A Proposal for Implementing Building Information Modeling (BIM) to Manage the Prerequisite Activities in Construction Projects

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Abstract. The common practice of construction planning may not formulate the schedule at the appropriate level of detail. Some prerequisite activities such as material supply, plant installation, and document preparation are unorganized. Failure in managing prerequisite activities may increase the risk of delay. Thus, an improvement of the current scheduling practice is substantial which can be performed by adopting technologies. Building Information Modeling (BIM) is an innovative concept that allows us to integrate the schedule and the building element with the ability to control the information systematically. Considering the implementation of BIM is still limited, this paper aims to investigate the potential of BIM to improve the project schedule by detailing the prerequisite activities. The study is started by an extensive literature review to define the status of the current studies and the research gaps. The state of BIM implementation as a tool to improve the project schedule is examined. Lastly, the potential merge between BIM and the utilization of the prerequisites activities is elaborated. The proposal is an initial step to develop a BIM-based system which can automatically assign the prerequisite activities to every building element. It enhances the scheduling practices and minimizes the risk of delay.

1. Introduction
The construction schedule is perceived as one of the critical project success factors in construction projects [1]. Creating a schedule is not just about organizing construction activities but managing the project performance during the limited time with limited resources. Indeed, the development of a schedule as an effective tool to assist the project stakeholders to perform their project in achieving the goals is challenging. The schedule shall contain a series of complete activities with clear dependencies, the duration of each activity that is relevant to the available resources, and more importantly, a sufficient level of detailed activities.

Due to the complexity, type size, and nature of the construction projects substantially regarding the number of activities, the scope of works, and the limited time and resources, it is substantial to have a detailed and systematic construction schedule. However, in practice, the schedule fails to achieve a certain level of detail which includes prerequisite activities. It is hardly noticed that the project stakeholders organize the schedule of the prerequisite activities such as material supply, plant installation, and document preparation. Managing prerequisite activities seems trivial but failure to manage it can increase the risk of delay. Thus, an improvement of the current scheduling practice is substantial which can be performed by adopting technologies such as Building Information Modeling (BIM).

BIM is described as a concept of technology and a solution to enhance productivity by delivering an improved design, construction, and maintenance practice [2]. BIM involved an object-oriented
Computer-Aided Design (CAD) which supports the representation of 3D geometric of the building. It helps us to visualize the building conditions accurately [3]. Several benefits, in terms of technical perspective, knowledge management, standardization, diversity management, integration, economic, and scheduling are proofed to be the main reason for implementing BIM in construction [4].

Several BIM implementation in scheduling and planning has been performed to increase productivity. Considering that the scheduling process is laborious, time-consuming, and error-prone, an automated schedule generation system is created by implementing BIM and a discrete-event simulation [5]. Another approach of schedule development using BIM is proposed by identifying the process pattern and template of construction activities [6]. The automated quantity take-off on the BIM platform is also a piece of potential information to determine the duration of activity and allocate resources [7]. The automated generation of construction schedule by applying several constraints such as resources also highlights the implementation of BIM on construction scheduling [8] [9]. The BIM-generated schedule can be extended into scheduling during the operation and maintenance phase by integrating BIM and digital programming [10]. These previous research show that BIM integration on scheduling is potentially improving construction management practice. However, their focus is on the schedule creation, without mentioning any details on prerequisite activities.

The prerequisites activities such as document approval, material procurement, and plant/manpower allocation are barely investigated as the main attention of research. Nevertheless, it contributes directly to the risk of delay. As time is considered to be one of the project success factors in construction, minimizing the potential risk towards it becoming substantial, particularly by implementing current technology. Therefore, this study aims to identify the potential merge between the BIM implementation and the development of prerequisites activities by extensive literature review, expert verification, and matching process among its features. The prerequisite activities are scoped down into material preparation, labor, equipment, document preparation, and related predecessor activities. Even though this paper is still a proposal, it describes the main goal of the study in which to develop a BIM-based prerequisite activities system. It is designed to detail the schedule and to generate an automated notification for upcoming prerequisite activities. It helps us detailing the schedule therefore we can gain more control over the activities with minimum effort. The warning system of upcoming prerequisite activity potentially lowers the risk of delay.

1.1 BIM Potentials

BIM is a modelling technology to produce, communicate and analyse building models [2]. BIM has several method and implementation as commonly referred as BIM use. Several BIM uses has been identified and verified [11] in which representing the method to improve the project management using BIM concept. During the development of the study, this verified BIM use is utilized to support the proposed system.

