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Standardization of highway construction delay claim analysis: A highway bridge case study

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STANDARDIZATION OF HIGHWAY CONSTRUCTION DELAY CLAIM ANALYSIS – A HIGHWAY BRIDGE CASE STUDY

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ABSTRACT

Highway construction efficiency is critical to highway users such as the trucking industry given today's era of shortages in funding, and given the need for major re-investments in the highway system. One topic that can add to project costs relates to delays and how contractors are reimbursed for such delays. Delays are common in construction, especially in complex heavy highway and other infrastructure projects, and the claims they generate have negative effects on project schedules and costs. In spite of this, the analysis of claims is hindered due to the variety of methods and analysis techniques in use and lack of standardization in the incorporation of delay claim analysis methods in construction contracts. This paper reviews different methods for delay claim analysis and outlines their advantages and disadvantages. A case study of a bridge project is used to demonstrate the potential for manipulation by using different methods for the same delay case. The analysis shows clearly that a standardized process for delay claim analysis would improve highway construction contracting. Research needs to create a standardized process are outlined.

INTRODUCTION

Highway construction effectiveness and efficiency is very important to highway users, including both commercial and personal users, given today's era of shortages in funding, and given the need for major re-investments in the highway system. One topic that can add to project costs relates to delays and how contractors are reimbursed for such delays. This article addresses some of the issues related to delays analysis and how these delays are evaluated. The method of analysis can affect how much reimbursement contractors receive.

Delays are common in highway construction projects, especially in heavy civil and infrastructure construction and rehabilitation projects (Thomas, Hester, Hunter & Logan, 1985; Aibinu & Jagboro, 2002; Assaf & Al-Hejji, 2006; Haseeb, Xinhai-Lu, Bibi, Maloof-ud-Dyian & Rabbani, 2011). The resulting claims impose costs on all contractual parties and can create a poor image for the construction industry (Kaliba, Muya & Mumba, 2009). Claims are notably serious for the heavy construction industry, especially for roads and bridges because of their public ownership, complexity and size. This is why state transportation agencies stress timely completion of projects,given major impacts on the economy, public welfare, and safety (Ellis & Thomas, 2002).

The analysis of delays and schedule exceptions is important to explain the factors causing them, especially the magnitude, impact and significance of the variations between the baseline and operating schedules (Majerowicz, 2001; Arcuri, & Hildreth, 2007; Henschel & Hildreth, 2007). Tools for analyzing schedule impacts and use of the critical path method (CPM) for analysis are needed to analyze delay claims. This paper reviews current methods and provides a case study to identify and explain the differences between analytical and forensic techniques. The following case study is realistic, but is based on a hypothetical situation to protect sensitive information and to facilitate the use of the information required for the comparison of methods. The results of the analysis and case study are used to provide a recommended process for standardization of delay analysis methods. The methods examined include the As-planned vs. As-built method, Impact As-planned, Collapsed As-built, Time Impact Analysis and Schedule window Analysis.

DELAY-BASED CLAIMS IN ROAD AND BRIDGE CONSTRUCTION PROJECTS

Origins of Delay Claims

Delay claims originate from several sources during the various phases of construction projects. The origins of delay claims could be changes, disruptions, and uncoordinated accelerations, among others that also result in added time and cost on projects. In general, delays can be a direct or indirect result of the following:

- Design Changes: Any additions, deletions or revisions to the project scope that affect the project cost or schedule (Ibbs, Wong & Kwak, 2001). Other changes and definitions are in the literature (Lee, 2007; Hanna, Camlic, Peterson & Nordheim, 2002; Schwartzkopf, 2004; FHWA, 2001).
- Disruptions: actions or events that affect a party (e.g. contractor) from executing all or part of the planned work and which negatively affect productivity (McDonald & Zack, 2004). Other definitions are mentioned in Finke, 2000; Meyer, 1994; Hanna, Lotfallah & Lee, 2002.
- Acceleration: having more work to perform in the same project time period or having to perform the same work in a shorter project time (Thomas, 2000). Acceleration is usually a root cause for other claim sources, such as overtime, over-manning and congestion, and shift work. Acceleration techniques usually are accompanied by added costs and higher accident rates.
- Weather: delays caused by weather can affect not only schedules but also productivity due to worker inability to work in such extreme conditions as high and low air temperature, wind, humidity, air movement, and heat radiation (Hancher & Abd-Elkhalek, 1998).

