A Novel Approach for Delay Analysis

Mojtaba Ziaei, and Siamak HajiYakhchali

Abstract—Delay analysis and its impact on completion time of project is controversy. Several delay analysis methods have been developed to deal with this issue. Each of these methods has some assumptions, strengths and weaknesses which make them appropriate or inappropriate in some circumstances. Although, some advances are achieved in analysis the time impacts of delays, but there is a little discussion about the costs that these delays impose to projects, in a systematic way until now. In available methods some items in time analysis are not significant enough but these items play important roles in cost of projects. Some examples of these items are time value of money, non-critical activities, pacing, acceleration and mitigation. In this work we discuss about them and delay analysis methods which can handle them appropriately. At last we propose some general modifications in available techniques to deal with cost analysis in projects.

Keywords—About four key words or phrases in alphabetical order, separated by commas.

I. INTRODUCTION

Basically, projects have greatly complex situations during implementation, include many project stakeholders and interfaces, and are affected by many external factors. Therefore, delays and their claims are a common incident in projects. When delays occur, they need to be assessed rapidly and managed efficiently. However, the entire topic of delay and the several analytical techniques available is one which provokes much debate and argument due to the complicated and conflicting direction provided on them. Due to the complication of contracts and the various levels of familiarity with scheduling or delay analysis, problematical topics arise from time to time when developing or reviewing claims for additional time.

When there is disagreement over the responsibility for obnoxious delays to completion time of project, major arguments can arise due to the failure to manage the influence of change, and claims for extra time, in an appropriate or effective manner during the progress of the project.

In these circumstances there is a necessity for dependable analysis and evaluation of the delay impact which addresses quantitative, qualitative and right perspectives to ease an agreement. Much of course turns on the selection and implementation of the most suitable delay analysis technique. Delay analysis, which involves both the study and inquiry of historic events, also involves assessing which of those events actually affected the project completion time.

Uncertainty is an inherent characteristic of projects and it is well known that ‘no project is risk free’. Uncertainty can be minimized, managed, shifted, shared, or accepted. It cannot be discounted. If it is accepted that uncertainty is inherent in projects, then it must also be accepted that delays are also inherent in the process and should therefore be expected and managed and treated in a similar manner as uncertainty. When delays are happened, this is not inevitably an indication that the management or process team is breaking down. Delays are frequently simply the consequence of an event which has to be managed by a regular process so as to anticipate the influence of that event on the scheduling, and to minimize the uncertainty of additional delay. Systematic management of delay during the development of the project also guarantees that the cause of that delay is recognized, and documented, at the earliest opportunity [1].

In selecting the most proper technique to suit the project, the related facts, the timetable, the nature and number of delay events, as well as size of the possible argument to guarantee proportionality is preserved, have to all be considered. Current delay analysis methods examine delay liabilities based on delay evidences and information. In conversing how to select a delay analysis method, concluded that selecting a feasible analysis method hangs on various factors, containing availability of information, time of analysis, methodology capabilities, funds, time and effort assigned for analysis. Reference [2] says that based on an empirical study in UK, six group factors (project features, contractual requirements, features of baseline program, cost proportionality, timing of the analysis and availability of records) impact the selection of delay analysis methodologies were recognized. Briefly, while some advanced delay analysis methods have been developed, including a few commercial systems, available delay analysis methods cannot fulfill the practical requirements of delay analysis and these methods need some improvements to be completely suitable for analysis.

Delay analysis methods are known by many generic labels. Each technique can be applied in several ways and the broadly known methods of delay analysis are subject to frequent misapplication. The application of the same method by two differing experts frequently produces various and inconsistent results. The name applied to a method is not as significant as the application of that technique. Although there are many variations on the themes, all of the generally applied forensic delay analysis methods normally conform to one of the following major categories: Impacted As-Planned, Collapsed As-Built, As-Planned versus As-Built, Time Impact Analysis [3]–[4]–[5]. Many of experts also list ‘windows analysis’ as a method, but the term ‘windows’ basically refers to the period.
of time being analysed [6]. Windows can be identified at unvarying intervals (e.g. weekly, monthly) or unbalanced periods determined by the completion time of significant key tasks (e.g. the accomplishment of a key milestone). When key milestones are relied on, the same approach is occasionally referred to as ‘watershed’ analysis [7]–[8].