The most common use, and considered as an initial implementation of BIM use, is BIM authoring. It aims to create visual representation of building which consist of several elements [2]. These elements carried out the detailed geometric data and visualization purposes which lead us to the second BIM use, which is visualization using 3D coordination. It helps us to enhance the level of understanding regarding the building conditions [12]. In addition, the element is able to withhold non-geometric element which extend the BIM use into database information management. BIM concept can also be implemented in phase planning or scheduling. The BIM uses incorporates the feature of time into the 3D model [13]. The result of this BIM use is 4D BIM model.

1.2 Prerequisite Activities

Construction projects consist of several repetitive activities such as concrete casting, steel reinforcement, steel erection, formwork production, etc. Construction projects are unique depending on the natural conditions and resources owned by the project. Therefore, even though the work is repetitive, the process of compiling the order of work and its scheduling cannot be uniformed easily. The challenges during the implementation of the construction schedule are inadequate problem in the pre-preparation
phase the defect of planning design, implementation, inspection, control process, the opposition and reunification of duration, cost and quality [14].

Generating construction schedule usually performed manually to establish a plan for each project. Nonetheless, the individual process of each task is usually organized through several phases with a variety of recurring, identical yet different, subprocesses that can be simplified to common reusable process patterns if properly generalized [15]. Since manual development of scheduling process is laborious and error-prone, a new approach is needed to optimize this process [5].

There are several scheduling methods developed and used widely in construction project such as Gantt chart, Critical Path Method (CPM), Precedence Diagram Method (PDM), and Line of Balance Chart (LOB). Critical path scheduling is one of the most popular way to illustrate the construction schedule and activity sequence. To perform a critical path scheduling, a project needs to be divided into smaller activities or tasks with specific duration and resources. Each activity needs to have connection each other with a certain sequence. A predecessor relationship in a schedule means that one activity should come before another. While a successor relationship implies that one activity comes after another activity.

To produce a good project scheduling, the planner must understand project sequence. The project sequence consists of a predecessor and a successor activity. For example, to be able to do concrete casting, the predecessor activity that need to be completed is reinforcement and formwork installation. Meanwhile, a pre-requisite activity is a required activity or sources that need to be done before starting another activity. The required activity not only focusing on the completion of predecessor activity, but also the availability of resources (machine, materials, man), and availability of legal aspects such as document approval from supervising consultants / owner.

2. Methodology
This paper were developed through three main stages as follows:

2.1 Semi-systematic literature review
First, several literatures such as journal, book, and conference paper were collected and summarized. The objective of the literature review is to obtain what is the latest research related to scheduling and pre-requisites activities. The publication was an academic and peer-reviewed study written in English. The result of this step is useful for finding research gaps in this area of research. The next step was to conduct a qualitatively depth interview with some stakeholders from construction company. This step aims to confirm the scheduling planning methods commonly carried out in the field and what factors need to be considered to plan a construction project schedule. Problems occurred in the actual construction project was also identified to ensure that the output of this research could help solve the problems.

2.2 BIM workflow investigation
Based on the research gap, we selected several BIM uses that potentially improve the current practice of prerequisite activities. Each of BIM uses are investigated regarding the workflow and the information needed. Several BIM implementation standards are utilized to support this step. As a result, the details of BIM uses were summarized.

2.3 Matching process and framework development
As the details of BIM uses which consists of workflow and the required information were identified, we matched the selected BIM uses with the features of prerequisite activities. Thus, it demonstrates on how BIM implementation can improve the current practice of prerequisite activities. Lastly, the workflow of the proposed system was assembled by combining the workflow of each BIM uses.
3. Results and Discussion

3.1 Current development prerequisite activity system

The result of the semi-systematic literature shows that previous research related to process patterns and automated scheduling has been carried out by several researchers. The pattern of the construction schedule process and construction activities can be identified and decomposed down into smaller parts [6]. The recognized pattern is used to determine process template during the development of BIM-based schedules which can help save the planning time and increase the productivity. Meanwhile, [8] proposed a BIM-based integrated scheduling approach which facilitates the automatic generation of optimized activity-level construction schedules for building projects under resource constraints, by achieving an in-depth integration of BIM product models with work package information, process simulations, and optimization algorithms.

A study regarding BIM-based schedule is performed to introduce a methodology that helps automate the time schedule generation in bridge construction projects [5]. This study aims to reduce the labour intensive and error-prone by using a 3D model-based application and makes interactive assignment of construction methods to single building elements. The approach is based on a constraint-based simulation of activities by considering available resources and the interdependencies between individual tasks. Constraint input data for the module consists of activity packages affected building element, the required materials, machinery and manpower resources, and the technical preconditions of an operation to be carried out. Once the simulation is started the user determines the resources available for the project. A chosen construction method applicable for a specific building part or component will generate the required resource (material, labour, equipment), and dependencies between individual and subprocess activities. Thus, the constraint for each activity can be created automatically. The simulation built on constraints is then repeatedly carried out, performing a Monte Carlo analysis in order to find a good schedule. The resulting detailed schedule can be easily combined with the 3D model of the project to generate a 4D animation of the construction process.

