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Simple Delay Analysis Methodologies Selection Advisor For Construction Practitioners (DAMSA)

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Delay analysis is one of the constructions industry dilemmas. Several researches and best practices have been developed to deal with this issue but none of the current techniques responds accurately to all of the four common delay issues: real time delay, concurrent delay, acceleration, and pacing delay. In addition most of the researchers did not accommodate the construction management conditions and levels . In fact even if CPM is implemented in the project many projects are not following the CPM and many projects are not implementing CPM . Most of the current researches and practices concentrate only on CPM or on Non CPM .
In most cases the two parties in many of the construction projects even though the mega and multi-billion projects in north Africa and the Middle East try to find the simplest method to calculate the delay and the extension of time although of the presence of their armies of project management professionals.
At the beginning I have tried to develop an expert system by integration of Primavera Project Management , Primavera Contract Management and Knowledge Base. Many factors and the huge amount of variables moreover the complexity that shall face the user declined this approach.

Through the experiences and the survey answered by hundreds of professionals it's clear that most of the construction practitioners have no idea about delay analysis even most of the experienced planners who are in most cases schedulers were not able to monitor neither ability nor knowledge about this subject.

This paper shall focus of presenting an easy method to select the delay analysis methodology that may fit the case meanwhile shall present a tool to enrich the schedulers knowledge about the subject.

Introduction

Construction problems and disputes arise due to several factors including; technical, climatic and logistic events, while resolution of construction disputes is influenced by people's motivation, behavioral and cultural implications (McINNIS 2001).

Conflict and disputes can exist at all levels in the contractual chain: client/consultant,client/contractor,contractor/subcontractor,subcontractor/sub ¬ subcontractor, and so on. Types of conflict and dispute arising from this contractual relationship can be summarized into three categories:

- "Time" related. (i.e. Claims from the contractor for extensions of time for completion of the project.)
- "Money" related. (i.e. Claims from the contractor for payment of the value of variations and/or reimbursement of loss and expense.)
- "Quality" related (i.e. Assertions by the client of defective materials and workmanship).

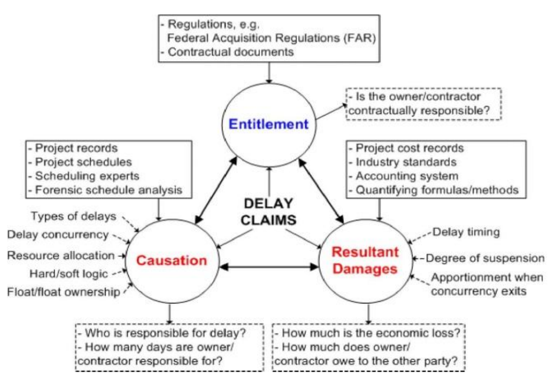

Figure 1 Extended "triad of proof' in delay claim.

In legal terms, claims on construction projects fall under four main categories]:

(1) contractual claims;
(2) ex-contractual or common law claims;
(3) *quantum meruit* claims ; and
(4) *ex gratia* awards or claims.

The most common claims arise from time claims which may present cost overrun claims in most of the cases. With the various delays analysis techniques there is a need to have a mind map for the construction industry.

In fact even if CPM is implemented in the project many projects are not following the CPM and many projects are not implementing CPM . Most of the current researches and practices concentrate only on CPM or on Non CPM .

There is a need to have a mind map for the construction industry practitioners to have a complete guide to select the appropriate delay analysis technique .

Many attempts have been presented either by researchers or professional entities such as AACE and SCL. Some researchers tried also to present expert systems to deal with the complicated issue.

Although contractors and owners do not universally implement the CPM on every project, courts prefer to use the CPM as legal evidence in delay claims. However, before the CPM can be used as evidence in a construction claim, an adequate foundation must be laid. CPM The court will not allow a CPM analysis that is insufficient. An expert can be used to provide the CPM analysis during in-trial testimony. The expert can be either a CPM expert or somebody who has first-hand knowledge of the project. Although the CPM is most commonly used for delay claims, there is judicial precedent to allow its use also for productivity claims.

Causes of Delays

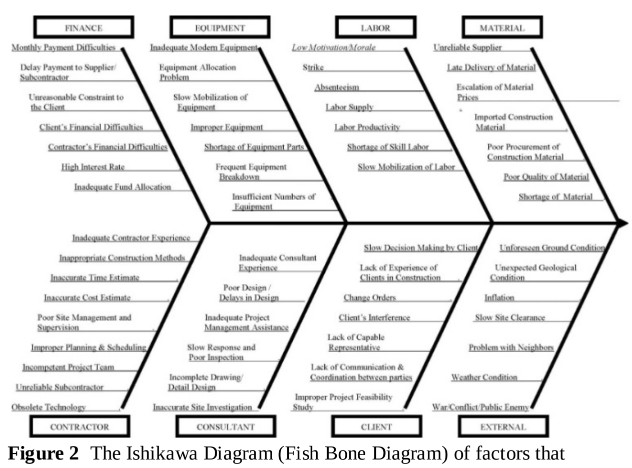

Figure 2 The Ishikawa Diagram (Fish Bone Diagram) of factors that contributed to the causes of delays.

According to Kelleher (2004), the number of companies that practice CPM scheduling has significantly increased over time. Moreover, the percentage of claims applying the CPM in their analysis increased, between 1990 and 2003, from 71% to 86%. Furthermore, the number of publications pertaining to the application of CPM in delay analysis has continued to increase from the early 80's.

Background

Schedule delay and time extension

A delay is defined as the time during which some part of the construction project is completed beyond the projected completion date(s) or not performed as planned due to an unanticipated circumstance (Callahan, Quackenbush and Rowings 1992).

