Preliminary Evaluation of BIM-based Approaches for Schedule Delay Analysis

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Abstract. The problem of schedule delay commonly occurs in construction projects. The quality of delay analysis depends on the availability of schedule-related information and delay evidence. More information used in delay analysis usually produces more accurate and fair analytical results. How to use innovative techniques to improve the quality of schedule delay analysis results has received much attention recently. As Building Information Modeling (BIM) technique has been quickly developed, using BIM and 4D simulation techniques have been proposed and implemented. Obvious benefits have been achieved especially in identifying and solving construction consequence problems in advance of construction. This study performs an intensive literature review to discuss the problems encountered in schedule delay analysis and the possibility of using BIM as a tool in developing a BIM-based approach for schedule delay analysis. This study believes that most of the identified problems can be dealt with by BIM technique. Research results could be a fundamental of developing new approaches for resolving schedule delay disputes.

1. Introduction
The problem of schedule delay commonly occurs in construction projects. Although schedule delay analysis and claim management for construction projects have received much attention, the contractor usually has to pay a lot of time and resources to deal with the affairs of resolving delay analysis and claim preparation when encountering schedule delay problems. Now, there are a lot of diversified approaches for schedule delay analysis, but none of the delay analysis methodologies is perfect because they all include an element of assumptions, subjective assessment and theoretical projection [1]. To select a suitable delay analysis approach is one of the key issues in delay claim management [2]. Besides, this study focuses on another issue: how to develop an innovative approach with advanced technology. Although different studies have proposed different approaches for delay analysis to deal with different issues or situations, the processes related to claim management can be divided into the following five stages: (1) Preparation: to collect required documents, (2) Diagnosis: to identify impacted delay events for further analysis, (3) Analysis: to employ available and reliable delay analysis methodology to calculate delay impact value, (4) Interpretation: to clarify schedule impact on critical path or total duration, (5) Summation: to summarize all analysis results and to generate a comprehensive analysis report [3]. The aforementioned works are commonly conducted by schedule professionals with a great effort. The delay analysis itself is usually complex but can be aided
by a computerized approach [4]. Therefore, computer aided construction delay analysis and claims preparation is necessary [5], which is the topic this article concentrates on.

Recently Building Information Modeling (BIM) technique has been recognized as an essential tool for improving construction productivity in the construction industry. Through its capability of visualization and rich information, BIM has been used in different construction project phases for different purposes. There are many BIM guides developed to help users to implement BIM in real projects. One of the most popular guides is the BIM Project Execution Planning Guide developed by the Computer Integrated Construction Research Program (CIC) in the Pennsylvania State University [6]. Accompanying with this guide, another guide (The Uses of BIM: Classifying and Selecting BIM Uses) is developed for classifying and selecting BIM uses, in which a BIM use is defined as the method of applying BIM during a project’s life-cycle to achieve one or more specific objectives. CIC defined twenty-five BIM uses, and “4D modeling” is one of them. It is a powerful visualization and communication tool for a better understanding of project milestones and construction plans [7]. Under that BIM use, project schedules can be integrated with BIM elements. Therefore, project schedules can be easily represented for visualization.

Over the past few decades, many attempts are made to identify the causes of delays, and some computer-based systems/programs for delay management related works are consequently developed. The applicability of project management software and advanced IT techniques in construction delays mitigation has been examined [8]. Namely, to incorporate advanced IT techniques in construction delay mitigation has receive much attention. Through reviewing the literature on delay claims, a previous study identified two challenges that delay analyst’s encounter one is the retrieval of information, and the other is clear representation of the analysis. The ways to combat identified challenges include the proposed technological opportunities in the form of document management systems as well as computerized visualizations [9]. That study proposed BIM as a suitable tool that can assist through the ease of access to coordinated contemporaneous project information and the use of visualization through multiple dimensions. Based on that research outcome, this research targets on discussing the possibility of incorporating BIM into delay analysis.

2. Problems in current schedule delay analysis approaches
Although there have been many delay analysis methods developed [3], new methods continue to be developed, including the delay analysis under multiple baseline updates [10], the isolated collapsed but-for delay analysis methodology [11, 12], the critical path effect based delay analysis method [13] and the computerized total float management [14]. It shows that there doesn’t exist one schedule delay analysis method applicable for all conditions. Therefore, to select a suitable approach that can represent the best interests is a key issue in schedule delay claim. However, the selection can be influenced by a variety of factors consisting of project characteristics, contractual requirements, characteristics of baseline program, cost proportionality, timing of the analysis and record availability [15]. Notably, the availability of records usually plays a key role in winning a delay claim. For solving schedule delay analysis problems, all works can be divided into three stages: data collection, data analysis and data presentation. The problems in the three stages are discussed as followed.

