (6km – 6+400km)	14/06/12	30/11/12	Excavation and earth work of 5km-10km stretch	

Analysis

5. Insert fragnet to appropriate updated schedule
6. No change in date of completion of any activity; calculated dates of 5km – 10km stretch do not match the original. Reduce delay duration to match with original dates of programme to see how much of duration can be accommodated with in the original programme without changing.
7. Insert agreed durations.
8. Redesign programme to have optimum respond (divide master programme 5km-10km stretch in to 2 phases)

   Reduce time durations to complete 5km-10km (except 6km-6+400km)

Output

1. No additional time due to this reason because the delay event is not in path of analysis.
2. with the impact of delay event sequence of programme changed

Event 2

Rock blasting for structures

Inputs

1. Variation occurs when quantities of rock blasting as per the BOQ completed
2. Agreed date of completion as at variation occur is 1/10/2013
3. Appropriate progress update as at 23/10/2012. Appropriate available progress update is on 01/10/2012
4. Reschedule activates new date of completion 1/10/2013 not changed due to delay of activities
5. Parties analysis resource requirement and available resources to perform rock blasting and agreed to 120days to complete rock blasting in 1 stretch of road

6. Accepted Fragnet

Activity	Start	Finish	Predecessor	Successors	Note
Rock blasting 0km-5km	1/10/12	29/11/12	Excavation for structures	Culverts Retaining wall	Parties agree 30days for rock excavation
Rock blasting 5km-10km	30/11/12	28/1/12	Excavation for structures Rock blasting 0km-5km	Culverts Retaining wall	Parties agree 30days for rock excavation

Rock blasting 10km-15km	29/1/13	29/3/13	Excavation for structures Rock blasting 5km-10km	Culverts Retaining wall	Parties agree 30days for rock excavation

Analysis

7. Reduce duration to match all calculated dates with original schedule
   Assume that is the rock blasting duration, which can be accommodated within the original programme without imposed a variation to the contract.

8. Delay period is not very long
   4b No need to reduce dates at end of the delay duration to mitigate delays
   OR
   4a Redesign activities to have optimum respond

9. Insert agreed durations

Output

As per the original programme construction of road way is independent from the construction of structures. Structures are on the critical path and when contractor lagging behind the road way construction, the impact of quantity exceed in rock blasting lay in concurrent with road way construction delay.

The Critical decision is whether the initial assumption of road way can constructed independently to the structures is correct, if it was decided it was not correct programme shall be redesigned.

Contractor informed exceed of quantities on 23/10/2012 before that the quantities exceed were within the limit of the contract.
Project has delayed and extended beyond the date of completion due to poor work progress

Event 3

Adverse weather condition

1. Consider adverse weather is a single event commence from the start of the project which reduce the productivity of the project.
2. Reduce the productivity by assigning non-working days in the project calendar
3. Progress update from the commencement of the project – use original work schedule as appropriate progress update
4. Fragnet

Start	No of days	No of days impact
1/6/2012	2	3
10/6/2012	1	2
11/7/2012	1.5	2
20/7/2012	3	5
5/8/2012	2	3
8/10/2012	2	2
12/10/2012	1	1

Insert fragnet as 'Adverse weather impacted calendar'

Output

5. 10days total impacted extended resulted

Event 4

Landslide

1. Appropriate progress update near to 10/5/2013 is 30/4/2013
2. Fragnet

Activity	duration	Start	Finish	Predecessor	Successors	Note
Work hold due to Landslide 1km to 2+200km	6	15/5/13	20/5/13			
Remove landslide	2	20/5/13	22/5/13		Construction activities of road way and structures	
Repair asphalt damage	2	29/5/13	31/5/13		Other asphalt work	1 gang has allocated to asphalt work
Repair base damage	3	25/5/13	28/5/13		Asphalt work of particular stretch	
Repair sub base damage	3	22/5/13	25/5/13		Base construction of particular stretch	

Analysis

3. Reduce delay duration to match with the original programme dates after insert the delay event. Maximum delay can be accommodate within original schedule was identified.

