An Overview of Various Techniques and Approaches of Concurrent Delay Analysis in the Sri Lankan Construction Industry

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Abstract— Concurrent delay is a very complex and controversial topic in the construction industry. Analysis of the concurrent delays became challenging due to the absence of clear provisions in the standard form of contracts. Meanwhile, project parties try to pass the contractual liability to the other parties and make the situation more problematic. The lack of knowledge on the concurrent delay analysis procedure among project parties would be another reason to increase the complications. Even though various delay analysis techniques and approaches are available in the construction industry, all of them cannot be used to assess any concurrent delay situation. Hence this study aims to investigate the adaptability of various techniques and approaches for concurrent delay analysis in the Sri Lankan construction industry. The research was conducted based on expert interviews by adopting a qualitative research approach. The collected data was analysed via content analysis using NVivo software. Research findings revealed that the lack of proper record-keeping, the ambiguity of concurrent delays, and the lack of advanced scheduling software as the main challenges of concurrent delay analysis in the Sri Lankan construction industry. Further, the time impact analysis method and window analysis method are the most recommended Critical Path Methods (CPMs) for concurrent delay analysis in the Sri Lankan context. However, in some cases, one CPM is not adequate to analyse the entire delay of a project and research findings recommended to use a combination of CPMs in such situations. Ultimately, the study concluded that the selection of concurrent delay analysis techniques depended on the type of construction schedule of the project and available project records.

Keywords: *concurrent delays, delay analysis techniques and approaches, critical path method, construction industry*

I. INTRODUCTION

In the construction industry, a delay is a time overrun either beyond the completion date specified in the contract or beyond the date that the parties agreed upon for delivery of a project (Shahsavand, Marefat & Parchamijalal, 2018). However, it is a very common feature in the construction industry that the projects are unable to be completed within a stipulated period and the consequences of the delays will lead to ineffective cost and quality optimisation (Tahir, Haron, Alias & Diugwu, 2017). Delays in construction projects are extremely expensive and result in severe damages to the involved parties (Dinakar, 2014). The main causes of construction delays are considered as conflicts and disputes among project parties (Braimah & Ndekugri, 2008). Kraiem and Diekmann (2002) classified construction delays into three major types based on the liability as compensable, excusable and non-excusable. Irrespective of a project being small or large in scale, a combination of the above delay types is very often seen in construction projects which can be recognised as concurrent delays (Baram, 2005).

There are no such standard or coherent definitions for concurrent delays, due to their complex nature. But Munvar, Mengistu, and Mahesh (2020) described that in concurrent delays, two or more independent delay events should occur at the same time, one being an

employer's risk event and the other one is a contractor's risk event. Concurrent delay analysis is an extremely complex task. Past researches identified various techniques and approaches to analyse concurrent delays in construction projects. Perera and Sudeha (2016) pointed out that delay analysts can either use one or a combination of delay analysis techniques to analyse concurrent delays since it is more complicated. Even though various delay analysis techniques are available in the industry, all of them are not suitable to analyse all of the concurrent delays (Al-Gahtani & Mohan, 2011). However, some analysis techniques and approaches are well-suited for concurrent delay analysis but most of the organisations are unable to use them practically since they are lacking with technical analysis facilities.

Therefore, it is necessary to review the requirements, essential records and process of concurrent delay analysis techniques and approaches specific to the Sri Lankan context to enhance the performance of construction projects. Hence, this study aims to investigate the adaptability of different techniques and approaches for concurrent delay analysis in the Sri Lankan construction industry. To fulfill the research aim, objectives were identified; critically review the popular concurrent delay analysis techniques and approaches in the construction industry, explain the current practices and challenges of concurrent delay analysis in the Sri Lankan context, assess the suitability of various concurrent delay analysis techniques and approaches to the Sri Lankan context and finally, appraise the significance of different contemporary records required by delay analysis techniques towards effective delay analysis in Sri Lanka.

II. LITERATURE REVIEW

A. Concurrent Delays

Concurrent delays can be considered as one of the notoriously problematic areas in construction law and the most complicated and controversial kind of delay dispute due to its nature (Bubshait & Cunningham, 2004). In concurrent delay claims, contractor party or other project parties can cause project delays and the impact and remedies vary from case to case (Bubshait & Cunningham, 2004). O'Leary (2014) addressed complications of concurrent delays such as no agreed definition of what is meant by concurrency and how it should be interpreted and applied.

