Streamlining Information Transfer between Construction and Structural Engineering
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A GRAPHICAL USER INTERFACE (GUI) FOR FORENSIC ANALYSIS OF DELAY AND DISRUPTION

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Disrupting events are common in construction and can have a significant impact on the successful completion of a project. Disputes concerning disruptive events often arise because no party wants to accept responsibility for the extra cost incurred. The resolution of this kind of disputes lies within the clear demonstration of causation, liability and the quantification of the disrupting event. Purpose of this research is to explore the potential of Building Information Modeling (BIM) in assisting forensic delay and disruption analysis supported by a Graphical User Interface (GUI). An extensive literature review highlighted the shortcomings of current practices and identified the reconstruction of events through incomplete and unstructured documentation as one of the primary challenges faced by the analysis expert. The findings of the literature review formed the basis for the development of a GUI designed to incorporate all the necessary information for the identification of the causal link of events, the liability and the calculation of damages. The usability of the GUI prototype was tested on a case study, indicating an increase in the overall efficiency and reduction of time spent by the forensic analyst in the retrieval of relevant information.

Keywords: Construction claims, Building information modeling, Documentation, Dispute prevention, Dispute resolution, Information management.

1 INTRODUCTION

Construction projects can be influenced by several factors such as the numerous participating parties, weather conditions, risks associated with the construction process as well as unforeseeable events which can impact the successful completion of a project (Chan *et al.* 2004). The effects of disrupting events can be manifold and can lead to delay to activities or to the overall completion date as well as increase in cost (Rosenfeld 2014). The successful resolution of claims regarding delay and disruption are based on the clear demonstration of causation, entitlement and quantification (Williams *et al.* 2013). One of the primary challenges encountered in analysis of delay and disruption is the reconstruction of events through incomplete as-built documentation (Hammad and Alkass 2000).

The emergence of technology has greatly improved the process of project documentation in the last decades, but the construction industry has been slow to adapt, especially concerning construction progress documentation (Stowe *et al.* 2014). Apart from Project Management software, Building Information Modeling (BIM) has emerged to revolutionize the construction industry. It has opened up opportunities for optimization in all phases of construction, and research has already identified the potential of BIM in dispute prevention and dispute resolution (Greenwald 2013) as well as to support forensic analysis of delay and disruption (Gibbs *et al.* 2012).

The objective of this study is to develop a prototype GUI linking together all necessary information stored in BIM and Project Management software, to be used as factual evidence supporting a claim. The aim is to alleviate the difficulty of information retrieval as well as to facilitate the forensic analysis. The prototype was tested on a simple case study to determine its usability and identify possible limitations.

2 DISRUPTION CLAIMS AND BIM TECHNOLOGY

The success of forensic analysis both for delay and for disruption is based on the quality of the project progress documentation available. Retrieval of all relevant documentation is the first step in claim preparation, not only to gain insight into the events leading to delay and disruption, but also for the comparison of the as-planned (AP) and the as-built (AB), their discrepancies and the analysis of the causal link between events and their primary and secondary effects. The documentation requirements for the impact assessment of disrupting events include, accuracy through continuous updates during the construction process, systematic structure, high level of detail and comprehensive composition (Reister 2007).

Proper contemporaneous project documentation can be very time consuming (Vidogah and Ndekurgi 1997) and is often regarded as unnecessary or superfluous. In the last decades the progress of Information Technology has alleviated the onerous task of contemporaneous project documentation, but non-existent, erroneous, or lacking information still rank highest as obstacles in delay analysis methods (Braimah and Ndekurgi 2009). As delay and disruption analysis has to be supported through a plethora of evidence it is very paper-intensive (Gibbs et al. 2017) with the elementary information retrieved from disruption notifications, documentation of performance change, as-planned and as-built construction schedules, allocation of resources, daily site reports, photos, consultation meeting reports, correspondence and request for information and respond lists (Trauner 2009, Vygen 2011).

BIM technology offers novel opportunities of integrated and interoperable processes in the construction lifecycle providing a centralized virtual information environment (Eastmann *et al.* 2011). Research and practice have already recognized the potential of BIM in easing the access to coordinated contemporaneous project information through multiple dimensions (Chou and Yang 2017). Studies focusing on assisting delay claims through BIM have illustrated that 4D Models, linking building components from the 3D model to the construction schedule (Kensek 2014) and visualizing the construction sequence by comparing the actual versus the planned construction process can support the presentation of the analysis and findings (Pickavance 2007). Coyne (2008) outlined the integration of 4D tools into typical schedule analysis steps. Guevremont and Hammad (2018) illustrated the benefits of identification, visualization, quantification, and responsibility assignment of delay events by identifying the resulting spatiotemporal conflicts in 4D simulations. Burr (2016) states that benefits gained through the implementation of BIM can only be obtained through the premise of best practice project management such as qualitative construction documentation. Gibbs *et al.* (2017) conducted a study presenting computer-generated exhibits (CGE), such as videos of virtual construction sequences, highlighting the importance of "displaying only the facts" as well as accompanying the presentation with "a narrative from the CGE creator". The study also emphasized that there is still an element of distrust in this kind of evidence presentation methods and the accuracy of the supporting facts. Chou and Young (2017) conducted an extensive literature review on whether a BIM-based approach can aid the mitigation of problems encountered in schedule delay analysis and concluded that although it can greatly benefit information collection there is a lack of focus on the presentation of analytical results.