Activity	duration	Start	Finish	Predecessor	Successors	Note
Work hold due to Landslide 1km to 2+200km	2	15/5/13	20/5/13			
Remove landslide	2	20/5/13	22/5/13		Construction activities of road way and structures	
Repair asphalt damage	2	29/5/13	31/5/13		Other asphalt work	
Repair base damage	3	25/5/13	28/5/13		Asphalt work of particular stretch	
Repair sub base damage	2	22/5/13	25/5/13		Base construction of particular stretch	

4. Insert agreed durations and analyze.

Output

5. Total Delay 21/5/2013 – 16/5/2013

Event 5

Work temporary suspended due to public protest

1. Appropriate progress update near to 31/10/2013 is 11/11/2013
2. Fragnet

Activity	duration	Start	Finish	Predecessor	Successors	Note
Work temporary suspend and work stopped due to public protest	15	11/1/13	25/11/13		Entire project	
Work further suspended 5-10km	19	26/11/13	15/12/13		5-15km	

Analysis

3. Reduce duration to 0 to obtain 0 network calculation
4. Mitigation of delay / allow 10km-15km to work independently
5. Insert agreed duration to the fragnet

Output

6. Delay duration 5/2/2013 – 25/2/2013 15days delay
7. Wearing activity and priming activity has conflict

Activity	duration	Start	Finish	Predecessor	Note
Priming	20				
Wearing	20			SS Priming +2 days	Priming and wearing don't have FF relationship and priming can extend beyond the wearing

8. Schedule redesign to obtain maximum respond

Activity	duration	Start	Finish	Predecessor	Note
Priming	20				
Wearing	20			FF Priming +2 days	Wearing complete 2 days after the priming

9. Delay duration 24/2/2014 – 30/3/2014 30days delay

Event 6

Work suspended due to non-payment

1. Appropriate progress update near to 20/12/2013 is 31/12/2013
2. 50% of work slowdown due to non-payment was justified in case1 and 5days agreed to resume work
3. Fragnet

Activity	duration	Start	Finish	Predecessor	Successors	Note
50% of slow down due to non-payment	25	20/12/13	15/01/14		Entire project	Effective delay duration 12days
Work temporary suspended	25	15/01/14	10/02/14		Entire project	
Work resume	5	10/02/14	16/02/14		Entire project	

4. Insert 0 durations to 0 network calculations
5. Insert agreed durations
6. Delay 30/3/14 – 4/5/20114

4.1.3 Summary of case study

Case study was done to identify parameters (governing the results) of the TIA method.

Case	Identified situations	Variable factors which can govern the results
Event 1	Delay event is not laid in critical path	1. Delay duration 2. Progress update at the time of delay event
	TIA protocol allowed break down activities further	1. Level of breakdown of activities in initial programme is not impact on TIA results
Event 2	Employer delay and contractor delay occur concurrently	1. Date of occurrence delay event 2. Progress update at the time of delay event
Event 3		Not performed
Event 4		Not performed
Event 5	TIA protocol allowed redesign of programme and logically change the original sequence of activities	1. Nature of original interrelationship between activities not impact on the results of TIA
Event 6	Impact of other delay events	1. Effect of previous delay events on TIA results
**Some parameters effect results of CP analysis but nullify in TIA protocol		

Table 3 Summary of Case Study

4.1.4 Subjective parameters identified in case study research

1. Duration of delay event
2. Date of progress update
3. Level of progress at the time of occurrence of delay events
4. Interrelation ships between activities
5. Effect of past delay events

4.2 Simulation

This simulation will be done to evaluate the response of the TIA results under variability of deferent parameters and evaluate the combine effect of deferent delay events. Model was simulated by changing other parameters while keeping one parameters constant.

2 delay events identified in case study is simulated to identify the response of TIA method when variability of parameters.

Delay event 1 – Design Change due to landslide

Delay event 2 – Quantity increase of rock blasting

Paths represent 2 delay events assembled to build up the combine-effect both events to the project.