Types of Delays

Schedule delay types have been classified in several ways. Most writers classify them according to responsibility and compensability as in four categories: excusable, non-excusable, compensable, and concurrent delays (Kraiem & Diekman, 1987; Trauner, 2009; Zack, 2000; Zack, 2006). Brief definitions follow:

- Excusable Delays: Delays attributable to unforeseen events that are beyond the any party’s control without any fault or negligence e.g. floods, strikes, government regulations, or in some cases it is differing site conditions. Recovery from these delays varies between granting time extensions and offering some compensation. Most of the industry is leaning towards time extensions only.
- Non-excusable Delays: Delays attributable and caused by the actions, inactions, or fault of the contractor, their subcontractors, or their suppliers. These delays do not entitle the contractor to a time extension or any compensable recovery for delay damages. These force the contractor to use voluntary enforced acceleration to make up the schedule and upon failure to make the schedule, they grant the project owner any contractually-enforced liquidated damages.
- Compensable Delays: Primarily owner-caused delays. These delays are attributable to the owner or any of the owner’s agents or third parties by

contract and include failure to furnish the site on time, incomplete drawings, faulty design or specifications, and others. These delays entitle the contractor to a time extension in addition to monetary compensation for delay damages.

- Concurrent Delays: the most complex type of delay, involving situations where two or more types of the delays occur simultaneously. These can be complex to resolve in terms of recovery, damages, or absolute remedies. One approach is a concurrent delay remedy matrix, where any delay concurrent with an excusable delay is remedied by a time extension, while any compensable delay concurrent with a non-excusable delay is remedied by either time extension or apportionment of the delay (Kraiem & Diekmann, 1987).

Delay Costs

After causality and liability of a claim have been established, the claim is quantified, which creates a process that can be complex and tedious because of the many parameters involved as discussed earlier. These costs should be identified for future quantification and can be identified partially as (Cushman, Carter, Gorman & Coppi, 2001; Schwartzkopf et al., 1992):

- Direct Costs – represented in labor, equipment and material costs.
- Indirect Costs – represented in site overhead (SOH) (Lankenau,2003; Ibbs & Nguyen,2007a), home office overhead (HOO) (Darbyshire, 1982; Zack,2001) and other indirect costs such as bond and insurance costs, lost profit, interest and attorney fees, and claim preparation costs. These costs are situational and some are excluded as non-enforceable in public work contracts (TXDOT, 2009).

Schedule and Critical Path Method (CPM) Delay Analysis Techniques

CPM is the most widely used method of scheduling, and other schedule analysis techniques and tools have been developed to evaluate the magnitude, impact and significance of the variation between the baseline and current operating schedules or to quantify the effect of delays or change impacts on a project schedule (Majerowicz, 2001; Arcuri, & Hildreth, 2007; Henschel & Hildreth, 2007). Each method will be explained briefly:

- As-Planned vs. As-Built Method (AP vs. AB)*:* Also known as “total time method” or “net impact method”. Basically, the AP vs. AB method compares the as-built schedule to the as-planned one where the difference between the two schedules is considered as recoverable delays. It is an inexpensive, simple and easy method to use. (Alkass, Mazerolle & Harris, 1995; Stumpf, 2000). An advanced version of this method is called “modified total time” (Nguyen, 2007; Stumpf, 2000).
- Impacted As-planned Methods (IA*P):* Also known as “what-if” or “adjusted-baseline”, this method addresses delay responsibility by using the original CPM as-planned schedule and inserts the delays by parties that impacted the schedule (Trauner, 2009; Nguyen, 2007).
- Collapsed As-built Method (CAB*):* This method is also known as “what-if”, “but for” or “adjusted-baseline” Method. In contrast to the IAP method, it tends to prepare a detailed as-built schedule including all known delay events, then removes the delay of a party and illustrates how the schedule would have progressed but for that delay or delays (Lovejoy, 2004).
- Schedule Window Analysis*:* Also known as “snapshot method” or “contemporaneous period analysis.” In contrast to the other methods that analyze the whole schedule, the name “snapshot”

refers to analysis of specific periods within the schedule. The method uses the as-planned schedule as its baseline and divides the total project duration into smaller time period "windows" that specify major milestones, significant modifications in the critical paths or major delays and revisions. Then it analyzes the delays in each window successively within the critical paths in the schedule and accounts for their variation throughout the analysis (Hegazy & Zhang, 2005). Variations include modified Window analysis, delay analysis using delay selection and daily window delay analysis (Kao & Yang, 2009). Courts, boards, practitioners, and research scholars have agreed that the window analysis is one of the best available options (Hegazy & Zhang, 2005; Ibbs & Nguyen, 2007b; Kartam, 1999; Stumpf, 2000).

- Time Impact Analysis (TIA*):* Time Impact Analysis yields the most reliable analysis results (Arditi & Pattanakitchamroon, 2006; Nguyen, 2007). It can be considered an advancement of the window analysis method where the difference is that the TIA focuses on a specific delay or delay activity in contrast to the focus on time periods or a snapshot of the schedule in the window analysis method (Alkass, Mazerolle & Harris, 1996). This method works by using the as-planned schedule, and updates it in real time as soon as any delay, change or disruption calls for a schedule impact analysis. This is accompanied with analysis of CPM network changes and variations when the event occurs. These variations can be a critical path shift, float consumption, or new interrelations where all impacts are analyzed, revised, and reflected in the as-built schedule (Arcuri & Hildreth, 2007). One of the major benefits of this method is that it provides a disciplined basis for the contract parties to keep an updated project schedule (Wickwire, Driscoll, Hurlbut & Hillman, 2003).