Each of these primary methods have many secondary derivatives, depending on the number of delays being analyzed, the occurrence and/or duration of the windows, the time periods being analyzed, and whether they are to be applied prospectively (simultaneous, forward-looking, predictive modeling) or retrospectively (forensic, after the fact analysis, as-built delay modeling) [1].

The objective of delay analysis is to satisfy the problem of founding ‘cause and effect’. Whether the analysts take on the analysis starting from the cause or the effect is a factor which must be considered when determining whether a prospective or retrospective forensic technique of analysis is utilized. The cause is the event, factor, or circumstance which resulted in a potential delay to completion time of the project. When an actual delay has been experienced, the effect is a delay period which is calculable in some way, using the available as-built progress documents, achieved milestones or scheduling information.

Commencing with the ‘cause’ requires the analyst to identify the most possible effect of that event. Otherwise, starting the analysis based on the actual delay experienced (the ‘effect’), needs one to work backwards, by determining the most possible ‘cause’ of that effect.

### TABLE I

<table>
<thead>
<tr>
<th>General Approach</th>
<th>Primary Method</th>
<th>Secondary Derivative Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additive</td>
<td>Collapsed As-Built</td>
<td>Chronological Insertion of Delays (one at a time)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gross Insertion (all delays at once)</td>
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<tr>
<td></td>
<td></td>
<td>Windows Analysis (delays in each window)</td>
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<td></td>
<td></td>
<td>As-Built Critical Path Deduction</td>
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<tr>
<td></td>
<td></td>
<td>Total Time Claim (gross difference)</td>
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<tr>
<td></td>
<td></td>
<td>As-Planned vs. Contemporaneous Updates</td>
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<tr>
<td></td>
<td></td>
<td>Gross time reconciliation (total time claim)</td>
</tr>
</tbody>
</table>

Delays to completion can be characterized as being either ‘excusable’ or ‘non-exusable’ and ‘compensable’ or ‘non-compensable’. The likely effect of these events is summarized in the Table II:

### TABLE II

<table>
<thead>
<tr>
<th>Type of Event</th>
<th>Employer Risk Event (ERE)</th>
<th>Contractor Risk Event (CRE)</th>
<th>both CRE and ERE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excusable</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Non-Excusable</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Compensable</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Non-Compensable</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

Firstly, risk events can be at either the employer’s risk or the contractor’s risk and are defined below for ease of reference:

- Employer Risk Event (ERE) – an event, cause or circumstance which, under the Contract (or by subsequent determination of a formal court), is at the risk, liability and the responsibility of the owner.
- Contractor Risk Event (CRE) – an event, cause or circumstance which, under the Contract (or as later formally determined), is not at the risk, liability and the responsibility of the owner.

Secondly, delay events can be either ‘excusable’ or ‘non-excusable’, depending on who is responsible for the risk of the event, circumstance or cause which contributes to the delay.

- Delay Event – a CRE or ERE which is found to contribute to delay to either planned or contract completion.
- Excusable Delay – a delay event caused by an owner risk event which extends planned completion (whether that date is earlier, or later, than the Contractual date for project completion).
- Non-Excusable Delay – a delay event caused by a contractor risk event, which could have been prohibited, or was a consequence of a breach of Contract or contractor’s negligence (e.g. actions of domestic subcontractors).

Thirdly, and debatably the most challenging to determine, are the periods of time in which time-related delay damages are recoverable and the periods in which they are not. These are classified as ‘compensable’ or ‘non-compensable’ time windows. A compensable delay is one where damages, in the form of straight time-related costs, as well as indirect time-related costs (site or head-office overheads), are recoverable under the contract.