4.2.1 Summary of Simulation 1

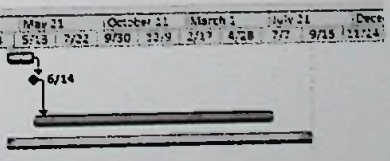
Delay duration

This simulate to understand the response when delay durations of two delay event vary. Two delay events have two paths. Two paths can be assembled by keeping 1 path constant (As progress updated on data date). When delay duration varies following situations can be observed and response of TIA to those situations can be evaluated.

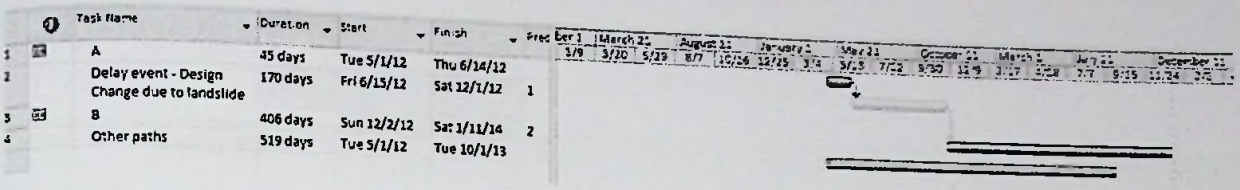
1. When both delays simulate under certain time durations, delay events intercept and concurrent delay events occur
2. Either 1 delay event could be critical

Design change due to landslide – before insert agreed duration

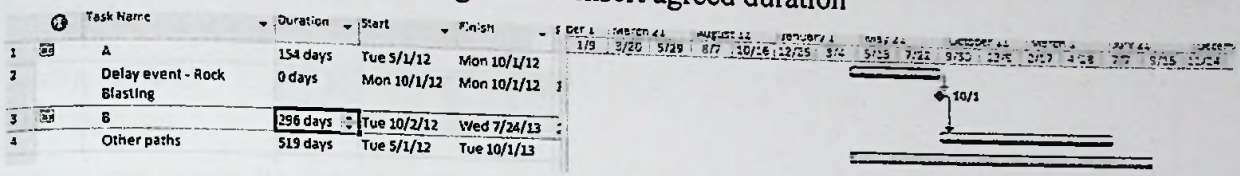
	Task Name	Duration	Start	Finish	Prec
1	A	45 days	Tue 5/1/12	Thu 6/14/12	
2	Delay event - Design Change due to landslide	0 days	Thu 6/14/12	Thu 6/14/12	1
3	B	406 days	Fri 6/15/12	Thu 7/25/13	2
4	Other paths	519 days	Tue 5/1/12	Tue 10/1/13	