B. International Protocols on Concurrent Delays

There are two published well-known international protocols for concurrent construction delays; (i) The Society of Construction Law (SCL) Delay and Disruption Protocol and (ii) Association of the Advancement of Cost Engineering International (AACEI)-International Recommended Practice No. 29R-03 Forensic Schedule Analysis Protocol. However, the Fédération Internationale Des Ingénieurs-Conseils (FIDIC) 1999 version was silent on this concurrent delays in construction projects but FIDIC 2017 version requires project parties to adopt rules and procedures to deal with concurrent delays through the special provisions.

C. Concurrent Delay Analysis

Construction delay analysis will be conducted to calculate the project delays and allocate responsibility among respective parties of the project. According to Rankin, Rosenberg, and Fick (2018) in the analysis of concurrent delays, the following three steps should be followed by analysts; i) Identify the critical path ii) Establish where it has been delayed and iii) Determine what events caused by these critical events. Hence this analysis process needs a general critical path delay analysis method. Eventhough various delay analysis techniques are available in the industry, mostly critical-path methods are popular among analysts and project parties (Yang, Huang & Lee, 2010). However, none of these techniques are perfect and have some limitations (Yang & Tsai, 2011). The below-discussed delay analysis techniques are most commonly used in the construction industry to analyse delay events (Yang, Huang & Lee, 2010).

1) As-planned vs. as-built method

This method can be identified as a traditional delay analysis method that reviews the change of work to determine where and how the revisions were incorporated in the schedule (Salunkhe & Patil, 2013). This method simply compares the activities of the as-planned CPM baseline schedule with the as-built schedule for a detailed assessment of the delay (Ndekugri, Braimah, & Gameson, 2008).

2) Collapsed as-built method/but-for method

This method uses an as-built schedule as a basis for analysis comparison and then eliminates delays from the as-built schedule to collapse the schedule (Yang & Yin, 2009).

3) Window-based delay analysis method

The window-based analysis method divides the construction period into discrete time increments called "windows" and examines the effects of the delays attributable to each project party.

4) Time impact analysis method

This method updates the as-planned programme by imposing each delaying activity in succession and disregarding any concurrency of delaying activities (Ng, Skitmore, Deng, & Nadeem, 2004).

5) Adjusted as-built method

This method can be implemented by only using the as-planned schedule. In this method, first create an adjusted as-built schedule by linking the delaying events to the relevant activities. Then it compares the completion dates in the as-planned schedule and adjusted the as-built schedule to decide the delay period to identify the difference between the two schedules (Alkass, Mazerolle & Harris, 2002).

6) Snapshot method

The snapshot method can be considered as one of the logical and accurate methods for delay analysis. This method is using the window concept and analyses delays by dividing the schedule for specific periods. Here, the as-planned schedule is used as a baseline schedule. After adding delays to the schedule and dividing it into specific snapshots and compare each snapshot with the original as-planned schedule (Al-Gahtani, & Mohan, 2011).

After calculation of the concurrent delay by employing the above CPMs, the next step is the allocation of responsibility of concurrent delays among project parties (Pappalardo & Spa, 2006). This can be implemented by referring to the contractual provisions of respective projects. Unfortunately, the contracts often do not include the relevant provisions specially in the Sri Lankan context and it becomes necessary to refer to the governing laws of the country. However, Gunarathna (2016) identified that, available concurrent delay analysis approaches which were used to allocate the responsibility of concurrent delays were developed through past case laws such as apportionment approach, first-in-line approach, but-for test, dominant cause approach, and Malmaison approach.

D. Contemporary Records

Contractors are submitting delay claims with an average of 60% success rate in Sri Lanka and the remaining 40% is unsuccessful due to inadequate documentation and failures due to the improper selections of the delay analysis techniques (Ramachandra, Rotimi & Gunaratne, 2014). The unavailability of contemporary project records may constrain the selection of the most appropriate delay analysis technique specially in analysing concurrent delays (Dinakar, 2014). SCL protocol and also some previous researches identified required contemporary records to analyse concurrent delays using different techniques (refer Table 3). As per the literature review, the updated construction schedule is the essential project record to analyse concurrent delays.

III. RESEARCH METHODOLOGY

The qualitative research approach was adopted in this research based on interpretivism research philosophy. Accordingly, literature synthesis was conducted to critically review the popular concurrent delay analysis techniques and approaches in the construction industry as a secondary data collection method. Further, appraisal of the significance of different contemporary records required to delay analysis techniques and approaches were partially revealed through the literature synthesis. Thereafter expert interviews were conducted to identify the current practices and challenges of concurrent delay analysis in the Sri Lankan context. Expert interviews were designed as semi-structured interviews conducted online for about 30–45 minutes. The reason to select the semi-structured interviews for expert interviews was to offer the freedom for interviewees to contextualise the data. Accordingly, six experts were interviewed who are having more than 15 years of experience and comprehensive knowledge of delay analysis of construction projects. Experts were selected using the convenient sampling method. The demographic data of the interviewees were presented in Table 1.