Delay versus disruption

Delay and disruption are two different types of damages. Delay damages cannot be traced to specific activities, whereas disruption damages can. Delay damages are valid only if delays to the overall project completion time are involved, while disruption damages can be caused by any change in the planned condition of work that can happen regardless of the change in the project completion time. Disruption refers to a loss of productivity involving a specific activity and is caused by changes in working conditions, such as stacking of trades, work area congestion, resource diversion, skill dilution, and dilution of supervision

Excusable and non-excusable delay

Delays can be classified as excusable or non excusable, compensable or non compensable, and critical or noncritical. Some delays are related to time extension, but some are not .

Excusable Delay (ED) – as used in the schedule impact analysis techniques, a delay not attributable to either the contractor or owner

Excusable, Compensable Delay – a delay that will serve to justify an extension of contract performance time, as well as award delay damages; a delay at fault of the owner .

Excusable, Non-Compensable Delay – a delay not attributable to the contractor or owner, which will serve to justify an extension of contract performance time, but no monetary compensation

Non-Excusable, Compensable Delay – a peculiar situation in which an owner and contractor are concurrently delaying the project, and monetary compensation for the owner's delay can be properly apportioned

Non-Excusable, Non-Compensable Delay – a delay caused by the contractor's actions and/or inactions that denies the contractor claims for either time extensions or compensation; the contractor may also be held liable for liquidated damages.

Critical and noncritical delay

Delays can also be classified as critical or noncritical (Callahan, Quackenbush and Rowings 1992). A "critical delay" results in an extended contract project completion date.

Conversely, a "noncritical delay" is either one involving a non-critical path activity that has positive total float or one that does not extend the contract project completion date.

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Delay Analysis Techniques

General delay analysis processes

To help delay or claim analyst for collecting required

Although these different approaches cover different topics, they can be divided into five phases: (1) preparation phase: to collect required information including as-planned schedule, bid documents, construction daily reports etc.; (2) diagnosis phase: to identify impacted delay events for further analysis; (3) analysis phase: to calculate schedule impact according to each impacted delay event; (4) interpretation phase: to clarify schedule impact on critical path or total duration and (5) summation phase: to summarize all analysis results and to generate a comprehensive analysis report.

Global Impact Technique (Non CPM Method)

Global impact technique Simply calculating delay value by examining final schedule evidences. It ignores the effects of concurrent delays, does not distinguish delay types, and it assumes that every delay has an equal impact on the project duration.

Net Impact Technique (Non CPM Method)

The requested time extension is the difference between the as-built and the as-planned completion dates.

Adjusted As-built CPM Technique

This technique uses the CPM format to develop an as-built schedule. Delays are shown as activities and tied to specific work actions.. The difference between the as-planned completion date and the adjusted as-built completion date is the amount of time the claimant would demand a compensation for.

This method is called the as-built method by Conlin J. et al., (1997).

As-Planned Versus As-Built Analysis

The Theory—If you figure out what sequence of activities actually defined the length of the project, you can then determine what and who caused the delays to the project completion.

The Method—As in the collapsed method, construct an as-built schedule. Identify the as-built critical path. Compare these activities to the planned schedule and determine the actual delays to the project. Then review the record to determine responsibility for the delays.

Advantages—This approach generally yields the most accurate result, as it benefits from 20-20 hindsight. It identifies and quantifies both owner and contractor delays and therefore addresses concurrency and compensability. The resulting conclusions are readily supported by contemporaneous documentation.

Limitations—The analysis is both time consuming and generally requires a greater level of expertise to accurately perform.

Collapsed As-Built Analysis

The Theory—If you subtract the owner delays from the actual project duration, you would end up with how long the contractor would have actually taken to build the project but for the owner delays.

The Method—Develop a schedule, based on job records, reflecting how the project was constructed. Remove the owner delays from this as-built schedule and recalculate the schedule allowing the remaining activities to collapse. The difference between the resulting completion date and the actual completion date of the project is the delay attributable to the owner.

Advantages—For the contractor, who never produced an acceptable schedule during the project, this method is the method of choice, since no as-planned schedule is required.

Limitations—This approach does not address concurrent delays, therefore is limited to calculating time extensions but not compensability.

Snapshot Technique (Windows)

The snapshot analysis (SA) method is based upon the as-planned, as-built and any revised schedules that have been implemented during the execution of the project. The total project duration is divided into a number of time periods, or snapshots. The dates of these snapshots usually coincide with major project milestones, significant changes in planning or when a major delay or group of delays is known to have occurred. The relationships and duration of the as built schedule within the snapshot period are imposed upon the as planned schedule, while maintaining the relationships .

Time Impact Technique

The time impact technique focuses on a particular delay, and not on a time period containing delays. The concept is to compare the schedule just before a delay occurs with the adjusted schedule right after that delay. The difference between the completion dates is the effect of inserting a specific delay into the schedule. Although this technique considers the real time CPM, it fails to classify delays before the analysis and it does not address concurrent delays (Alkass et al., 1996 & Conlin et al., 1997). It is also known as baseline adding impacts (Bordoli and Baldwin, 1998).

Isolated Delay Type (IDT) Technique

The IDT technique combines the systematic approach of the time impact and snapshot techniques with the delay scrutinizing ability of the “but for” technique.Although it covers the concurrency issue, the assessment of concurrent delays has to be performed manually prior to the analysis (Alkass et al., 1996).

FLORA (float, logic and resource allocation)

Nguyen and Ibbs (2008) presented FLORA, which addresses the effect of change in float, logic, and resource allocation on delay analysis. It deals with such changes simultaneously by using a predefined set of rules which are agreed upon by the project parties. Although it works for real-time and after-the-fact analysis, it is demanding, complicated and requires more records and information than other methods.