2.1. Data collection
A previous study concluded that delay analysis method selection depends on the time and available resources, and on the accessibility of project control documentation after comparing four windows-based delay analysis methods and identifying their advantages and limitations [16]. However, contemporaneous documentation during the course of a construction project may not exist, may contain errors, or may omit important information [17]. Collecting necessary data and information related to project control is a tough task, especially those required for delay analysis.
For advanced schedule delay analysis methods, in general, schedule-related information is the basis for delay analysis. The common required documents are the as-planned schedule, updated schedule and as-built schedule. Previous studies [18-20] have focused on the issue of producing different schedules that can be organized to use. For example, the as-built schedule is useful for many schedule delay analysis methods. However, to construct an as-built schedule is time-consuming and costly [20]. This study believes that data collection and organization for delay analysis needs more supports by advanced IT techniques.

2.2. Data analysis
There are more than ten schedule delay analysis methods that can be classified into three categories: mathematical model, process-based model and computer-based model [3]. All of the methods require the information in project schedules and delay events to perform necessary time impact analysis. A good delay analysis method should contribute to a fair and accurate delay analysis result that can be accepted by contract participants and professional schedule analysts. However, to provide such a result is difficult due to the complexity of delay events and analytical processes. On the other hand, in some advanced methods, detailed analysis is expensive, time consuming, and may not support a delay claimant’s recovery request [21]. Some of the identified problems can be solved via developing a computer-based schedule delay analysis method [22].

There are some commercial schedule delay analysis software. Besides, a lot of advanced project management professional software have provided functions to perform fundamental schedule comparison that can be used for delay analysis. Developing a holistic and accurate delay analysis software is still challenging the current delay analysis practices. Therefore a previous study has tried to develop a web-based software [14]. Even though some computer-based systems are developed, the users still cannot get rid of their works on managing schedule and evidence of delay events. It is implied that to perform necessary delay analysis requires a lot of extra efforts. This study believes that to incorporate data management and data analysis would be of value for delay analysis and could be supported by advanced IT techniques.

2.3. Data presentation
A successful delay claims management program includes organization expertise that covers the three basic claims scenarios: claims prevention, claims preparation and claims defense. Each of these scenarios requires a skilled staff who are trained in the proper claims analysis and preparation techniques [23]. In general, engineering background staffs or professionals can perform necessary analyses with sufficient data. They usually present analytical results according to their engineering presentation style. However, in dispute resolution mechanism, the judge or the arbitrator may not have sufficient engineering background to understand the results produced by those staffs or professionals. How to make a persuasive presentation with analytical outcomes of schedule delays is a challenge to any unexperienced person.

Simple and clear presentation of delay impacts is a critical element of a construction delay claim. By using a standardized claim presentation form and compelling graphics, the contractor or owner can avoid presentation pitfalls and maximize the ability to prove entitlement and recover damages [24]. Furthermore, project management tools and techniques that if implemented properly have the potentials to address the main factors contributing to the occurrence of delays [25]. It is anticipated that incorporating project management tools in project planning, control, as well as delay analysis and presentation could be a possible research direction, in which different schedule participants contribute and receive necessary information easily and correctly. Namely, this study believes that using advanced IT techniques to support data presentation in delay analysis is necessary and is possible for an advanced schedule delay system.
3. BIM and its uses in schedule management

BIM has been widely used in different stages in a construction project. Through reviewing 35 construction projects, several BIM benefits have been identified, which include those related to project management objectives, i.e., cost reduction and time savings [26]. Obviously, BIM can be a powerful tool for project management. Excluding the applications and related benefits for a construction project in pre-construction stage, BIM can be employed during the construction stage for recording and presenting project information attached with BIM components. Possible BIM implementations are still expanding.

Among popular BIM uses [7], 4D modeling can provide visualized BIM models through different time frames. It is a good communication tool and provides possible approach for a better understanding of project schedule and construction plans. There are a lot of 4D BIM applications and advanced researches. In schedule management domain, BIM has been used in the following issues: project planning and scheduling [27], automated project progress tracking and measurement [28, 29] and schedule management [30, 31].

It is clear that to incorporate BIM technique into schedule management is possible and has received a lot of research attention. Schedule delay analysis is time-consuming. General it requires a lot of information that is clearly connected to delay events and activities. BIM not only provides accurate virtual models of a building or a facility but also contains accumulated diversified information along the life cycle of a project. Namely, it is suitable to employ BIM for delay analysis.