Table 1. Details of interviewees

Interviewee Code	Designation	Organization Type	Experience
ER-01	Company Director	Consultant	43 Years
ER-02	Senior Quantity Surveyor / Lecturer	Consultant	21 Years
ER-03	Quantity Surveyor / Lecturer	Consultant	19 Years
ER-04	Contract Specialist	Consultant	15 Years
ER-05	Contract Specialist	Consultant	18 Years
ER-06	Company Director / Claims Specialist	Consultant	45+ Years

The data collected from the expert interviews were subjected to content analysis using the NVivo software.

IV. RESEARCH FINDINGS

The analysis at a glance is presented in Figure 1.

A. Concurrent Delay Analysis

All the interviewees defined concurrent delay commonly as "a situation in a construction project where the impact of two different delay events occurs simultaneously whereas the employer/engineer is responsible for the one event and the other one by the contractor." The interviewees recommended that both CPMs and legal approaches should be employed for the successful analysis of concurrent delays, specially in the Sri Lankan context. The main reason for using a mix of techniques and approaches is due to the difficulty of analysing the ultimate responsibility in concurrent delays. However, this research confirmed that in the Sri Lankan context only 20% of concurrent delay cases are using CPMs for delay analysis. Further legal approaches can be prioritised when the construction programme are not standard and advanced enough to carry out a critical path analysis and when there are not available project records to analyse the impact on the critical path.

B. Challenges Encountered in Concurrent Delay Analysis

Based on the expert interviews results, six key challenges were identified in the concurrent delay analysis in the Sri Lankan context. The main issue faced by delay analysts was the unavailability of updated construction schedules of the projects. Further, interviewees argued that analysing concurrent delays require specialised and high-quality scheduling and programming software such as Primavera, Microsoft Project and etc. Unavailability of such advanced scheduling and programming licensed software in the Sri Lankan context also leads to complications of concurrent delay analysis. Interviewees further investigated that, even though all other requirements were fulfilled, it is not successful to analyse concurrent delays properly due to lack of sufficient analysis knowledge and skills of delay analysts. Similarly interviewees accepted that same definition for concurrent delay is always not applicable to each and every delay events in the projects and due to this ambiguity in concurrent delays also lead to analysis complications. Further lack of contractual provisions in standard forms of contracts becomes a key challenge in concurrent delay analysis.