Daily Delay Measure

Livengood and Laush (2003) presented a tool called the daily delay measure. It allows an analyst to track activities on a regular basis (daily) and calculate the difference between the actual and planned activity data over the span of the activity duration. It is not a replacement of traditional analysis techniques, but rather an auxiliary tool to help to identify and represent delays.

Method for Integrating EVM with Delay Analysis Technique

The integrated method overcomes the shortages of the two basic methods. First, it solves the deficiency of calculating the delay of the EVM method. Second, it responds to the drawback of quantifying the delay location in using TF Management technique thatis used a daily methodology in their analysis. Third, the derived equation from EVM method can be used for quantifying the loss of productivity.

Defficulties in delay analysis techniques selection .

Jyh-Bin Yang (2010) have 35 methodologies appeared or discussed in 28 articles.

(1) Reams' Systematic Approach (Reams, 1989);

(2) What-if (Schumacher, 1995);

(3) But-for (or termed collapsing technique) (Schumacher, 1995);

(4) Contemporaneous Period Analysis (or termed Windows Analysis) (Schumacher, 1995);

(5) Global Impact Technique (Alkass et al., 1995);

(6) Net Impact Technique (Alkass et al., 1995);

(7) Adjusted As-built CPM Technique (Alkass et al., 1995);

(8) Snapshot Technique (Alkass et al., 1995);

(9) Time Impact Technique (or termed modified as-built) (Alkass et al., 1995);

(10) Isolated Delay Type (Alkass et al., 1995);

(11) Impacted Baseline Schedule (Zafar, 1996);

(12) After-the-fact and Modified CPM Schedule (Zafar, 1996);

(13) Dollar-to-time Relationship (Zafar, 1996);

(14) Collapsed As-built Method (or termed As-built Less Delay Analysis) (Al-Saggat, 1998);

(15) As-built Method (or termed As-planned vs. As-built) (Conlin and Retik, 1997);

(16) As-planned Method (Conlin and Retik, 1997);

(17) Affected Baseline Schedule (Al-Saggat, 1998);

(18) Bar Chart Analysis (or termed As-built Bar Chart) (Bordoli and Baldwin, 1998);

(19) Scatter Diagram (Bordoli and Baldwin, 1998);

(20) As-built Network (Bordoli and Baldwin, 1998);

(21) As-built Subtracting Impacts (Bordoli and Baldwin, 1998);

(22) Baseline Adding Impacts (Bordoli and Baldwin, 1998);

(23) B&B's Delay Analysis Method (Bordoli and Baldwin, 1998);

(24) Modified As-built Method (Bubshait and Cunningham, 1998);

(25) Impacted As-planned Method (or termed As-planned Plus Delay Analysis) (Stumpf, 2000);

(26) CPM Update Review (Zack, 2000);

(27) Linear Schedule Analysis (Zack, 2000);

(28) Construction Delay Computation Method (Shi et al., 2001);

(29) Modified Windows Analysis (Gothand, 2003);

(30) Impacted As-built CPM (Gothand, 2003);

(31) New Isolated Delay Type (Kumaraswamy and Yogeswaran, 2003);

(32) Apportionment Delay (Ng et al., 2004);

(33) Daily Windows Delay Analysis (Hegazy and Zhang, 2005);

(34) Modified But-for Method (Mbabazi et al., 2005);

(35) Delay Section (Kim et al., 2005).

Jyh-Bin Yang (2010) Study results reveal following findings. (1) There are at least 35 approaches been developed from 1989. (2) The most cited approaches are the But-for, Windows Analysis (Contemporaneous Period Analysis), and Time Impact Technique approaches. (3) For the source-identified delay analysis approach, B&B's Delay Analysis Method, Modified Windows Analysis and New Isolated Delay Type are the most cited approaches.

Several types of CPM schedules are employed in analyzing the impact of the project completion date. Project schedules can be classified into five major types (Arditi and Robinson 1995; Alkass et al., 1996; Finke, 1999):

a) As-Planned Schedule
b) As-Built Schedule
c) Projected Schedule
d) Adjusted Schedule
e) Entitlement Schedule

Baram, Finke, Zack, and Stumpf address the importance of the dynamic nature of project critical paths. Time impact analysis performs a series of analyses throughout a project period, in contrast to the major disadvantage of the previously mentioned methods that observe a schedule at a single point in time.

The level of acceptability of each technique depends on its credibility and the court or board ruling the corresponding delay claims. Recent studies have tried to consider float ownership in delay analysis but they only deal with this issue or provide unrealistic alternatives.

There are effectively four main criteria for selecting which delay analysis methodology to use. These are:

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

There are four main stages in analyzing and presenting delay claims:

- the collection and analysis of the factual data;
- interpretation of the data and preparation of the network programmes ;
- determination of matters of causation and in particular issues of concurrency;
- preparation of the presentation.

The successful settlement of a typical DD claims usually requires that the claimants goes through five main processes (Lee, 1983; Williams *et al.*, 2003; Klanac and Nelson, 2004):

(i) establishment of contractual/legal basis for the claim(Liability);

(ii) establishment of causal link between each delay and/or disruption event and the resulting extended duration and/or additional cost (Causation);

(iii) evaluation of effect and quantify the amount of time and/or cost of the impacts (Quantum);

(iv) compilation and submission of claim; and

(v) Negotiation of settlement.

A number of factors may influence the result of delay analysis regardless of which delay analysis method is used. These factors are most of the time specified in contract clauses and include concurrent delays, float ownership, theories of critical path, and scheduling software options.