There have been attempts to make retrieval of information more user-friendly by increasing efficient and effective distribution of information amongst different BIM users. Lee *et al.* (2011) proposed a Web-based interactive GUI to support acquisition of required information with 2D, 3D views, and 4D simulations, options for data search as well as the location of the construction site on Google Maps.

3 GUI FOR RETRIEVAL OF INFORMATION FOR DELAY AND DISRUPTION ANALYSIS

In the analysis of delay and disruption particular focus is placed on the comparison of the AP versus the AB schedule linked to the allocated resources for the visualization and identification of discrepancies in time and cost. Figure 1 illustrates the system schema behind the design of the GUI, incorporating information regarding construction progress provided by digital on- and off-site documentation stored in Project Management software with additional attributes and metadata of the construction process. The BIM system provides the AP and the AB model with the construction schedule and the respective cost. APIs (Application Programming Interfaces) enable automated data extraction from the respective systems.

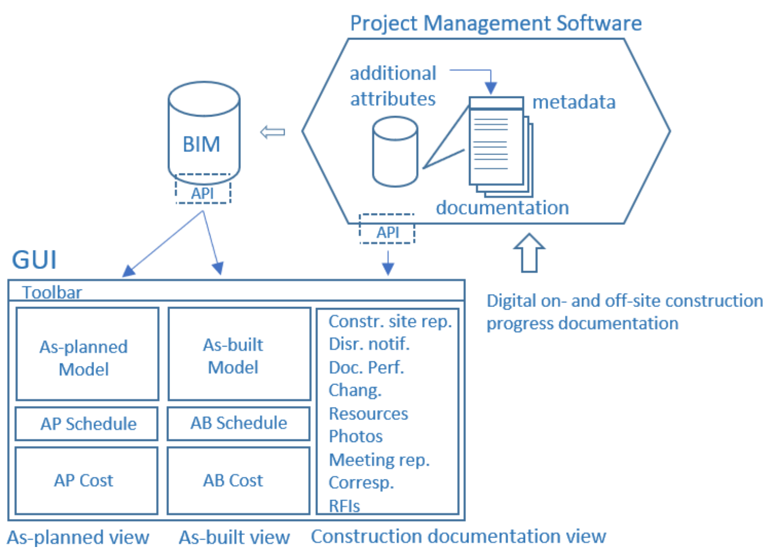

Figure 1. System schema of developed GUI.

Figure 2 shows the developed GUI prototype, which was tested on a simple case study to demonstrate the functionalities, intended to increase the overall efficiency and reduction of time spent by the forensic analyst in the retrieval of relevant information. In the GUI the expert is able to contemporaneously visualize the AP and the AB construction process, analyze the AP and AB schedules and costs, as well as retrieve information from progress documentation such as, disruption notifications, documentation of performance change, construction schedule, daily construction reports, photographical documentation, consultation meeting reports, relevant correspondence and requests for information submittal and respond lists.