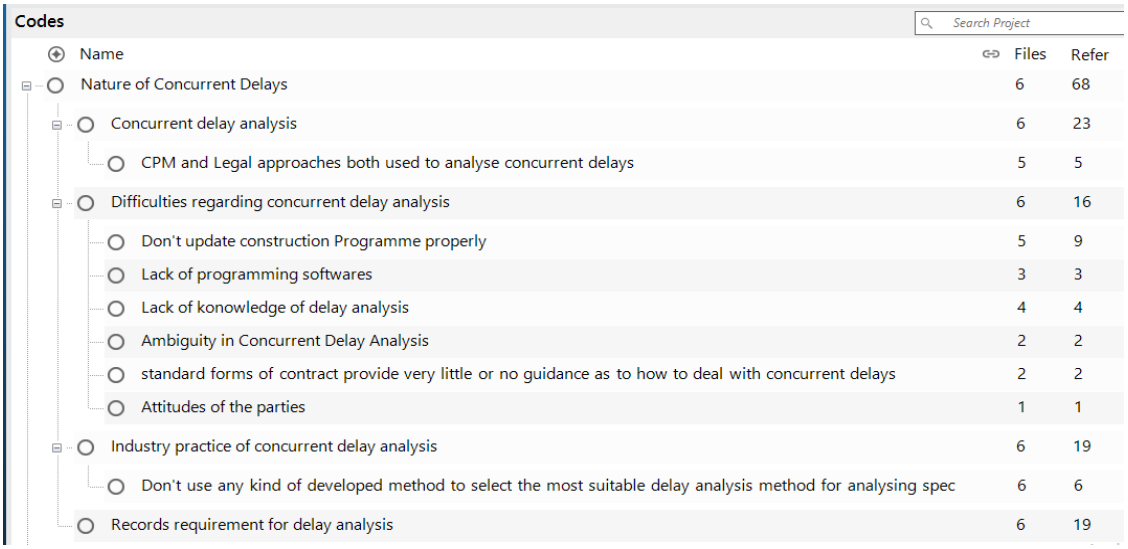

Figure 1. NVivo codes of expert interviews

C. Concurrent Delay Analysis Techniques

Past researchers who conducted researches on delay analysis and concurrent delay analysis, identified the most suitable delay analysis techniques specifically for concurrent delay analysis. Further, these selected techniques were contextualised via expert interviews to select the most suitable delay analysis techniques for concurrent delay analysis in the Sri Lankan construction industry. Table 2 presents the opinions of past researchers regarding the most suitable delay analysis techniques for concurrent delay analysis and expert opinion on the most suitable concurrent delay analysis techniques to the Sri Lankan context.

Table 2. Suitable Delay Analysis Techniques for Concurrent Delay Analysis in Sri Lankan context

	As-planned vs as-built method	Collapsed as-built method / But-for method	Window-based method	Time impact analysis method	Adjusted as-built method	Snapshot method	Additional proposed methods
Literature Review							
Kraiem and Diekmann (2002)							Easy rule and fair rule
Alkass et al. (2002)		✓			✓	✓	
Gothand (2003)			✓				
Ng et al. (2004)				✓		✓	
Kim et al. (2005)			✓				
Mbabazi Hegazy and Saccomanno (2005)							Moderated but-for analysis method
Adhikari et al. (2006)				✓			
Arditi et al. (2006)	✓			✓			
Menesi (2007)			✓				Moderated but-for analysis method and window methods
Al- Gahtani et al. (2011)		✓	✓			✓	Moderated but-for analysis method and window methods
Expert Interviews							
ER-01		✓	✓	✓		✓	
ER-02		✓	✓	✓		✓	
ER-03			✓	✓		✓	
ER-04			✓	✓			
ER-05		✓	✓	✓		✓	
ER-06		✓	✓	✓		✓	

Based on the literature survey results, out of six popular delay analysis techniques, only four analysis techniques were identified by the past researchers as the most suitable for concurrent delay analysis. Those are collapsed as-built method/ But-for method, window-based method, time impact analysis method and snapshot method. Out of these four techniques, the window-based method and time impact analysis method were identified as the most suitable delay analysis techniques to the Sri Lankan context through expert interviews.

The snapshot analysis method is a type of window analysis method and analysts are practically considering one to two months as one snapshot. Eventhough the snapshot method is extremely suitable for analysing concurrent delays, this is not popular among the Sri Lankan construction industry. The window analysis method was identified as one of the most suitable methods for analysing concurrent delays in the Sri Lankan context. Here, the new completion date will be compared with the as-planned completion date to determine the delay of respective windows of the construction schedule. Further, all experts recommended the time impact analysis method as the other most accurate delay analysis method to analyse concurrent delay events in the Sri Lankan context. Experts justified that, when incorporating each delay into an updated CPM baseline schedule sometimes they use a 'fragnent' or sub-networks. Further the experts witnessed that, the SCL delay analysis protocol also recommending time impact analysis for concurrent delay analysis. The collapsed as-built method/ but-for method was introduced as a method of choice when the contractor is lacking an acceptable construction schedule of the project or when the as-planned schedule was not required by the contract. This method subtracts all delays from the as-built programme and determines the earliest date that the contractor can complete the project, but for the delay, events relied upon.

In addition to that, experts recommended the Malmaison approach and apportionment approach as the most viable legal approaches for concurrent delay analysis in the Sri Lankan context for the allocation of delay responsibility. The Malmaison approach reflects on the allocation of risk agreed by the parties when they entered into the contract.

D. Contemporary Records Required to Analyse Concurrent Delays

Experts reviewed the construction schedules as the key records required for concurrent delay analysis which decides the analysis method based on the available types of construction schedules. Further construction schedule should be precisely updated and able to draft the as-built schedule from that. Contemporary records required by each analysis technique which were identified in the expert interviews were presented in following Table 3.

V. DISCUSSION

SCL and AACEI delay analysis protocols defined that, concurrent delays are comprised of two instances of delay events. Similarly, experts revealed that there should be two delay events in concurrent delays where those events should not be simultaneous but the impact sould be simultaneous. CPMs are the most scientific methods to analyse the impact of concurrent delays as recommended by the SCL protocol. But experts indicated that unfortunately in the Sri Lankan construction industry, there is a lack of record maintenance specially the updated project schedules. Project schedules are not detailed hence not advanced enough to conduct proper CPMs in the Sri Lankan context. As per the expert opinions, in most of the concurrent delay events, a basic schedule analysis was conducted to calculate the delay period and distribute the responsibility based on common sense and negotiation among project parties.