Other methods and techniques for schedule analysis have been developed such as computerized delay claim analysis (CDCA) (Alkass et al., 1995) and a number of others (Shi, Cheung & Arditi, 2001; Oliveros & Fayek, 2005; Ibbs & Nguyen, 2007b; Nguyen & Ibbs, 2008; Hegazy & Zhang, 2005; Mbabazi, Hegazy, & Saccomanno, 2005).

Productivity Loss Analysis Methods

As discussed previously, productivity losses may be claimed as a result of change orders, added work, acceleration, disruption, changed conditions and owner-caused delays. Methods for estimating lost productivity are available in forms such as project-specific studies, project comparison studies, specialty industry studies, general industry studies, cost basis, and productivity impact on schedule (AACE, 2004). The most widely used methods are:

- Simple Calculating Techniques: These include the "Total Cost Method" (Jones, 2001; Burke, 1991), the "Modified-Total Cost Method" (Silverberg, 2003) and the "Jury Verdict Method" (Caplicki III, 2003).
- Detailed Calculating Techniques*:* These include the "Baseline Method" (Barrie & Paulson, 1992; Abdulmalak et al., 2002), the "Actual Method"/"Segregated Cost Method"/ "Discrete Cost Method" (Schwartzkopf &McNamara, 2001) and the "Measured Mile Analysis Method," *a*lso known as "Modified Baseline Method" or "Estimated Cost Method" (Finke, 1998; Guevara, 2013).

Other methods for productivity analysis have been used such as the Factor-Based method and the Disruption Distribution method (Abdul-Malak et al., 2002; Kallo, 1996; Kasen & Oblas, 1996; Finke 1998).

In addition to the above methods, modeling and simulation techniques can be used to increase the efficiency and capability of claim analysis and productivity losses specifically. They enable a focus on individual activities and can simulate resources involved and the sequence of activities to provide a realistic and holistic approach to claim analysis (AbouRizk & Dozzi, 1993; AbouRizk, Manavazhi & Dozzi, 1997; Luo & Najafi, 2007).

HIGHWAY BRIDGE CASE-STUDY

Purpose and Scope

The purpose of this case study is to identify and explain the differences between the analytical and forensic techniques for analysis of delay-based claims. It demonstrates different delay claims analysis techniques, their differences, and their advantages and disadvantages. It identifies the susceptibility of results to be manipulated by using different forensic scheduling techniques. This investigation shows the need to standardize the process so that it cannot be abused or manipulated.

The goals of the case study are:

- To identify the differences between the methods and results used to analyze delay claim costs.
- To determine the outcomes from different methods to demonstrate the advantages and pitfalls of the methods and their suitability in different situations.
- To expose the susceptibility of the results of delay analysis to be manipulated using different techniques for the same delays.
- To help establish a standardized delay claim analysis technique based on best practices to avoid most pitfalls and obtain robust results.

The case study setting is for construction of a small pre-cast bridge in Boston, Massachusetts where the main parties are the owner (Massachusetts Department of Transportation or MassDOT) and an anonymous contractor. As it was formulated, the writers studied whether data from an actual case could be used, but a study of many road and bridge projects showed how difficult it is to obtain the level of data required (Hashem Mehany, 2014).

The bridge is 350 feet in length and 60 feet in width. It has two roadway lanes and sidewalks on both sides for a total area of 21,000 square feet (1,950 square meters). The project scope consists of precast abutments, steel beams and precast slab decks topped by pavement. The scope also includes excavation, backfilling and grading along with limited landscaping. Other obligatory preconstruction activities also include storm water protection, water control measures, and signage and shoring systems. Demolition of sub and super structures and repair of an underground drainage structure are also required. Utility relocation is not in the scope for the bridge contractor and is the responsibility of the owner to coordinate and complete. The total project consists of 73 different activities that were divided into 3 milestone activities, 31 preconstruction activities, 1 utility relocation activity and 38 construction activities.

Project Schedule and Cost

The total project cost was originally estimated at $3,348,851, including the construction and preconstruction activities. A number of activities were equally divided between two phases. The project schedule had a start date of May 12, 2013 and finish date of November 4, 2013 with a project planned duration of 176 days on a 7 days/week project calendar.

There was a projected increase in labor wages and materials costs around November 9, 2013, which should not affect the project if it was completed on time

Case Study – Analysis and Results

The schedule delays were taken into account in the as-built schedule with a duration of 191 days finishing by November 19, 2013 which pushed the project into the escalation period for wages and materials. Also, it pushed the schedule into a more uncertain period of weather conditions. Now, using methodologies of schedule analysis that were highlighted earlier, the analysis will illustrate the differences, advantages and pitfalls in the different methods and techniques as well as to outline some associated costs. Primavera P6 software has been used for all the scheduling processes during the case study analysis. Figure 1 shows the logic of the claim case study and the interaction of its cost and schedule constituents.