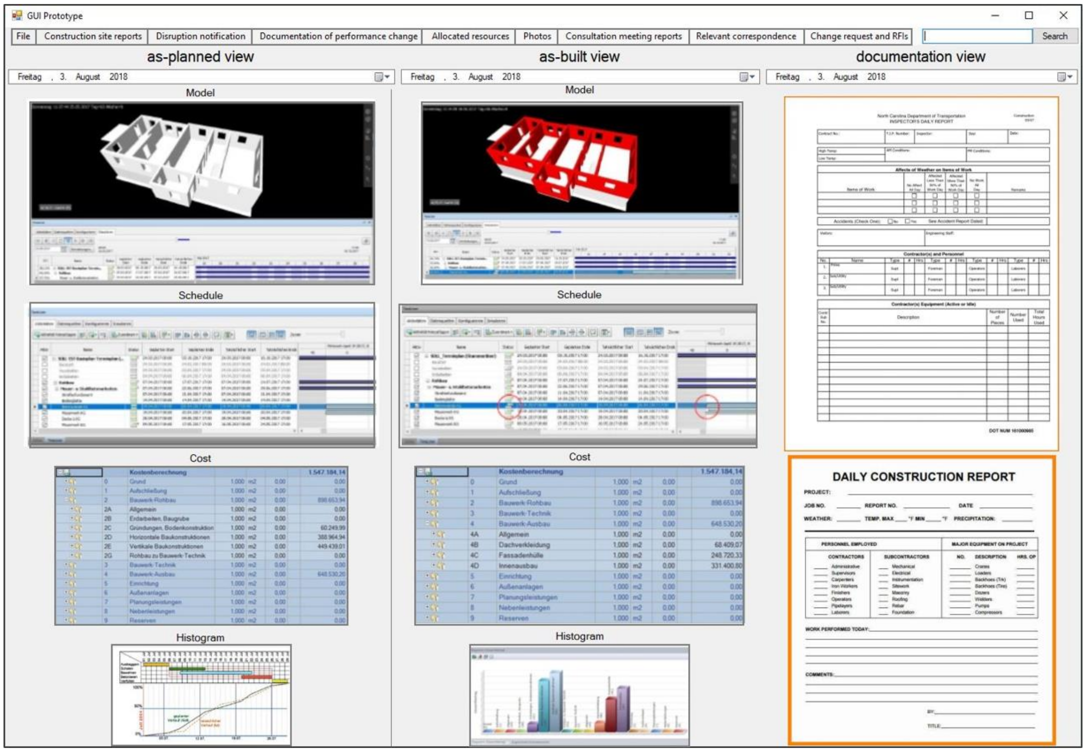

Figure 2. GUI displaying information necessary for delay and disruption analysis.

3.1 Case Study

The applicability of the developed GUI was tested on a theoretical case study of a two-story residential building. Forensic analysis was called to settle a dispute regarding a claim made by the contractor requesting compensation for additional cost of construction site overhead, labour and equipment. The contractor's claim stated that due to differing site conditions the foundation excavation works were extended by five days, affecting masonry work on the critical path. The contractor was granted an extension of time (EOT) but compensation only for three out of the five days. The client argued that the contractor was able to accelerate the works after the delay, resulting in only three days delay to the project completion date.

Figure 3 illustrates the steps in the application of the GUI for the reconstruction of events by the forensic analyst. The contractor's disruption notification stated that the schedule was disrupted due to differing site conditions claiming an EOT of five days and additional costs for site office overhead, 2 extra labourers dispatched to the site, and an additional excavator. Contemporaneous AP and AB visualization as well as photo documentation provided an overview of the effect of the delay on downstream activities and the completion date of the project. Causal link between events was determined with a schedule delay analysis method and extra cost incurred by the affected resources. Construction progress documentation, AB schedule and cost calculation showed that the contractor was able to speed up downstream activities by dispatching two extra labourers to the construction site. The delay to the completion date was reduced from five to three days.

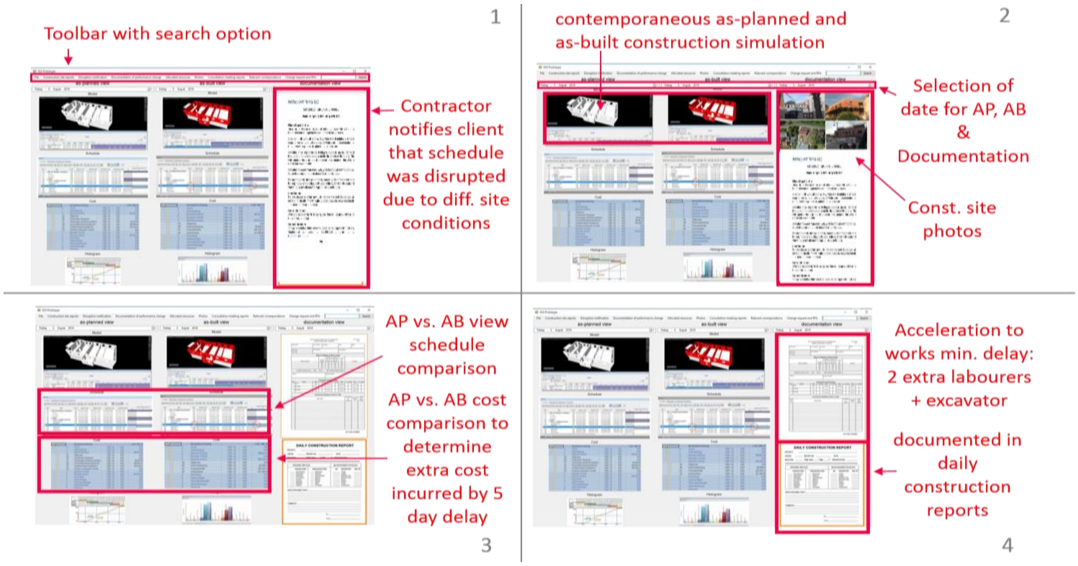

Figure 3. Case study information retrieval for forensic analysis of disrupting event.

The forensic analysis concluded that the contractor was entitled to the EOT and the extra cost incurred by the two additional laborers, excavator, and site overhead, but only for the three days delay to the completion date.

4 CONCLUSIONS

There are various triggers that can cause delay and disruption in a construction project, some attributable to the owner, others attributable to the client or in case of true concurrency to both. Effects of delay and disruption can be diverse and must be individually identified and analyzed.

The developed GUI prototype was designed to integrate information to support the analysis and be used as factual evidence, aiming to alleviate the difficulty of information retrieval as well as the distrust in new presentation methods. The prototype was tested on a simple case study indicating an increase in the overall efficiency and reduction of time spent by the forensic analyst in the retrieval of relevant information. It is important to note that the forensic analysis expert continues to play a significant role in the determination of the accuracy of the provided information and the subsequent schedule analysis, identification of the causal events, and appointment of liability.

Further research is necessary in order to test the developed GUI on larger more complex projects and conduct a usability study with experts to identify possible limitations.

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