Table 3. Contemporary Records Required to Delay Analysis Techniques

	Time impact analysis method	**Window analysis method**	**Collapsed as-built method/ But-for method**	**Snapshot analysis method**
Literature Review				
Yang, Kao, and Lee (2006)	As-built schedule	As-built and As-planned schedule	As-built schedule	As-built and As-planned schedule
Yang and Kao (2009)		As-planned schedule, as-built schedule, and identified liability documentations		As-planned schedule, as-built schedule, and identified liability documentations
Yang and Yin (2009)			As-built schedule	
Construction Management Guide (2011)		As-built schedule and As-planned schedule	As-built schedule	
SCL (2017)	Logic linked baseline programme, Updated programmes or progress information required to update the baseline programme	Logic linked baseline programme, Updated programmes or required to update the baseline programme	Logic linked as-built programme	
Magdy, Georgy, Osman, and Elsaid (2019)	As-built schedule	As-built schedule	As-built schedule	
Expert Interviews	Latest adjusted schedule before delay events	As-planned schedule (Not essential logic linking to the schedule)	Logic linked As-built programme	Logic linked as-planned programme

However ER-03 and ER-05 revealed that, most of the time construction projects are using CPMs to analyse concurrent delays in the global context specially in the Middle Eastern construction industry but unlikely in Sri Lanka. Further, based on the experience, the experts highlighted that mostly a combination of delay analysis methods was used in concurrent delay analysis to investigate the impact on cost and quality. Moreover, literature and experts were identified that every CPM cannot assess the concurrent delays and only a few methods are well-suited for it. Even though literature interpreted that legal approaches are suitable to analyse concurrent delays, the experts highlighted that in the Sri Lankan context legal approaches are not very popular.

VI. CONCLUSION

Concurrent delay analysis is mainly consisting of two stages; (i) CPM analysis and (ii) assignment

of responsibility among project parties. There are several CPMs are available to analyse delay events in construction projects. The most recommended four CPMs by the past researchers to analyse concurrent delays are (i) the snapshot analysis method (ii) the window-based analysis method (iii) the time impact analysis method and (iv) collapsed as-built method/but for method. Further experts identified the most suitable two key CPMs to analyse concurrent delays in the Sri Lankan context as window analysis method and time impact analysis method. However, experts recommended using a combination of CPMs to analyse concurrent delays once it is not sufficient to use one CPM alone based on the nature of the delay event. According to the expert opinions, the most difficult task would be the assignment of responsibility of concurrent delay among parties and several legal approaches were developed based on the past case laws. However, the Malmaison approach was extremely useful in Sri Lankan projects. The collapsed as-built method is the only subtractive method that is proceeding to subtract delays from the as-built schedule and the remaining three methods are additive and starting with the as-planned schedule. Moreover, the window analysis method and snapshot analysis method evaluate the interim assessment of delay on updated schedule at a specific period of the project. However, the time impact analysis method is unique since it focuses on a specific delay or delaying event but not on periods containing delays or delay events.

In concurrent delay analysis, project parties faced some challenges in the Sri Lankan context such as lack of project records for analysis, lack of scheduling and programming software, lack of knowledge and skills of delay analysts, the ambiguity of concurrent delays, lack of contractual provisions in standard forms of contracts and attitudes of the project parties on concurrent delays. Lack of project records will be the featuring challenge among them specially in the Sri Lankan context. To promote effective concurrent delay analysis among the Sri Lankan construction industry, practitioners should come up with some strategies to overcome such challenges. Experts highlighted the requirement of contemporary records for concurrent delay analysis specially the schedule with updates. There are three types of schedules in concurrent delay analysis; (i) as-planned schedule (ii) as-built schedule and (iii) adjusted schedule. Moreover, the selection of delay analysis techniques depends on the nature and availability of these types of schedules. However, the success of the concurrent delay analysis always depends on the satisfaction of the project parties regarding the apportionment of responsibilities among them. Therefore to prove the responsibility and to argue on the decision, it needs comprehensive project records.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

- CPM - Critical Path Method
- SCL - The Society of Construction Law
- AACEI - Association of the Advancement of Cost Engineering International
- FIDIC - Fédération Internationale Des Ingénieurs-Conseils

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