4. BIM for schedule delay analysis

Any delay analysis application can be considered as a result of the combination of contract documents, scheduler, record-keeping mechanism at the site, communication among project participants, delay analyst, and delay analysis methodology [32]. This paper has discussed the problems in current schedule delay analysis approaches, this section further discusses the possibility of using BIM to aid schedule delay analysis.

4.1. Data collection

Schedule network, daily construction report, quality control report, correspondence, progress curves, productivity measurement and change-order log are the essential delay indicators [33]. Among them, at least four types of schedule network, namely, as-planned, as-built, adjusted and entitlement schedules are commonly used in various delay analysis methods [3]. To collect schedule-based information will be the key to develop a BIM-based approach for schedule delay analysis. Some previous studies have examined the possibility of automatic generation of project schedule, especially for automatic as-built modeling [34] and even automated schedule updates using as-built data and a 4D BIM [35]. In other words, to enhance visualization of the updated as-built schedule for comprehensive schedule management is possible. A previous study has proved its possibility through a prototype system called the Construction BIM-assisted Schedule Management (ConBIM-SM) [36].

Excluding managing project schedules in BIM environment, to retrieve required information that is beneficial to delay analysis would be another issue. A previous study has examined the possibility of retrieval of information and visualization through BIM technique to support construction schedule delay claims [9]. Furthermore, to use commercial software is the first choice for project stakeholders in construction practice. But available commercial BIM or project management professional software suites do not provide sufficient functionality for BIM-based project schedule management. In general, to construct a 4D simulation in current BIM-based software commonly requires combining the information managed in BIM and project management professional software respectively. How to solve the problems mentioned above requires more research efforts.
4.2. Data analysis

Computer-aided construction delay analysis and claim preparation has received much attention. The tools/techniques/technologies used for delay analysis and claim preparation include expert systems [5], professional project management software [12] and web-based programming language [14]. As BIM technique is developed quickly, it is possible to incorporate BIM as another option for delay analysis and claim preparation [9].

A previous study has explored the use of 4D models, which provide a virtual construction simulation by linking a 3D model and project schedule, in support of CPM schedule delay analyses [37]. Furthermore, based on available schedule delay analysis methods, to incorporate analytical mechanism into popular commercial scheduling software is a possible direction [3]. However, it requires further investigations in realization and integration issues.

4.3. Data presentation

A previous study has focused on visual representation of project status through graphical attributes applied to 3D geometries, as well as the ability to digitally navigate within the 4D deliverable [38]. Therefore, a 4D deliverable for construction schedule updates is possible. 4D deliverable is valuable for the persons (the judge or the arbitrator) without strong engineering background. Furthermore, a BIM-based 4D model can contain quantity information as well as schedule in site level [39], which provides an essential assistance to clarify delay problems. The use of 4D models allows scheduling professionals to efficiently explore multiple schedule alternatives and contributes to the effective management of project change requests and time impacts. Notably, 4D BIM has the clarity required for conveying the bigger picture, yet was perceived as most useful for early project stages [40]. That is BIM provides a good alternative to be a more easy-to-understand tool. However, it requires more investigations to improve its practical use.

A previous study has proposed an approach to integrate as-built schedules and BIM models to improve the effectiveness of using as-built schedule in identifying schedule-related dispute problems [41]. However, most of the previous attempts focus on examining the feasibility of integrating BIM and information collection for delay analysis. Only a few study tries to explore the answers to the presentation problems of analytical results. This study believes that it is also necessary and valuable to investigate the possibility of solving data presentation problems by using BIM technique.

5. Conclusions

Many schedule delay analysis methods and systems have been developed. However, none of the methods or systems can provide a total solution to delay disputes. In general, more information put into delay analysis can usually produce more accurate and fair analytical results. Recently, BIM technique has been recognized as an essential tool for improving construction productivity in the construction industry. Although possible BIM implementations are still expanding, at least twenty-five BIM uses can be selected by considering the purposes of gathering, generating, analyzing, communicating and realizing information throughout the life cycle of a project. BIM can be regarded as an information-intensive visualization tool. Therefore, this study believes that BIM is an ideal means to solve the problems encountered in schedule delay analysis domain.

This study has completed an intensive literature review to discuss the problems encountered in available schedule delay analysis approaches and the possibility of using BIM as a tool in developing a BIM-based approach for schedule delay analysis. Identified problems in this study could be research issues. Hopefully, research results could be a fundamental of developing new approaches for resolving schedule delay disputes.
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