Design change due to landslide –after insert agreed duration



Additional quantity of rock blasting–before insert agreed duration



Additional quantity of rock blasting–after insert agreed duration

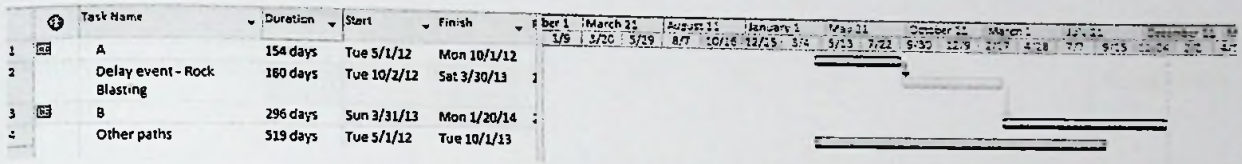


Figure 19 Simulation of Delay Events

Assemble two elements keeping one constant while other parameters simulate

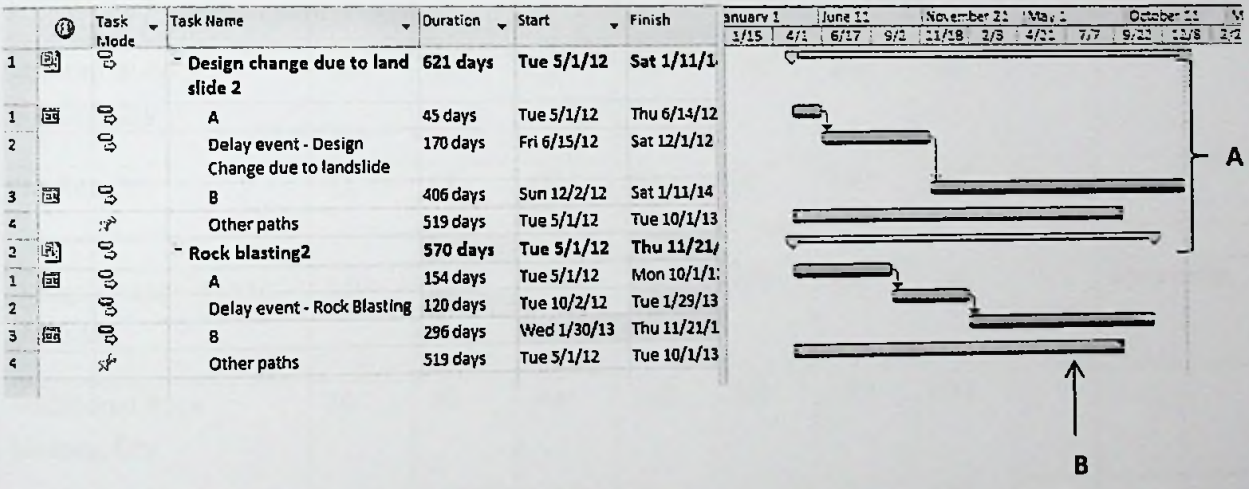


Figure 20 Assemble Delay Events to Obtain Total Impact Simulation 1

4.2.2 Simulation Results

Duration of Delay event										
Design change due to landslide	120	120	120	120	120	120	120		keep const	
Additional Rock blasting Qty	10	50	100	120	150	180	200			
TIA Results	52	52	52	52	80	110	130			
Design change due to landslide	50	50	50	50	50	50	50		keep const	
Additional Rock blasting Qty	10	50	100	120	150	180	200			
TIA Results	0	0	30	50	80	110	130			
Design change due to landslide	80	80	80	80	80	80	80		keep const	
Additional Rock blasting Qty	10	50	100	120	150	180	200			
TIA Results	12	12	30	50	80	110	130			
Design change due to landslide	140	140	140	140	140	140	140		keep const	
Additional Rock blasting Qty	10	50	100	120	150	180	200			
TIA Results	63	63	63	63	80	110	130			