The right side of Figure 1 lists the 5 different schedule delay analysis techniques that were used for the case study along with the involvement of acceleration and disruption due to the delays in the project and their effect on productivity. The left side is studying the associated direct and indirect costs with all their elements affected by the delays and based on the results of the schedule delay analysis along with the productivity loss costs.

Schedule Delays Scenario

In the schedule delays scenario, several delays occurred during project construction and pushed the finish date to November 19, 2013 which stretched the project duration from 176 to 191 days. Table 1 outlines a summary of the 6 delays that happened during the project.

Table 1 classifies each delay according to the activity's Primavera software P6 ID and its duration in the original schedule. Then it states each activity's predecessor activities according to the schedule and the delay for each activity. The last two columns show the delay type and party responsible.

CLAIMS CALCULATION AND EVALUATION

The claims calculation and evaluation are divided into two separate but dependent / correlated parts: the forensic schedule analysis which proves the time that qualifies as entitled

FIGURE 1
CASE STUDY METHODOLOGIES LAYOUT

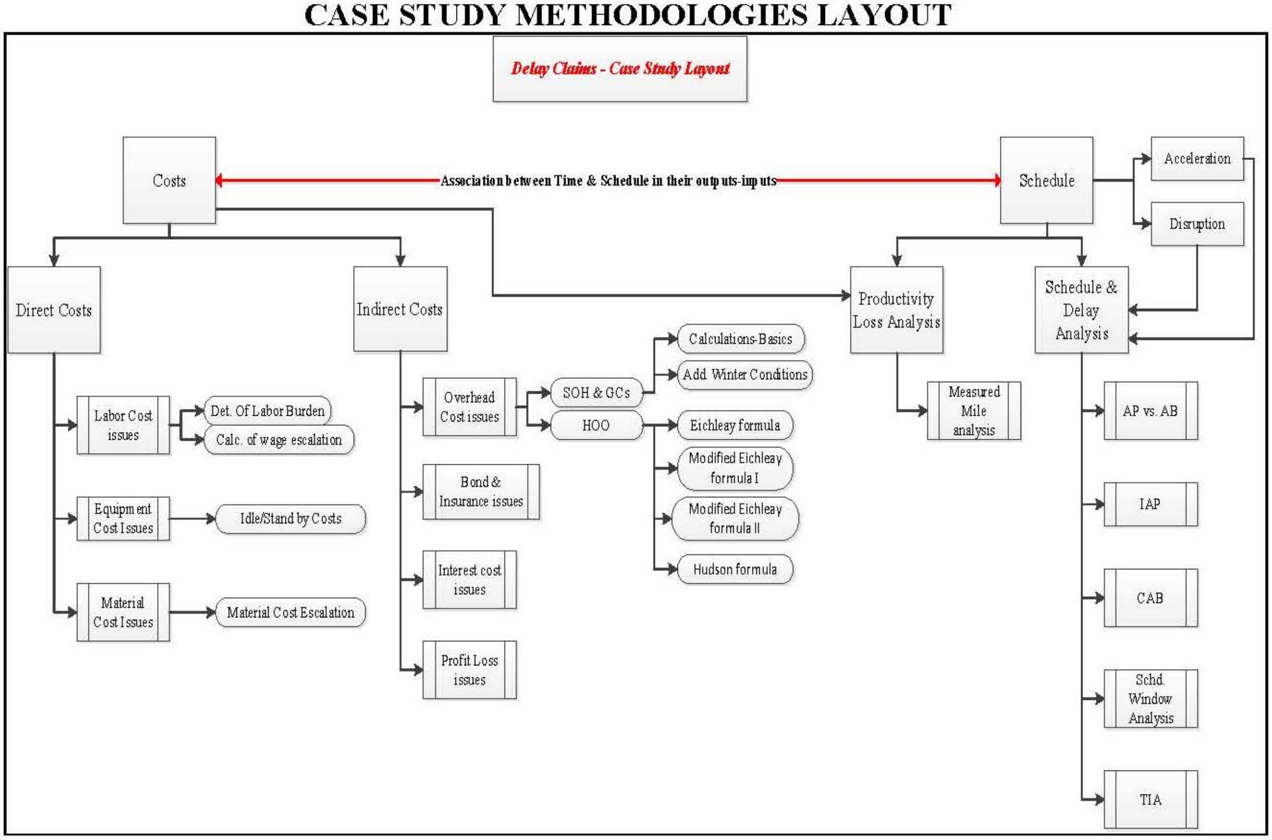

TABLE 1
DELAYS ENCOUNTERED IN THE PROJECT PER ACTIVITY

P6 Activ. ID	Activity Name	Orig .dur.	Predec essors	Delay Time (days)	New dur.	Delay Type	Responsible Party
U120	Utility Relocation	67	NTP	22	89	Utility Conflicts	Owner
P670	Review & Approve - Precast Deck Shop Dwgs.	30	P660	7	37	Late Approval/Defective Specs	Owner
P680	Fabrication & Delivery - Precast Deck	55	P670	5	60	Late Delivery	Contractor
C815	Set & Grout Precast Abutments - P2SA SB	5	C805	5	10	Unavailable Equipment	Contractor
C320	Backfill & Grade - P2SC SB RDWY	12	C200	3	15	Weather Conditions - Excusable	Excusable
C525	Install Steel Beams - P1SB NB	7	P610, P480, C515	2	9	Crane Position - Owner Disruption	Owner

delay duration and the pricing components of this delay accordingly.

