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BUILDING INFORMATION MODELING AND FORENSIC ANALYSIS OF DELAY AND DISRUPTION

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Delay and Disruption is a common occurrence in construction projects. The challenges of forensic schedule analysis and the evaluation of the extent of project delay increase with the degree of complexity of a project. The occurrence of multiple concurrent delays, secondary effects and the cumulative impact of delay and disruption events can render the establishment of entitlement to extension of time and reimbursement a difficult task. In order for the claiming party to receive compensation for project delay and disruption, causation, liability and quantum have to be demonstrated and proven. Advances in technology have made a shift from conventional delay analysis methods towards delay and disruption analysis supported by Building Information Models possible. Research and application of Building Information Models has increased in recent years, exploring information coordination on multiple dimensions. Linking the fourth dimension of time to a 3D model enables the user to visualize a representation of the construction process. The application of 4D simulation in forensic schedule analysis is a great tool for the visualization of delay events and their effects on the project schedule and the construction process. Although 4D Building Information Models are able to assist forensic schedule analysis, the identification of the cause and effect relationship of delay events of complex construction works, requires an expert who is not only familiar with the software tools but has also experience in delay analysis and is able to clearly determine the accuracy of the produced data. 4D Building Information Models can simulate a high level of project performance, producing great quantities of data. The role of the delay analyst is to identify the relevant facts from the great quantities of data simulated in the 4D model, in order to support his findings of entitlement, causation and resulting damages. The purpose of this paper is to investigate the use of 4D Building Information Modelling in delay and disruption claims and outline the expertise required to perform the forensic schedule analysis.

Keywords: Construction, 4D BIM, Scheduling, Dispute, Expert.

1 INTRODUCTION

Characteristics of construction projects range from simple, low cost programs with short schedules to highly complex with extensive budgets and complicated schedules. The magnitude of a project relates to the complexity of the delay and disruption analysis and therefore to the difficulty of the forensic schedule analysis in the case of dispute. There are various triggers than can cause delay and disruption, some attributable to the owner, other times attributable to the client or in case of true concurrency to both (Nguyen 2007). A contractor can claim excusable or non-excusable delays. Excusable delays can be further categorized into compensable or non-compensable delays. There has to be a distinction between delay and disruption claims, as their investigation requires separate analysis methodologies (Braimah 2008).

Delay occurs when the contractual completion date is not identical to the actual completion date of the construction project (Lee *et al.* 2005, Doughery 2015). Disruption occurs when an event leads to the loss of efficiency of the planned productivity, leading to increased difficulty of performance, cost and possibly delay (Finke 1997, Keane *et al.* 2008). Effects of delay and disruption can be diverse and must be individually identified and analyzed. Compensation claims may include increased home office overhead, additional cost of labor, material and equipment (Schwarzkopf 1995, Haese *et al.* 2001). A disruption that leads to loss of productivity does not necessarily lead to delay, but may still incur extra cost (Braimah 2008). The challenge of delay and disruption analysis does not only lie within the proof of causation, quantification of the delay and damages incurred (Williams *et al.* 2002) but also the distinct separation and identification of the root causes and their primary and secondary effects as well as direct and indirect damages (Doughery 2015).

Apart from conventional methods used internationally in forensic schedule analysis, advances in research and technology as well as the increased application of Building Information Models (BIM) in construction projects in recent years, has revealed a potential implementation in forensic schedule analysis.

2 CONVENTIONAL FORENSIC ANALYSIS METHODS

Forensic analysis methods do not have standardized titles and can be found under various terms (Braimah 2008, Barry 2009). One of the fundamental requirements common to all methods for a correct analysis is that all techniques must be based on accurate data, it is therefore important to use realistic baseline schedules, where resources, linked activities and durations are realistically and accurately calculated (Trauner *et al.* 2009). The baseline schedules must be continuously updated during construction in order to incorporate discrepancies between the planned and the built schedule.

Five commonly used conventional schedule delay analysis methods are the Impacted As-Planned Analysis, the Time Impact Analysis, the Collapsed As-built Method, the Windows Analysis and the As-planned vs. As-Built method (Arditi *et al.* 2008, Streckel 2011).

Schedule delay analysis can be conducted prospectively, contemporaneous with the delay event i.e., during the construction process or retrospective after the delay event has occurred. In highly complex delay claims a combination of prospective and retrospective methods is required, in order to verify the results of the analysis (Keane *et al.* 2008).

In the prospective methods (Impacted As-Planned, Time Impact, Windows Analysis) the baseline schedule is updated and activity relationships, resource allocation and float calculation are reevaluated in order to estimate the likely impact of the delay event on the completion date. Retrospective analysis methods (As-Planned vs. As-Built, Collapsed As-Built) aim to reconstruct historic events to account for actual progress and completion dates (Barry 2008).

Like delay analysis methods, there are a number of methods to calculate damages resulting from disruption. Some of the most widely used methods are the Total Cost Method, Modified Total Cost Method, Industry Studies and Guidelines and the Measured Mile Method. Similar to the delay methods they are described in the literature under various titles (Braimah 2008). All disruption analysis methods aim to identify inefficiencies or loss in productivity, the responsible party or in case of cumulative impact, the apportionment of responsibility, based on different sources of information and data (Braimah 2008).