Delay analysis techniques can be classified into three separate categories: the Foresight Method, the Hindsight Method, and the Contemporaneous Method. The differences between these delay analysis techniques involve the baseline schedule used for measuring the delay, the point in time when the delay is measured, and the treatment ,if any, of concurrent delay.
The Foresight Method, commonly thought of as the simplest and easiest, generally employs two approaches: Impacted As-Planned, where only the owner-caused delays are identified, and Adjusted As-Planned, where only contractor-caused delays are identified.
The Foresight Method is not generally favored by courts and boards, because it ignores the as-built history of the project; it produces theoretical results; it does not measure the effect of delay on actual performance; and it assumes that the as-planned schedule does not change.
The Hindsight Method centers on an as-built schedule — a schedule depicting the dates that events actually occurred. Delaying events are normally depicted as distinct activities on the as-built schedule, which are invariably tied to the critical path. Typically, under this method, there are two approaches: As-Built Critical Path, which allocates time by determining the responsibility for the delays on the so-called critical path of the project, and Collapsed As-Built, which removes delays caused by one party to determine when the work would have been completed, if not for the delays of the other party.
The Hindsight Method has a number of disadvantages that include difficulty determining which work activities or delay events controlled the pace of the work; not considering what was critical at the time a delay occurred; not considering float through various paths at different periods of time; not accounting for concurrent delay; and not attempting to determine the individual impact of each delay.
The Contemporaneous Method hinges on the principle that in order to determine the impact of delaying events, the status of the project must be established at the time those events occurred. In essence, the schedule needs, first, to be updated at the time of the delay and, second, to be updated to incorporate any planning changes to coincide with the contractor's plan for pursuing the work. The goal of this method is to develop a freeze-frame picture of the project—identifying the delaying event, the impact of the delay, and the plan to complete the remaining work at the time the delay occurred.
Two approaches are commonly used as part of this method: Time Impact Analysis, which looks at a particular point in time and utilizes a series of chronological time slices to evaluate major scheduling variations that occurred during the project, and Window Analysis, which examines the critical path between two points in time and assesses the delay as it occurs.
Courts and boards hold that contemporaneous schedule updates should be considered in evaluating delay. The Contemporaneous Method is favored because it provides a baseline for measuring delay; the status of the project at the time a delay occurs; the impact of delaying events on remaining work; and insight into float, changes to critical path, and revisions to the plan to complete.

The practical problems fall into one or more of the following categories:

to produce an analysis;

•Those that the analyst must recognize may affect his choice of analysis method; and

•Those which the method of analysis must be capable of accommodating.

The ability to repeat the success of US schedule impact analysis techniques in the UK is limited by differences currently existing and as revealed by the study of US decisions and articles and in particular:

the approach of contractors to construction planning;

•the contractual status of programmes;

•the willingness of the courts to descend into the detail of, for example, critical path analysis;

•the perception of matters of causation.

The approach may be prospective, contemporaneous or retrospective. The retrospective approach is likely to be the most appropriate for use in the UK. It is possible to define a number of techniques which can be used to analyze delay claims, particularly in areas of:

- the overall approach;
- data collection, methods and minimum requirements;
- analysis of the data;
- presentation of results;
- basic elements of proof.

Float and Criticality.

Float is the amount of time that an activity can be delayed without affecting the completion date of the project, and it is calculated based on the difference between either the early start and late start or early finish and late finish of an activity (Nguyen and Ibbs, 2008). Total float (TF) is another term for float that is frequently used in CPM scheduling. When noncritical activities have been impacted by delays, they consume their own float time and can then become critical (Trauner, 2009).

Float Consumption Management

Appropriate float allocation ensures an accurate and reasonable distribution of delay between parties. To better manage the float ownership issue, practitioners and researchers have developed several techniques over the past decades. A list of brief explanations of the different float distribution techniques follows (Al-Gahtani, 2009):
1. Owner has possession of the float.
2. Contractor has possession of the float..
3. Project has possession of the float.
4. Fifty-fifty float allocation approach.
5. Float is traded as a commodity approach.
6. Bar approach. Developed by de Leon (1986).
7. Contract risk approach.

<u>Presentaion of Delay Claim</u>

The presentation of a delay analysis is not sufficient in itself to justify compensation. It is necessary to establish,
(i) The event: the event to be identified as a fact, e.g. late supply of information, to a contractor.
(ii) Liability: determined by interpretation of the contract.
(iii) Effect: the change to the planned progress of the works as a result of the event. This may be demonstrated by a 'prospective' delay analysis (for entitlement to an extension of time), and/or a 'retrospective' delay analysis to assist in compensation. Sometimes the contract provisions may determine the methodology of delay analysis that is required, i.e. estimated future delay and/or the probable future delay (prospective analysis), or the actual delay (retrospective analysis).
(iv) Causation: The causal connection between the event, effect and compensation. In some instances the identified causative event may have been caused by a previous causative event. For example, delay caused by winter working may have been caused by the project being delayed into winter due to an earlier causative event. Therefore the chain of causation and the incidence of any secondary causative events will need to be investigated and established.

The procedures to follow to assess delay claims can be divided into the following phases :

 Preparation phase: All the necessary data, such as bid documents, daily construction reports, As-Planned and As-Built schedules are gathered.

 Diagnosis phase: The delaying events are identified and classified based on their liability.

 Analysis phase: Appropriate delay analysis methodology is employed to calculate the impact of the identified delaying events on the project date.

 Interpretation phase: The impact of delaying events on the critical path or on total project duration is determined. Meanwhile, for liability purposes, concurrent delays should also be taken into account for the contract parties.

 Summation phase: the analysis results are presented in an inclusive report.