The schedule delays will be analyzed according to several different analytical methods that included 1) As-Planned (AP) Vs. As-Built (AB) analytical method; 2) Impacted As-Planned (IAP) analytical method; 3) Collapsed As-Built Method (CAB) analytical method; 4) Schedule Window Analysis (SWA) analytical method; 5) Time Impact Analysis (TIA) analytical method

AP vs. AB Schedule Analysis – Net Impact Method

By Using the As-planned and As-Built schedules, the total delay duration entitled was calculated as in the following: Total Entitled delay duration = AB schedule duration – AP schedule duration = 191 days- 176 days; Therefore, the total delay duration entitled is ***15 days***.

Impacted As-planned (IAP) Schedule Analysis – What-If or "Adjusted AP"

The results for the IAP method is calculated using the AB schedule which includes all the delays and an AP-schedule which includes only the contractor's delays which arrives at 181 days. From the results of the two schedules, the total delay duration entitled is calculated as in the following:
Total Entitled delay duration = AB schedule duration – IAP schedule duration (including only contractor's delays) = 191 days – 181 days; Therefore, the total delay duration entitled is ***10 days***.

Collapsed As-Built (CAB) Schedule Analysis – But For or "Adjusted Baseline"

The result of this analytical method is evaluated through different schedules as in 1) AB-schedule; 2) AP schedule; 3) CAB- But for Owner delays: where all owner delays are excluded to; 4) CAB-But for Owner and excusable delays: where all owner and excusable delays are excluded.

After all the above schedules are created, the delay duration entitled is calculated according to the following simple equations:

- AB = AP + Contractor Delays + Owner Delays + Time extension; *Solve for Contractor's delay*
- Owner Delays = AB – But for Owner's delays
- Time Extension = But for Owner's delays – But for Owner & Excusable delays
- Total delay duration Entitled = AB – AP- Contractor's delay

After creating both schedules the entitlement calculations can be calculated with the equations available as in the following:

- Owner Delays = AB – But for Owner's delays = 191 – 184 = 7 days
- Time Extension = But for Owner's delays - But for Owner & excusable delays = 184 – 181 = 3 days.
- AB = AP + Contractor Delays + Owner Delays + Time Extension
- 191 = 176 + Solve X + 7 + 3
- Solving for (X), Contractor's delay = 5 days
- Therefore, Total Delay duration entitled = AB – AP – Contractor's delays = 191 – 176 – 5 = ***10 days.***

Schedule Window Analysis

A window schedule analysis was completed by taking several snapshots to analyze specific time periods within the schedule that have major delays as shown in Figure 2.

Each window was analyzed and assessed accordingly, and then the delay effects from all windows were summed up to come up with the total delay duration entitled. All the windows are based on each other to model the cumulative, contemporaneous effect of the schedule sequence and the cumulative effect is demonstrated as shown in Figure 3.

The results of the analysis are presented Figure 3 shows the original as-planned schedule, the analysis per each window and its cumulative results for each later window and finally, it shows the total as-built schedule with all the different window delay effects plugged in its overall duration.

Time Impact Analysis

Time impact analysis is a method that works using the as-planned schedule and updates it instantly as soon as any delay, change or disruption calls for a schedule impact analysis, in a very active real-time manner. As was previously explained in detail, the TIA is one of the most reliable and accurate methods which takes into account the effect of each impact happening in the project as an individual activity. In this case, all the six delays will be analyzed for their impacts along with their cumulative effect and summarized as shown in Table 2.

The overall entitled compensable delays are the sum of the analysis of the final results from all those impacts. In this case, the compensable delays are 12 days and three days of weather-excusable delays.

Summary of Schedule Analysis

All the results from the previous five types of schedule analysis were summarized and tabulated in Table 3.

Table 3 describes each technique's time entitlement duration, along with every aspect of the delay according to causality and compensability. However, the net impact method and the IAP do not have the ability to separate delays according to these parameters since they just adjust total duration and they do not anticipate concurrency and responsibility of delays.