Table 4 Summary of Simulation 1 Results

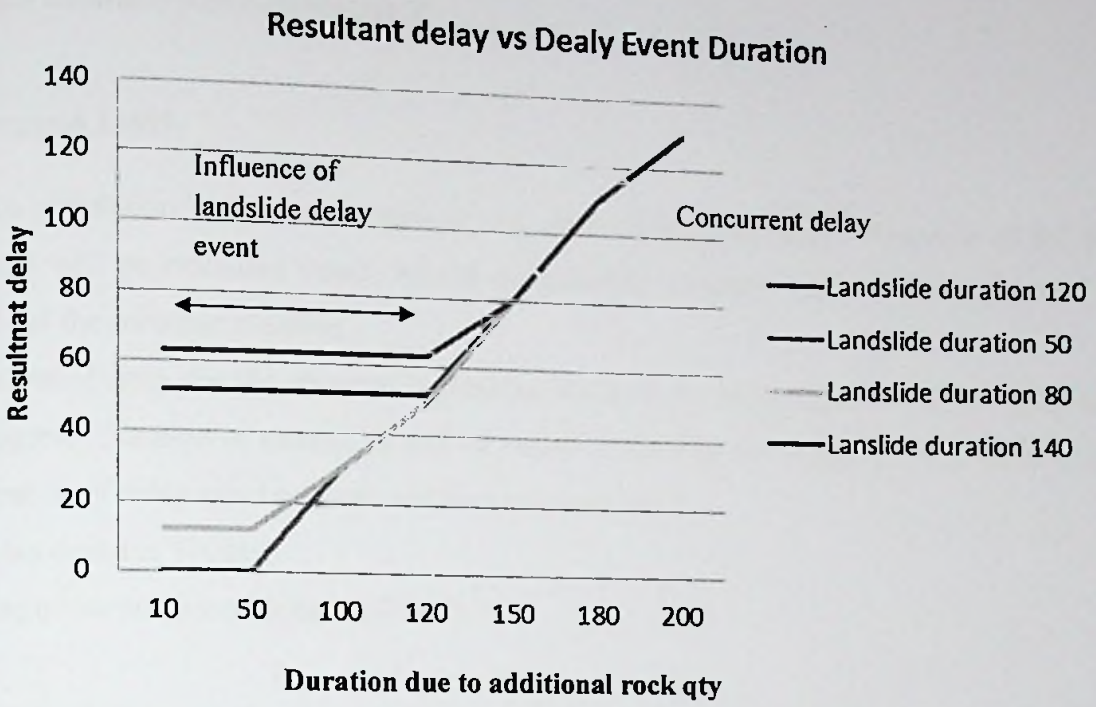


Figure 21 Resultant Delay Vs Duration of Individual Delay Event

The delay duration of delay event shall be exceeding certain level to result a delay. It depends on duration of previous delay event (land slide). After extending delay duration beyond some extent the delays get concurrent. When delays occur simultaneously the impact cannot be separately identified.

One delay event can be influenced on other delay event, even though both delay events are not simultaneous. Resultant influence will be calculated by TIA.

When delay events are concurrent, combine impact of delay events results.

The responsibility of the concurrent delay which occurs simultaneously cannot differentiate.

This analysis result the best path of balance work to be done and it support mitigation of delay.

4.2.3 Summary of Simulation 2

Progress Level

This simulation varies the progress levels, when delay event occur. Response of the delay event will be evaluated under 'behind the schedule situation', 'on schedule situation' and 'ahead the schedule situation'.

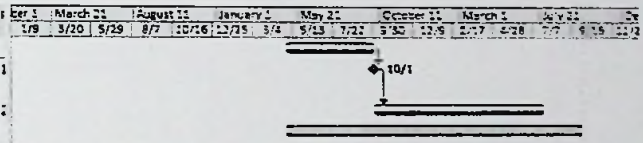
Estimated time for the element B (balance work to be done) depends on the level of its progress. Duration of element B will be varied to simulate the progress level, while keeping duration of delay event constant and response measured.

Delay duration 140days

Date of occurrence of delay 1/10/2012

Before insert agreed duration – expected date of completion 1/10/2013

	Task Name	Duration	Start	Finish
1	A	154 days	Tue 5/1/12	Mon 10/1/12
2	Delay event - Rock Blasting	0 days	Mon 10/1/12	Mon 10/1/12
3	B	296 days	Tue 10/2/12	Wed 7/24/13
4	Other paths	519 days	Tue 5/1/12	Tue 10/1/13



After inset the agreed duration

	Task Name	Duration	Start	Finish
1	A	154 days	Tue 5/1/12	Mon 10/1/12
2	Delay event - Rock Blasting	140 days	Tue 10/2/12	Mon 2/18/13
3	B	296 days	Tue 2/19/13	Wed 12/11/13
4	Other paths	519 days	Tue 5/1/12	Tue 10/1/13

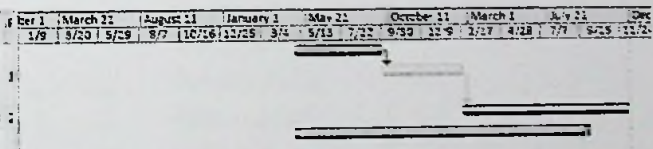


Figure 22 Simulation of Delay Event 2

4.2.4 Simulation Results

Duration of Delay event										
Slippage of Progress % on schedule	-50%	-25%	0% on schedule	10%	25%	35%	50%		keep const	
Estimated time duration for completion	444	370	296	266	222	192	148			
TIA Results	140	140	71	42	41	0	0			