A number of researchers have pointed out the difficulty for judges and tribunals to interpret technical drawings of great detail as well as gaining an understanding of the project and the events that transpired to cause delay and disruption from the numerous data and information presented in claims based on traditional forensic analysis methods (Keane *et al.* 2008, Gibbs *et al.* 2012).

In recent years the construction industry has experienced a shift from 2D CAD models to the implementation of BIM services, UK Government for example requires all public sector projects to use a fully collaborative 3D BIM as a minimum by 2016. BIM can be used as a collaborative planning and construction tool as well as for the coordination of construction work sequence and the visualization of the construction process (Kessoudis *et al.* 2015).

3 FORENSIC ANALYSIS WITH BIM

Building Information Models have several levels of development commonly described in terms of dimensions, linking the three-dimensional (3D) model to additional information and data of the project, producing additional management parameters to n-dimensional extensions simulating the project life cycle (Azhar 2011). Four-dimensional (4D) BIM links geometrical data from the three-dimensional (3D) model to the construction schedule simulating construction sequences with integrated dependencies of processes and resources (Kessoudis *et al.* 2015). 4D BIM has rendered the identification of time-space conflicts through visual inspection relatively easy in comparison to traditional 2D drawings and their shortcomings in relation to optimal use of workspace allocation (Jongeling *et al.* 2008). There is a variety of commercial software providing 4D schedule solutions with integrated object recognition with assigned categories and materials which offer visualizations of the construction sequence, workspace conflicts and detection of hidden flaws of the planned schedule (Dang *et al.* 2015). Furthermore, BIM tools are able to detect inconsistencies on level of detail amongst activities, omissions and errors in the schedule logic as well as identify potential accessibility problems on construction site (Koo and Fischer 2000).

Researchers have already identified the potential of BIM in dispute prevention and dispute resolution (Greenwald 2012) as well as forensic schedule analysis. Some have concentrated on the visualization option which can aid the demonstration of actual versus planned construction process in standalone or preferably comparative 4D models, highlighting the discrepancies resulting in delay and disruption (Pickavance

2007, Gibbs *et al.* 2013), as well as outline the integration of 4D Modeling tools into typical schedule analysis steps (Coyne 2008).
Apart from the benefits gained through the implementation of BIM, research has also highlighted the shortcomings that need to be further addressed and developed in order to generate automated and dynamic 4D models.

Currently 4D schedules are limited to visualizations, automated calculation of quantities and recourse capacities to establish work flow (Hartman *et al.* 2008, Dang *et al.* 2015), but there is an increasing demand for automated dynamic features in order to use 4D schedules throughout the construction process, especially in cases of changes where schedules, activity logic, relationships and associated resources have to be manually reestablished.

4 FORENSIC ANALYSIS EXPERT

BIM is an innovative tool that can be implemented throughout the lifecycle of a project with great advantages, but the efficient use of the tools lies upon the experts that use it.

Forensic schedule analysis can benefit through the implementation of BIM but it has also aroused the need for a new hybrid model of schedule analyst. Analysis of delay and disruption with BIM requires an expert who has experience in forensic analysis and is familiar with the software, in order to be able to determine the accuracy of the data produced.

The challenge of the analyst is to use all tools provided to identify the cause of the delay or the disruption, appoint the liability to the responsible party and calculate the damages. 4D BIM can simulate a high level of project performance, producing great quantities of data. The role of the delay analyst is to identify the relevant facts from the great quantities of data simulated in the 4D model, in order to support his findings. Visualizations have proven to be a great tool not only for communication inside the project team but also for providing a chronological narrative of the project and the events that led to a deviation from the as-planned to the as-built schedule. Apart from the challenges posed in forensic analysis of delay and disruption using conventional methods, the new challenge of the analyst is to sort through the infinite amount of data, and detect the relevant information, form it into factual evidence and decide upon the level of detail that will form the basis of the claim.

5 CONCLUSION

As technology has progressed and evolved, the application of BIM in construction projects has increased and opened new areas of potential implementation for 4D tools. 4D scheduling shows great promise not only during the planning and construction phase for the prevention of delay and disruption but also for the analysis of events during the forensic schedule analysis. The most important tool identified is the visualization of the chronological events and the comparative 4D models simulating the as-planned versus the as built construction process.

The limitation of automated generation of dynamic 4D schedules renders the use and updating of the schedule an onerous task, especially in case of changes where schedules, activity logic, relationships and associated resources have to be manually reestablished.

Further research is necessary to decrease or remove these limitations in order to be able to fully employ the capacities of 4D BIM during the lifecycle of a construction project. Technological advances and increased implementation of BIM have aroused the need for hybrid experts, who understand the technical part of the construction accompanied by a familiarity with BIM software tools. Forensic schedule analysis will have to find a balance between the two disciplines in order to obtain maximum benefit out of forensic schedule analysis with BIM.

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