- Compensable Delay – a period of time during which a critical delay event is happened which is:
  - an owner risk event; and
  - expressly identified as being recoverable under the contract terms and conditions.
- Non-Compensable Delay – a period of time during which a critical delay event is happened which is:
  - a contractor risk event; and
  - not expressly identified as being recoverable under the contract terms and conditions.

The term ‘neutral’ event has emerged in recent years. A neutral event is an excusable and non-compensable event which may lead to the contractor being awarded time, but no
Time impact analysis is based on the effect of delay events on the contractor’s purposes for the future conduct of the work in the light of advancement actually achieved at the time of the delay event and can also be used to support in resolving more complex delay scenarios involving concurrent delays, acceleration, mitigation, and disruption. It is also the best method for determining the amount of addition of time that a contractor should have been granted at the time an owner risk event happened. In this condition, the amount of addition of time may not accurately reflect the actual delay imposed by the contractor. That does not mean that time impact analysis produces hypothetical results — it makes results showing entitlement.

**B. Collapsed As-Built**

Collapsed as-built is a subtractive technique based on the effect of owner risk events on the scheduling of work as it was actually built. Similar to the as-planned versus as-built, the use of this method is restricted by its incapability to identify concurrency, re-sequencing, reallocation of resources or acceleration. This is particularly the case when the nature of the as-built logic is complicated, requiring subjective reconstruction of as-built logic. Where acceleration, reallocation of resources or re-sequencing has taken place during the course of the works to overcome the effects of events, this form of analysis may generate unreliable outcomes.

Some other methods are listed below:
- As-built based methods of analysis
- As-planned versus as-built windows analysis
- Contemporaneous windows analysis
- Month-to-month update analysis

**III. PROBLEMATIC ISSUES**

A number of problematic issues which arise in connection with both scheduling and delay analysis are considered. The main issues reviewed are float and its implications in delay claims, concurrency, the requirement for scheduling to be approved, and onerous specifications. Other topics reviewed, and which are related with scheduling in the field of delay analysis, include acceleration and delay mitigation, pacing, contractors’ entitlement to early completion and the assessment of disruption damages.

**A. Float**

Float is an integral part of critical path method scheduling and delay analysis and it is a relative quantifiable value which can and should be treated as a resource, like money. Float is a finite resource and "Who owns the float?" is a significant question which the answer could be contractor, owner or the project (first come- first served).

**B. Concurrency**

One of the most problematic issues which arise in the analysis of construction delay impacts is that of concurrency as it relates to delay and compensation for prolongation. Concurrent delay is a period of project over-run which is caused by two or more effective causes of delay which are of equal causative influence. Not only will there often be several delay events running in parallel, but there may be parallel critical paths to contend with, and also periods of acceleration and/or mitigation to take into account. There are various approaches to deal with concurrency such as the first-in-line approach, the dominant cause approach, and the apportionment approach.

**C. The Concept of Pacing**

When concurrent culpable delays are identified by the owner, contractors mostly argue that they were simply 'pacing the work'. For example, when designers are late with
Delays are ignored in calculating the cost because they have no impact on completion time of the project.

C. Pacing

When pacing the work happens in a project from both owner and contractor, they responded just-in-time, and there was no reason to hurry up and wait. Both the owners and contractors can argue that their delays were not relevant because they were simply pacing their work with pre-existing delays, and both of these scenarios are sometimes valid.

To solve the problems which deal with pacing, acceleration or mitigation we must fortify the contract to restrict the following possible arguments (i.e. all possible conditions that might be happened must be taken into account in contract) and use the more capable methods such as Time-impacted analysis.