Figure 23 Summary of Simulation 2

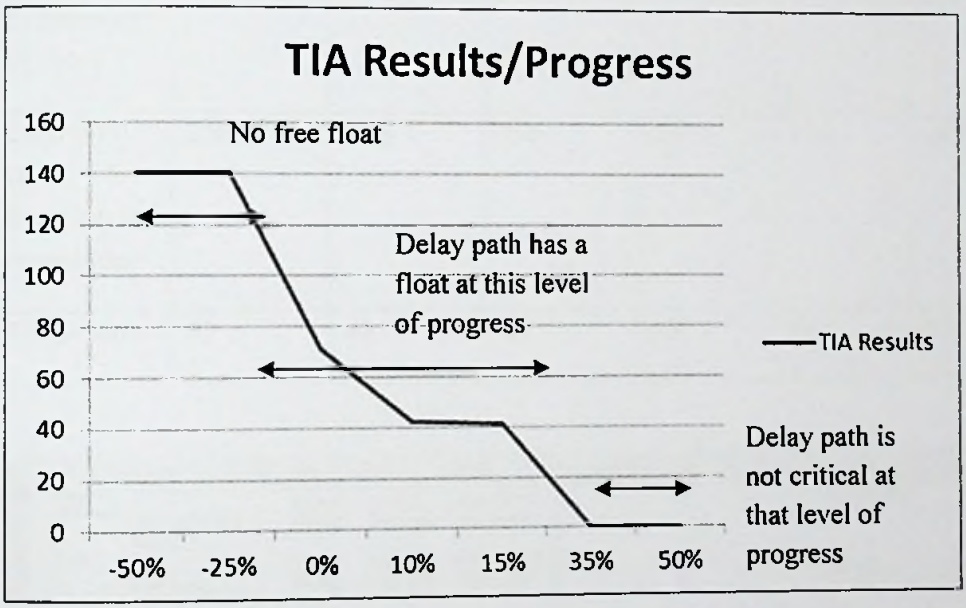


Figure 24 TIA Results Vs Progress Level

This simulation gives significant result on the behavior of the free float.

When project significantly ahead the schedule contractor will not be entitle for the additional time. In average progress there will be a free float remain in the project and it shall be reduced form the entitlement of time.

If project is consumed the free float 100%, contractor will be entitle for the long additional time duration.

4.2.5 Summary of Simulation 3

Time of Occurrence of Delay

Length of delay duration and level of progress by the occurrence of delay event will be kept constant, while the date of occurrence of the delay varies and response of TIA measured.

Delay duration 140days

Progress on schedule

Duration of Delay event										
Date of occurrence of delay	1/10/2012	1/11/2012	1/12/2012	1/1/2013	1/2/2013	1/3/2013				
Estimated time duration for completion	296	265	235	204	174	143			Progress Const.	
TIA Results	42	42	42	42	42	42				

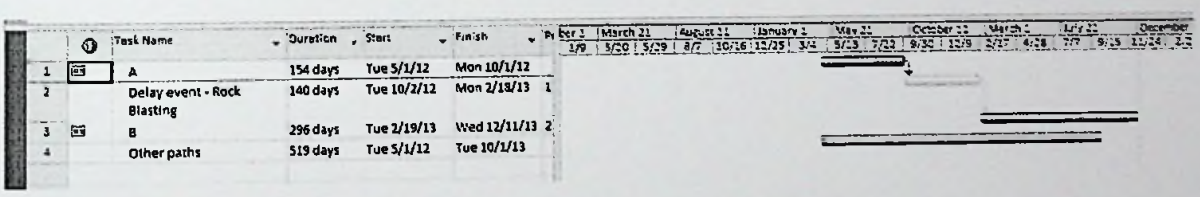


Figure 25 Simulation of Delay Event 3

TIA result is irrespective to the date of occurrence of delay event when progress level and delay duration constant.

4.3 Summary of Analysis

Following answers are achieved through the research;

1. Assessing criteria of a delay analysis method has been developed relative to the contract laws, good practices in industry and fundamentals of science. Those are found in literature and the assessing criteria was developed in literature review of the research.

2. Reasonable results shall be obtained from TIA method to assess the effectiveness. Illustration of TIA results with variable parameters of the delay analysis has been obtained. Those illustrations are given in the form of graphs or tables.

3. Results of analysis of deferent delay events were assessed by the developed assessing criteria.
   Illustration of TIA results reference to the variability of deferent parameters are assessed. This has summarized in table below.