Critical path analysis methods employ the CPM scheduling technique, introduced in the late 1950's and now utilized by 88% of the contractors in the UK and in the USA (Aouad 50 and Price, 1994). Furthermore, Ndekugri et al. (2008) has classified delay analysis techniques into two groups:

 Non-CPM based techniques such as S-curve, Net impact, and Global impact; and

Standardization and methodologies classification

In an attempt to have a standardized classification method, the RP of the AACEI (2007) employs a hierarchical classification framework comprised of

five layers to classify CPM-based forensic schedule analysis methods. The taxonomy layers are:
1. Timing: Prospective or Retrospective
2. Basic Methods: Observational or Modeled
3. Specific Methods: Observational Methods (Static Logic Observation, Dynamic Logic Observation) or Modeled Methods (Additive Modeling, Subtractive Modeling)
4. Basic Implementation:
a) Static logic observational methods that can be implemented in a gross mode or periodic mode.
b) Dynamic logic observational methods that can be implemented in contemporaneous/as-is or contemporaneous/split formats. They can also be implemented as modified or recreated.
c) The additive and subtractive modeling methods can be implemented as single-base or multi-base simulations.
5. Specific Implementation:
a) Fixed Periods vs. Variable Periods/Grouped Periods: These two choices of segmentation come with all of the usual specific implementations, except for the single mode and single base.
b) Global (Insertion or Extraction) vs. Stepped (Insertion or Extraction): This specific implementation takes place with the single base implementation that comes (sequentially) with the additive and subtractive modeling methods.

The AACE classifies delay analysis techniques into two divisions based on the timing of analysis:
1. Prospective analyses: these techniques are performed simultaneously with the delay event. They are employed as the project is in progress.
2. Retrospective analyses: these techniques are applied as the delay events occur and the impact(s) of delays are identified to the project parties.

Furthermore, retrospective techniques are classified into two subcategories: Observational and Modeled techniques. Observational methods review the project schedule by itself or with another schedule. By employing these types of techniques, the analyst does not make any changes to the schedule to develop any specific situation. In Modeled techniques, the analyst adds or subtracts delays to the corresponding activities and compares the generated results. AACE classification attempts to present a unified technological reference for the forensic application of the critical path method. All of these methods quantify the impact delay event on the project schedule by utilizing CPM schedules; however, not all methods are applicable to or acceptable in every case .

Taxonomy	1	RETROSPECTIVE														
	2	OBSERVATIONAL							MODELED							
	3	Static Logic			Dynamic Logic				Additive				Subtractive			
	4	3.1 Gross	3.2 Periodic		Contemporaneous Updates (3.3 As-Is or 3.4 Split)		3.5 Modified / Reconstructed Updates		3.6 Single Base[2]		3.7 Multi Base[1]		3.8 Single Simulation		3.9 Multi Simulation[1]	
	5		Fixed Periods	Variable Windows	All Periods	Grouped Periods	Fixed Periods	Variable Windows	Global Insertion	Stepped Insertion	Fixed Periods	Variable Windows or Grouped	Global Extraction	Stepped Extraction	Fixed Periods	Stepped Extraction
Common Names		As-Planned vs As-Built	Window Analysis		Contemporaneous Period Analysis, Time Impact Analysis, Window	Contemporaneous Period Analysis, Time Impact Analysis, Window Analysis	Contemporaneous Period Analysis, Time Impact Analysis	Window Analysis, Time Impact Analysis	Impacted As Planned, What-If	Time Impact Analysis, Impacted As-Planned	Time Impact Analysis	Window Analysis, Impacted As-Planned	Collapsed As-Built	Time Impact Analysis, Collapsed As-Built	Time Impact Analysis, Collapsed As-Built	Time Impact Analysis, Window Analysis, Collapsed As-Built

Figure 3 – Nomenclature Correspondence shows the commonly associated names for each of the taxonomic classifications.

In another attempt to deal with the delay and disruption in early stages of the project life cycle and to avoid accumulation of delays , the Society of Construction Law's (SCL) recommended periodically extension of time based on delay analysis which may be adjusted each month . SCL Delay and Disruption protocol identifies four major categories of methodology for the analysis of delay, being :
- As-planned versus as-built ;
- Impacted as-planned;
- Collapsed as-built; and
- Time Impact Analysis .

The Protocol concluded that time impact analysis is the most thorough but also the most time-consuming and costly . There is no definitive answer as to which method is the best in given circumstance.
The Society of Construction Law (SCL) has identified a number of factors that should be taken into account when selecting a delay analysis technique (SCL, 2002):

- The relevant conditions of the contract;
- The nature of the causative events;
- The value of the claims;
- The time available ;
- The recorded information;
- The schedule's accessible information; and
- The scheduler's experience with the project.

Most of the commonly-used techniques fit somewhere under one of the classes of this taxonomy, while some other methods may come under more than one class.
Braimah(2008) inspired by the need to address this problem, and developed a model for the selection of anappropriate DAM. This is intended to serve as a tool for assisting analysts in justifying their choice of DAM to their clients and/or the trier-of-fact when the contract is silent on the method to use.

Given that no single DAM is universally appropriate for all claims situations, respondents indicated that the most appropriate methodology is dictated by eighteen (18) criteria. These have different degrees of importance in influencing methodology selection with the top five as: records availability, baseline programme availability, the amount in dispute, nature of baseline programme, and updated programme availability; in that order. The 18 criteria were further grouped into 6 generic factors using factor analysis as: project characteristics, contractual requirements, characteristics of baseline programme, cost proportionality, timing of analysis and record availability .According to SCL, Time Impact Analysis technique is therefore the preferred technique to resolve complex disputes related to delay and its compensation.
Time impact analysis is distinguished from the impact as-planned and collapsed as-built analyses in the fact that it incorporates both party delays into the analysis. The excusable compensable, excusable non-compensable, and non-excusable delays can be separately identified. In addition to this advantage, Wickwire et al. [3] describe indirect benefits generated by the use of time impact analysis in that it also provides a disciplined basis for the contractual parties to keep a project schedule up-to-date and properly adjusted.