V. PROPOSED SOLUTIONS

In such situations which there is various interruptions in performing all activities as well as require, and some qualities and timings are misdirected, we want to evaluate the cost of all these unpleasant events. If some improvements are been performed on the available methods, we can anticipate that the analysis is more conformed with the real suffered cost to the project. These improvements are as follows:

A. Using weights for activities on critical and non-critical paths

Undoubtedly, delays for critical activities due to postponing the completion time of project are very important and can impose a large amount of additional cost to the project. If a project complete later than planned time, the owner deal with losing opportunities and customers dissatisfaction. But the point that has not been ignored is delays for non-critical activities suffer additional cost to project, too. However, these costs are greater for critical activities. For solving this problem we can use weights for critical and non-critical activities. To do this, we should use \( \alpha_1 \) for critical and \( \alpha_2 \) for non-critical activities which \( \alpha_1 \) is greater than \( \alpha_2 \) due to larger impact on delay costs. In this way, we consider both critical and non-critical delay costs suitably. For example, consider the following scheduling:

For example, in Fig. 1 If a delay occurs for 9th activity (Warehouse software analysis design) with duration of 2 months, completion date of the project does not change and in available delay analysis methods does not count, but cost of this delay have to be taken into account. However, if the same delay happens for first activity (Financial software analysis) due to straight impact on project completion, is accounted in available methods. The difference between these two conditions returns to critical and non-critical activities. According to this work, we have to consider both of them, not
the second one only. Although the second delay has greater impact on costs of project such as straight cost of the delay, loosing opportunities and dissatisfaction of customers due to postponing the completion time of the project but the point is that the first delay has some impacts on costs of project, too. We must consider both of them proportionately not only the more important delay. If we consider the \( a_1 \) weight for critical activities and \( a_2 \) weight for non-critical activities while \( a_1 > a_2 \), we can handle this issue.

B. Using Engineering Economy Techniques for Calculating Time Value of Money

As we mentioned earlier, delays which occur in first days after starting a project have greater impact on costs of the project due to 'rate of return'. For example, after completion time of project that we calculate costs for each party, we should not consider earlier and later delays which might be several years between them as the same. The money which we lose a few years ago has greater value in present time related to the latter ones. So, we have to use formulas that evaluate the present value of money. Regarding Fig. 2 we have the following equation:

\[
F = P(1 + i)^n
\]

Where:

- \( F \) and \( P \) are 'future value of money' and 'present value of money' respectively; \( i \) is 'rate of return' and \( n \) is time units that passed from a delay occurrence.

We can use this formula for monthly calculation that in these cases, rate of return for each month must be calculated. According to above, any delay in payments have to be recalculated relating to delay time and rate of return. For this, some assumptions must be considered:

- Allowable time and possible ways for each party for payments is mentioned in contract.
- If payments in any stage in not accomplished, the value recalculate in the next with respect to rate of return.

Although, it seems that the difference between this method and available methods is small and unnecessary but in projects with a lot of activities which need great time to accomplish, this difference could be very significant.

Consider previous example, if we have a delay on the first activity and this delay suffer 'A$' to the project and have a delay on the last activity of the project with 'A$' cost, because of passing 20 months from activity 1, the A$ for it, has a greater impact on total cost of the project due to time value of money. If we suppose that rate of return is equal to 1% monthly, the real cost that the first delay imposes to project is equal to:

\[
A(1 + 0.01)^{20} = 1.22A
\]

Therefore, the more passing times from a delay the more costs suffer to the project.

We should use all of techniques that are available in engineering economy to calculate the real impact of a delay on projects and without this consideration all estimations are kind of misleading.

VI. CONCLUSION

Delay analysis and its impact on completion time of project is a debatable issue. Several delay analysis methods have been developed to deal with this. Each of these methods has some assumptions, strengths and weaknesses which make them appropriate or inappropriate in some circumstances. Although, some advances have achieved in analysis the time impacts of delays, but there is no discussion about the costs that these delays impose to projects, in a systematic way until now. Some items in time analysis are not significant enough in evaluating available methods but these items play important roles in cost of projects. Some examples of these items are time value of money, non-critical activities, pacing, acceleration and mitigation. In this paper we have discussed about them and delay analysis methods which can handle them appropriately. Some engineering economy techniques are used to evaluate the cost of delays precisely and all of available methods can be developed with this approach. For declaring the importance of non-critical activities, we use weights so that the differences between them and critical activities become more obvious. We can incorporate these two modifications into available techniques to obtain more reliable results.

REFERENCES