4.4 Analysis results of simulation

Simulation	Results	Variable	Requirements in Industrial Standards								Requirements in Scientific method of measurements			
			Mitigation of delay	Free Float	Compensation	Concurrent delay	Neutral events	Identify impact to critical path	Identify impact to non-critical path	Identify Acceleration	Independent from person who perform	Unique results when repeat	Project affected by delay analyze	Results independent form internal procedure
Design change due to landslide and Qty exceed of rock	Refer graph 1	Duration of delay event and combine 2 events			Cannot be distinguish the impact	Cannot be distinguish the impact	Cannot be distinguish the impact	Identified	Identified		subjective to decisions when revision of the project programme		Project not changed	Impact of other delay events can be distinguished
Quantity exceed of rock blasting	Refer graph 2	Level of progress	Mitigation of delay performed	First consume the free float will have the benefit						Identify acceleration	No subjective decisions		Project not changed	
Quantity exceed of rock blasting		Date of delay									No subjective decisions	Unique results	Project not changed	Independent form time of occurrence

Table 5 Assessment of Effectiveness of TIA Results

Chapter 5 – Conclusion

There were 3 major steps in this research. The results shall be conclude considering those pillars which based to develop the research. Those 3 steps are Development of criteria to assess the effectiveness of delay analysis method, Development of model to simulate the TIA method and obtain results, assess the effectiveness of TIA method using simulation results and developed Assessing Criteria. Case study was done to develop the basis for the simulation.

There are many delay analysis methods, none of them are perfect, and have both merits and demerits. Deferent methods are applicable to deferent situations. Results of delay analysis could be questioned in legislation or dispute resolution process. Therefore those methods shall be justified logically. Fundamental laws in science, fundamentals in contract law and basic good practices in construction industry were based to develop the assessing criteria to assess the good delay analysis method.

TIA process is complex methodology. It has number of dependencies, internal relationships and both subjective and objective parameters. Those dependencies can be found by the case study. Results of case studies are not reasonable enough to have a generalize conclusion on the effectiveness of TIA method. Behavior of results with the variability of relevant parameters of the TIA method, were obtain and illustrated in graph or table. Those results were assessed by the developed assessing criteria. Dependency of TIA results on internal factors of TIA procedure is one aspect of assessing the compatibility of TIA method with fundamentals in scientific method of measurements. Level of breakdown of activities in project programme, nature of relationships of activities are some factors can be included in that. TIA protocol mitigate dependency of results over above subjective parameters.

TIA results are depend on the decisions taken by person who perform the analysis, when revision of project programme is done. In that aspect TIA is not compatible with a fundamentals in scientific method of measurements. TIA results independent from time it was performing. TIA analysis do not change the project programme. In this aspect TIA satisfy the requirements of scientific method of measurements.

TIA analysis identify the acceleration of the project, support mitigation of delay, and distinguish the impact on critical and non-critical delay events. Those are the requirements in contract laws and good practices in the industry. TIA analysis can work with revised work programme. Therefore no need to freeze the programme as it accepted by the employer. Therefore TIA method support liberty of the planner to revised work programme at any moment of the project to pursuit the best path of working.

TIA cannot distinguish liability of separate delay events to the resultant delay when they occur concurrently. When delay events occur concurrently with neutral event, TIA cannot distinguish effect of neutral events. This is a demerit of TIA method. Therefore when calculating compensation, based on TIA results a dispute may arise. TIA treat free float owns to the project. When the first delay event occur it consume the free float. When next delay event occur impact may arise either it is a default of contractor (who responsible for planning) or the Employer.

TIA is effective in analyzing impact of delay events, but not all the times. TIA shall be used with proper understand of its merits and demerits or compatibilities and incompatibilities.

Concluding the research, it was reviled there are more studies to de done in delay analysis process in debatable scenarios. Illustration of delay analysis is also very important. More studies and researches shall be done in this area to revile more clear and understandable illustration of delay analysis results.

Critical path software packages shall be developed with modules support delay analysis. Researches shall be done to revile the chaos behavior impact of delay event in construction project. Which make unpredictable impact on schedule by occurrence of delay beyond the analytical forecast.

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