Some limitations that exist in some actual construction projects may weaken the power of this method. First of all, time impact analysis requires a large amount of information in order to perform the analysis. An as-planned schedule in CPM format is necessary; additionally, the schedule needs to be periodically updated. The projects that lack strict administrative procedures and/or updated schedules are not good candidates for this method. Baram [29] suggests that the use of time impact analysis is the most desirable approach to handle a delay claim, but only when data and source documents are available in the required format and in the required time frame.

In conclusion, time impact analysis is a refined method that determines delay impact in construction projects. It incorporates contemporaneous data to simulate actual circumstances at the time the delay occurs and accumulates impacts of delay events by using a series of windows. However, it requires significant time and effort.

The delay analysis methods selection depends on four criteria including data requirements, time of analysis, capability of methodology, and time and effort required. Availability of information Delay analysis methods determine the impact of delay by using different types of schedules. As-planned and as built schedules and updates are commonly required as part of administrative procedures, while adjusted schedules and fragnets will be created specifically for delay analysis purposes.

Time of analysis

Delay analysis can be performed at different points in time relative to a delay. Foresight analysis is conducted to present the effects of potential delays caused by proposed events such as future change orders. For delays that have occurred, the best time to evaluate them is when they actually arise Hindsight analysis is a common practice in construction due to the hesitation of project parties to deal early with the delay.

Delay analysis and computer applications

Many researchers tried to presented a computer based framework to deal with this issue . Many researchers have considered MS - Project and established integrated computer system delay analysis technique based on it such as Golnaraghi (2011) proposed a reliable delay analysis technique that is integrated into the developed computer system delay analysis technique and integrated system .The modified isolated delay type (MIDT) analysis methods. However, the IDT overlooks concurrent delays and it is not able to track the fluctuation of the critical path throughout the delay analysis process. These factors should be addressed in delay analysis techniques to achieve more accurate and reliable results.

Abu-Osbeh presents a methodology for timely capturing and documenting delay data in a standardized, useful form. This data is then made easily accessible to delay and cost analysis modules through the integration of the scheduling program (MS Project) with the relational database (MS Access). In addition to the database and the scheduling software, the methodology includes modules for delay/acceleration analysis (apportioning project delay/acceleration between parties), cost analysis (delay/acceleration damage quantification), and a Visual Basic for applications (VBA) module. The VBA module is mainly used to automate procedures and integrate different parts of the framework.

Unfortunately the great solution presented by Golnaraghi and Abu-Osbeh did not change the situation in practice because Microsoft Prject is not suitable for construction projects for the following reasons :

1) MSP Baseline management is cumbersome and confusing for the average scheduler.
2) MSP updating method of using % Complete is not suitable for construction schedules.
3) MSP Data Date issues which in effect complicate the schedule update process are confusing for construction schedulers.
4) Because of the difficulty of using MSP to note uncompleted work before the Data Date, the difficulties in removing status for what-ifs, and the difficulty in identifying variances
between a series of MSP schedules, it is hard to do most types of delay analysis (except perhaps RP 29R-03 [6] MIP 3.1 and 3.2).
5) Because of all of the built-in update help routines that automatically insert made-up actual dates and remaining durations, it is difficult to assume that most MSP schedules contain accurate enough status data that is necessary for a detailed analysis.

Many researches has been presented to deal with the problem of lack of expert systems and software to deal with the claims and the delay analysis . Arrashid 2004 has presented Expert system for claims of ground water and soil conditions In this research, two types of claims were considered to build an expert system to help engineers and arbitrators reaching a fair solution. These types are: existence of unexpected ground water and unsuitability of the Soil for foundations claims .

To deal with the vast amount of data encountered in construction projects, computers are being utilized in an ever-increasing manner. Their use involves on-site data collection (Russell, 1993; McCullouch, 1993) and comprises a variety of project management applications, including those related to claims processing.

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Tribaldos (1994) developed an expert framework to classify delays and determine the costs associated with them. Cooper (1994) incorporated the claims-related provisions of the A.I.A. A201 general conditions document into an expert framework.

Diekmann (1984) developed a framework using AI techniques called the differing site conditions analysis framework.

Moselhi and El-Rayes (2002) developed a decision support framework that is designed to facilitate the analysis of weather-related construction claims..

A hypertext information framework to assist in claims analysis was presented by Bubbers and Christian (1992).

Some studies focused on integrating an expert knowledge base framework with existing control software to help in determining the causes of delays and suggesting actions to reduce them (Yates, 1993).

Spread sheets have been used to document site data on a daily basis and to construct as-built schedules (Hejazy, 2005a).

Alkass et al. (1995) introduced a system that integrates an expert system, a database and a project management system. The Isolated delay type (IDT) technique (Alkass and Mazerolle 1993; Mazerolle, 1993) was utilized in this framework. However, it is not a fully integrated framework and it requires frequent user interaction.

A database management system was developed to document and analyze construction claims in Kuwait (Al-Sabah et al., 2003).

Evrenosoglu (2008) suggested using relational databases in forensic delay analysis.

Conlin and Retik (1997) evaluated 16 different project management software packages. Although of all these efforts there is a need for an integrated delay analysis framework in which delay issues can be tackled in a timely manner. These delay issues include documenting delays, quantifying delay impacts on project duration, apportioning project delay responsibility/costs between parties, and quantifying delay-associated damages.

Mr. Faik Burak Evrenosoglu 2008 presents the potential uses of relational databases in delay analysis and provides a sample Microsoft Access database application. .