Figure 2

WINDOWS SNAPSHOTS DISPLAYED ON THE AP SCHEDULE

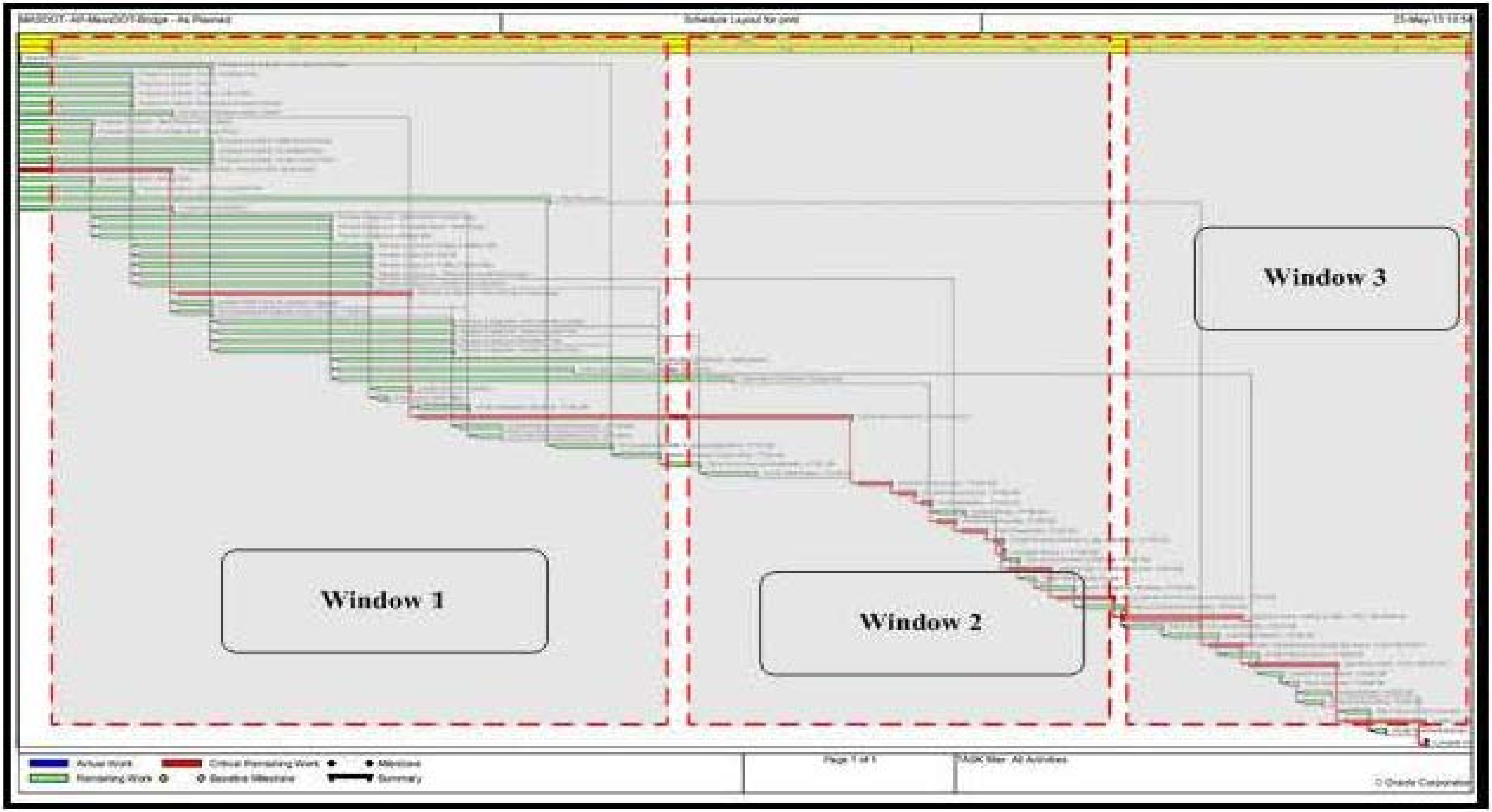

Figure 3
SUMMARY OF THE WINDOW ANALYSIS RESULTS

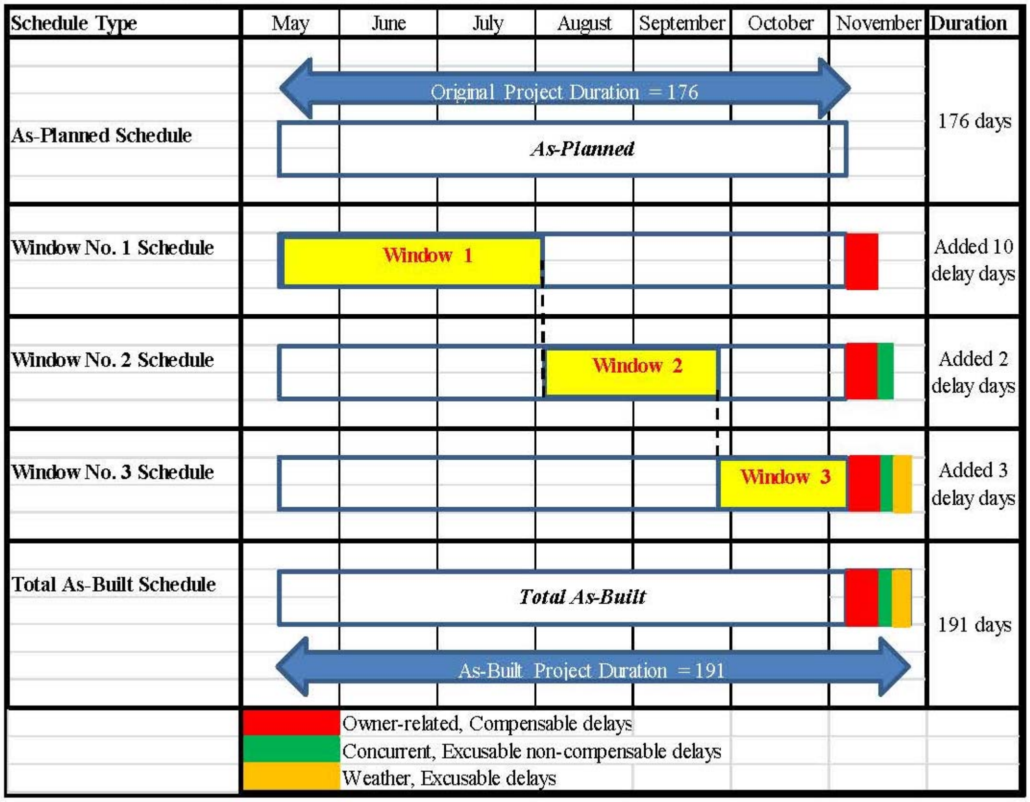

TABLE 2
SUMMARY OF TIME IMPACT ANALYSIS (TIA) METHOD

Impacts No.	delay duration (days)	Change in C.P	Responsibility	Preliminary status
After Impact #1 analysis	5	N	Owner	Compensable
After Impact #2 analysis	5	Y	Owner	Compensable
After Impact #3&4 analysis	2	N	Owner	Compensable
After Impact #5 analysis	0	N	None	
After Impact #6 analysis	3	N	Weather	Excusable
Total Delay duration Entitled =	12	days		

TABLE 3
DEMONSTRATION OF THE OVERALL RESULTS OF THE DIFFERENT SCHEDULE RESULTS FROM THE DIFFERENT SCHEDULING TECHNIQUES USED IN THE CASE STUDY

Schedule Analysis Techniques	Time entitlement	Compensable Owner-Caused	Inexcusable Contractor Caused	Excusable
AP vs. AB - Net Impact Method	15	N/A	N/A	N/A
IAP, What If, Adjusted AP	10	N/A	N/A	N/A
CAB, But For, Adjusted Baseline	10	10	0	5 (2 concurrent, 3 Weather)
Window Schedule Analysis	10	10	0	5 (2 concurrent, 3 Weather)
Time Impact Analysis	12	12	0	3 (Weather)

TABLE 4
SUMMARY OF THE TOTAL COSTS RELATED TO THE DELAY CLAIMS IN THE CASE STUDY

Cost Item type	Delay Costs Associated
Labor Costs	$ 864
Equipment Costs	$ 18,748
Material Costs	$ 6,400
Add. SOH / General Conditions	$ 19,449
Add. SOH - Winter Conditions	$ 9,862
Additional (HOO)	$ 15,000
Lost Productivity Costs	$ 1,158
Total delay claim costs	***$ 71,481***

From the different results represented in Table 3, it is very obvious that different methods can yield different results within the same case. That is because some of them do not account for certain parameters as concurrency, delay responsibility, or the sequence that the delays occur in within the construction process. This is simple yet very strong evidence of how variable the claim analysis can be, and there is a critical need for standardization of schedule delay analysis approaches within the delay claim management process. There is also a need to stick with the current best practice technique represented in the TIA.

Cost Analysis Results - Summary

All the results from the cost analysis associated with the entitled delay were summarized and tabulated in Table 4. According to Table 4, the total cost associated with the delay-entitled claim is $71,481.

DISCUSSION AND CONCLUSION

The paper provides an original contribution by applying diverse methods of delay claim analysis to a case study, and thereby bolstering the case for standardized delay claim analysis as a part of road construction contracts. Such a system of standardized delay claim analysis is important to ongoing efforts to increase the effectiveness and efficiency of highway and other construction projects. Highway funding is in very short supply currently, and both federal and state regulations and/or processes need to be followed so as to assure maximum return for available dollars. The proposed approaches can help with this overall goal. For the trucking industry, and other highway users, efficiency of construction projects is very important given the large backlog of needed projects.

The paper also identified the common negative time and cost effect of delays in road and bridge projects and showed the difficulty in analyzing and resolving delay claims due to the variety of methods in use. In achieving the goals for the case study, the paper listed the most common delay claim analysis techniques and methods along with their outcomes, advantages and pitfalls as follows:

As-Planned vs. As-Built Methods (AP vs. AB): Although it is a very inexpensive, simple and easy method to use, the biggest pitfall is that it is not very practical regarding the allocation of the delay. This is due to the fact that it is overestimating the duration of the delay considering it is all from one party.