• Requires database knowledge to develop the tool.
• Requires reliable baseline/re baseline schedules and adequately detailed project documents.
• Requires alignment of baseline with recorded actual project data. And,
• Will require training of the administrative staff.

Current Delay analysis techniques capabilities .

The most sophisticated delay analysis method (i.e., time impact analysis) may consume much time and may incur high cost compared to simpler methods such as the as planned vs. as-built, impact as-planned, and collapsed as-built methods.. Table 1 Comparison of delay analysis methods

Table 1 : Comparison of delay analysis methods

Table 4
Comparison of delay analysis methods

	As-planned vs. as-built analysis	Impact as-planned analysis	Collapsed as-built analysis	Time-impact analysis
Availability of information				
Type of schedule				
As-planned schedule	✓	✓		✓
As-built schedule	✓		✓	✓
Updated schedules				✓
Adjusted schedules		✓	✓	✓
Fragnets		Depends	Depends	✓
Type of information				
No CPM (bar chart)	✓			
No CPM but progress record			✓	
CPM approved/not updated	✓	✓		
CPM approved/updated	✓	✓	✓	✓
Time of analysis				
Foresight		✓		
Real time		✓		✓
Hindsight, during performance period	✓	✓	✓	✓
Hindsight, after project completion	✓	✓	✓	✓
Capabilities				
Float consumption/critical path	✓/depends	✓	✓	✓
Time extension	✓	✓	✓	✓
Compensation	Depends	Depends	Depends	✓
Concurrent delay	✓			✓
Resequencing	Depends		✓	✓
Dynamic nature of CPM				✓
Acceleration	✓			✓
Time-cost-effort				
Type of analysis	Observative	Additive	Subtractive	Additive
Level of effort	Low	Low	Moderate	High

A fair and effective evaluation of delay impact is possible if the most appropriate delay analysis method is selected that provides a reliable solution with the information available and within the time and cost allocated for this purpose. Time impact analysis is clearly accepted by the literature .

Table 2 : Comparison of delay analysis methods

Table 2 Comparison of current techniques on delay types used.

Delay analysis techniques	Real time delay	Concurrent delay	Acceleration credit	Pacing dalay
Global impact	×	×	×	√
As-Planned	×	×	√	×
As Built	×	×	√	×
Impacted As-Planned	√	×	√	×
Time impact	√	×	√	×
But-for	×	√	×	×
Window-IDT	×	×	×	×
Window-snapshot	√ *	√	×	×
Window-But For	√	√	×	×
TF management	√	√	√	√

*Less accurate

None of the current techniques responds accurately to all of the four common delay issues: real time delay, concurrent delay, acceleration, and pacing

delay. The "Window/But-for" technique is found to be fairly accurate; however, it needs to be adjusted to account for accelerations. The Day-by-day technique or Total Float Management technique is the only method that can solve the issue of pacing delay sufficiently because of its ability to track the float consumption for each of the project parties. In addition, the technique is the only one that has the ability to apply the two rules of concurrent delay. Moreover, the technique follows a systematic day-by-day approach that provides accurate results, as well as the ability to be computerized, which in turn increases the analysis accuracy.
technique .
The popular and comparatively accepted methodologies include the time impact method, the collapsed as-built method and the window method (Yang et al. 2006). However, these methods are varied in analysis approaches and require different information while they are employed. For a delay case, above delay analysis may provide different results while different viewpoints took or different methods used. That is, no one method is accepted for all project participants and suitable for all situations.
Arditi & Pattanakitchamroon (2006) discussed how to select a delay analysis method and concluded that the selection of a proper analysis method depends upon a variety of factors consisting of information available, time of analysis, capabilities of the methodology, and time, funds and effort allocated to the analysis. They discussed four delay analysis methodologies, including the as-planned vs. as-built method, the impact as-planned method, the collapsed as-build method and the time impact method.

Delay Analysis Methodologies Selection Advisor .

This report present the Delay Analysis Methodologies Selection Advisor ((DAMSA) as a simple method for selection of the delay analysis methodologies .
DAMSA may be used for any construction contract either CPM based or non CPM based .
For the CPM based DAMSA considered the AACE RP and Braimah computation of suitability scores of DAM.(See Table 8.2) separated and integrated with recommended literatures according to DMSA Version .
Table 3 : Comparison of delay analysis methods

Table 3 Computation of suitability scores of DAM

Group Factor	Selection Factor	Rank index	Weight	Rating	Score
Record availability	Record availability	97.5	1.0	Rd_1	$1.0xRd_1$
Baseline programme characteristics	Baseline programme availability	84.1	0.86	Rb_1	$0.86xRb_1$
	Nature of Baseline programme	71.5	0.73	Rb_2	$0.73xRb_2$
Contractual Requirements	Updated programmes availability	69.8	0.72	Rc_1	$0.72xRc_1$
	Applicable legislation	36.5	0.37	Rc_2	$0.37xRc_2$
	form of contract	59.2	0.61	Rc_3	$0.61xRc_3$
	Dispute resolution forum	54.4	0.56	Rc_4	$0.56xRc_4$
Timing of the analysis	Reason for the analysis	61.8	0.63	Rt_1	$0.63xRt_1$
	Time of the delay	62.0	0.64	Rt_2	$0.64xRt_2$
Project characteristics	Project complexity	65.8	0.67	Rp_1	$0.67xRp_1$
	The amount in dispute	73.1	0.75	Rp_2	$0.75xRp_2$
	Size of the project	50.9	0.52	Rp_3	$0.52xRp_3$
	Duration of the project	45.1	0.47	Rp_4	$0.47xRp_4$
	Nature of delaying events	64.6	0.66	Rp_5	$0.66xRp_5$
	Number of delaying events	66.1	0.68	Rp_6	$0.68xRp_6$
	The other party to the claim.	44.7	0.46	Rp_7	$0.46xRp_7$
Cost Proportionality	Cost of using method	58.0	0.59	Rs_1	$0.59xRs_1$
	Skills of the analyst	65.3	0.67	Rs_2	$0.67xRs_2$
				Total score	$S_j = \sum w_i r_{ij}$

The results of the trials of Braimah computation of suitability scores of DAM. showed that Braimah assumption are not accurate since the ratimgs may have values when there is no need for a certain document. This assumption led to have scores even if you do not have documents at all .