Impacted As-planned Methods (IAP): This method is considerably better than (AP vs. AB) but it still has several deficiencies represented in the following:

- The impacted schedule is not contemporaneous enough and does not show the project activities as they occur
- The decision for placing the impacts into the schedule is greatly subjective which can lead to more disputable analysis rather than solving the delay analysis.
- The method does not reflect the dynamic nature of construction projects and the critical path dynamics of change during the project.

Collapsed As-built Method (CAB): As one of the most accepted by the industry, it has the ability to address the concurrent delay issues. It also has several weaknesses since it is based on the CPM network and on as-built information that can be tweaked and manipulated to a predetermined conclusion.

Schedule Window Analysis (SWA): the main strength of this method was its ability to utilize contemporaneous information to account for the dynamic variation of the critical activities and the critical paths which can reflect the actual status of work in the as-built schedule and assess each period for delay, its cause and responsibility. And can also deal with concurrency effectively. However, there are still some points of weaknesses to this method represented in the following:

- The as-built schedule is still dealing after the fact and can still be subjected to errors and omissions that hinder accurate delay analysis.
- The window span being in the form of weeks or months, the focus is on the critical paths that exist at the end of the window time. Thus, the technique does not consider the fluctuations that occur in the critical paths as events evolve on site. As a consequence, the technique loses sensitivity to the time at which the owner/ contractor causes project delays within the window. Also, it loses sensitivity to the events of speeding up or slowdowns within the window.
- The delay representation of existing software systems makes the application and automation of the windows technique a very difficult task.

Time Impact Analysis (TIA): This method is widely considered the most reliable where it is an advancement of the SWA by focusing on a specific delay or the affected activities instead of a wider window that can miss some of the dynamics that evolved during that window as pointed out above. The main drawback of this method is the efforts required to keep a real-time accurate schedule along with all the records accompanying that schedule.

Based on the results from all of these techniques and methods of delay claim analysis, TIA is the recommended proactive method of choice. This is due to its ability to use the AP schedule and its real-time updates which captures the delays and its consequences represented in the schedule impact analysis in a real-time proactive manner. It also captures and deals with the real-time CPM network changes and variations when the event occurs as in the critical path changes, float consumption and delays concurrency. In short, it is considered the most proactive method and it calls on the contractual parties to keep an updated real-time schedule as part of the project conditions which limits the disputes and provides a good predictive tool to avoid further delays and impacts on the project cost and schedule.

It was also concluded that the measured mile analysis was one of the most reliable methods for calculating the lost productivity cost. Therefore it was used to come up with the costs for this study. This is because the measured mile analysis considers only the actual effect of the alleged impact and thereby eliminates disputes over the validity of cost estimates, or factors that may have impacted productivity due to no fault of the owner. However, its greatest challenge is to accurately identify the suitable un-impacted period in which the work being performed was sufficiently similar to that work performed in the impacted period.

Mostly, after all the methods were applied in the case study, they yielded different results for the same case. That is because some of them do not account for certain parameters as concurrency, delay responsibility, or the sequence that the delays occur in, within the construction process and other issues that have been pointed above. Thus, the case study of the bridge construction project showed the potential for manipulation by using different techniques for the same delay case within the same project condition.

This is simple yet very strong evidence of how manipulative the claim analysis can be since one party can manipulate the delay claims by using an advantageous scheduling method for the most compensation or entitlement. Therefore, there is a desperate need for standardization of the schedule delay analysis within the delay claim management process to limit the ability of any manipulation by any of the contractual parties. This should also limit future disputes for time and cost entitlements. Accordingly, there is a need to use the best practice techniques represented in the TIA since it has been proven to be the most proactive method that can accurately appropriate delays entitlement, limit the analysis disputes and even forecasts potential future impacts or delays.

There is a clear need for standardization of the methods of delay claim analysis. The standardization process should be included and developed into the projects specification books and enforced contractually. This standardized delay claim management system should be able to detect and document delays as soon as they happen in real-time using TIA or similar techniques. It should also include the following details:

- Detailed scheduled specifications
- Establish schedule evaluation standards
- Define unanticipated weather conditions
- Identify clearly the agreed-upon standard method for schedule analysis during the project
- Identify the requirements and inputs for that method
- Other specific issues such as float ownership.

A claim management system that includes such components should mitigate delay claims and disputes during a project as well as predict and enhance future project performance.

FUTURE RESEARCH

To address the issues represented in this paper and affirmed in the case study, future research should point toward a system and set of best practices for delay claim management to be used by owners and contractors as a fair and proactive process that minimizes disputes. The system should also be amenable to standardization. This research should establish a practical approach that will work at the lowest level with simple approaches. The management system should include selection of a method such as the recommended (TIA) to standardize the process and prevent manipulation by any party in the contract. Then, it should proceed with the requirements to implement that method of delay analysis along with related issues and schedule specifications in project specification books.

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