Braimah computation of suitability scores of DAM was excluded from DAMSA application.

The following table present a comparison between CPM Basics with the forensic schedule analysis .
Table 4 : Comparison of CPM Basics with Forensic Analysis Methodologies.

		3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9
		OBSERVATIONAL					MODELED			
No.	CPM Basic Building Blocs	As Plan v. As Built (APAB)	Periodic APAB	As-Is Windows	Halfstep	Modified Windows	Single Time Impact Analysis (TIA)	Multiple TIA	Collapsed As Built (CAB)	Periodic CAB
1	Schedule Represents the Project's scope	Y	Y	Y	Y	Y	Y	Y	Y	*
2	Relies upon Activities' Logic	Y	Y	Y	Y	Y	Y	Y	Y	*
3	Relies upon Calculated Early and Late Planned Dates	Y	Y	Y	Y	Y	Y	Y	Y	*
4	Evaluates Critical Activities	Y	Y	Y	Y	Y	Y	Y	Y	*
5	Evaluates the Longest Path	Y	Y	Y	Y	Y	Y	Y	Y	*
6	Differentiates between Start & Productivity Delay			Y	Y	Y				
7	Evaluates Float and Near Critical Activities	Y	Y	Y	Y	Y	Y	Y	Y	*
8	Evaluates Concurrent Strings and Activities	Y	Y	Y	Y	Y			Y	*
9	Uses Graphical Bar Charts to Convey Results	Y	Y	Y	Y	Y	Y	Y	Y	*
10	Addresses Acceleration			Y	Y	Y			Y	*
11	Considers Periodic Schedule Updates			Y	Y	Y		Y		*
12	Recognizes Updated Critical Paths			Y	Y	Y		Y		*

Table 1 — Comparison of CPM Basics with Forensic Schedule Analysis Methodologies

Model for DAMSA Results. (Web Based Application) .

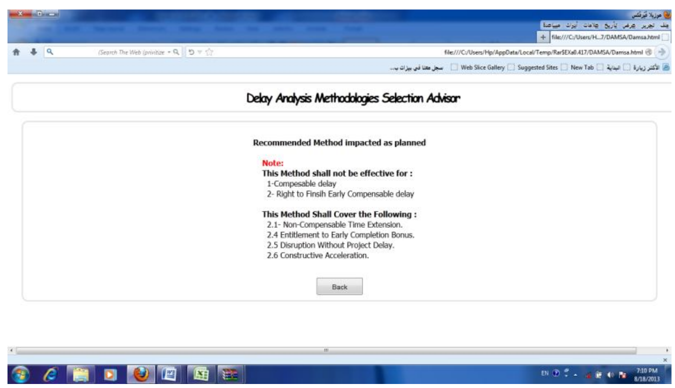

Figure 5 DAMSA results .

DAMSA Flowchart allows more comprehension of the basis for the selection in both CPM and non CPM based contract .

The system deals also with the predefined methods for delay analysis as per the contract requirements.

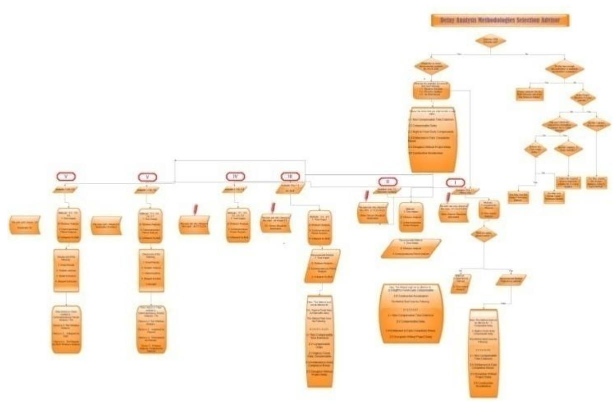

Figure 6: DAMSA Flowchart

The following table presents the concepts for DAM selection as per AACE RP.

Table 5: The documents availability , the applicable delay claim and delay analysis technique (DAM selection as per AACE RP.)

Documents Availability	Method No. as per AACE-RP	Baseline Only	As Built Only	Schedule Updates Only	Baseline + As Built	Baseline + Updates	Updates + As built	All are Available
2.1- Non-Compensable Time Extension	3.1							
	3.2							
	3.3							
	3.4							
	3.5							
	3.6							
	3.7							
	3.8							
	3.9							
2.2 Compensable Delay	3.1							
	3.2							
	3.3							
	3.4							
	3.5							
	3.6							
	3.7							
	3.8							
	3.9							
2.3 Right to Finish Early Compensable	3.1							
	3.2							
	3.3							
	3.4							
	3.5							
	3.6							
	3.7							
	3.8							
	3.9							
2.4 Entitlement to Early Completion Bonus.	3.1							
	3.2							
	3.3							
	3.4							
	3.5							
	3.6							
	3.7							
	3.8							
	3.9							
2.5 Disruption Without Project Delay	3.1							
	3.2							
	3.3							
	3.4							
	3.5							
	3.6							
	3.7							
	3.8							
	3.9							
2.6 Constructive Acceleration	3.1							
	3.2							
	3.3							
	3.4							
	3.5							
	3.6							
	3.7							
	3.8							
	3.9							

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