BIM as one promising tool for project management has also begun to be associated with scheduling. Wang et.al [16] proposes an interface framework using BIMs ability to produce quantity takeoffs of required materials (such as steel, forms, and concrete) to support site-level operations simulation and leading to the development of a project schedule. This system aims to improve BIM effectiveness in 4D applications by providing material quantities to evaluate task duration in a prompt and accurate manner and to evaluate resource allocation strategies. Using this framework, an animation and reliable working sequences could be generated to increase the effectiveness of 4D BIM usage. The generation of BIM-based schedule can be extended into the schedule for operation and maintenance phase [10].

These previous research show that BIM integration on scheduling is potentially improving construction management, however, their focus is on the schedule creation, without any detailing. The prerequisites activities such as document approval, material procurement, and plant/manpower allocation are barely investigated as the main attention. Therefore, this study is developed to fill the gaps.

3.2 BIM workflow

Based on BIM uses classification [17] and a guideline of BIM execution plan [18], the details of several selected BIM uses are summarized in Table 1. Table 1 shows that the 4D modeling has potential values to enhance the practice of construction scheduling, integrating planning and monitoring the supply chain. Those values indicate the benefit of implementing BIM. 4D modeling has a complex procedure that has been developed as shown in Figure 2. The process begins with identifying the construction sequences and information exchange requirement. The workflow also shows the need of 3D model, productivity information, and lead times. The 4D model is established by integrating 3D elements to activities. This workflow is adopted and modify to create the proposed system.
Table 1. The result of BIM uses workflow investigation

| BIM Use                      | Potential value                                                                 | Required information                                      |
|------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------|
| Phase planning (4D Modeling) | Understanding the phasing of the schedule, integrating planning of human, equipment, and material, monitoring procurement of materials | 3D model, schedule, productivity information, lead time   |
| 3D control and planning      | Utilizes the information model to control the                                   | Design specifications and intent, schedule, cost and labor info, construction families and libraries, design model, utilization model |
| 3D coordination              | Coordinate the building project through visual model; visualize the construction process | Construction documentation (architectural model, structural model, MEP model, other) |

The second selected BIM use is 3D control and planning. Although mostly the BIM use is utilized for construction layout analysis, it is adopted as a database management system in this research. This BIM use required to integrate the design specification, schedule, cost and labor information into the 3D model. This feature is in line with the proposed system as it needs database information system to collect the several data such as material and labor procurement documentation.

Lastly, the 3D coordination is selected as it helps us to visualize the building and gives us the current status of the construction process. This BIM use requires us to integrate the construction documentation such as architectural model, structural model, and MEP model. As the proposed system are planned to be used in construction stage, the coordination among those models are substantial. Therefore, this BIM use is adopted.

![Figure 1. Workflow of 4D Modeling [18]](image)

3.3 Potential BIM implementation on prerequisite activities

During the developing the proposed system, some BIM concept need to be clarified to make sure that it has the capacity to enhance traditional practice of project scheduling. The identified and selected BIM uses from previous step were then matched with the needs for planning pre-requisite activities. From previous research, the pre-requisites activities for each work were identified. In addition, expert interviews were also conducted to identify additional information that was needed in the development of the system. The result of the matching process is shown in Table 2.

A construction process can be decomposed into smaller activities. Depending on the site project, project budget and the resources owned by the contractor, each operation may be performed in various ways. Therefore, at the beginning of the formation of pre-required activities, it is necessary to decide the construction method [15] [5]. The different methods of construction can be visualized in BIM. For example, in concrete structure, there is an option to use cast in place concrete or precast concrete. This
difference can be visualized by implementing 4D modeling and 3D coordination. The selection of construction method is a crucial thing that will affect other information, namely resources (material, equipment, and labor), related subprocess, and its duration.

Each construction method will have implications for the sequence of work execution and the subprocesses of the selected method. Work sequence of an activity depend on two things, namely natural dependency and resources dependency. For example, the installation of beam formwork can be carried out after the installation of the scaffold. Even though there are sufficient resources available, if the scaffold has not been completed, the formwork work cannot be started, it is called natural dependency. While resource dependency, for example, is casting of beams and columns that cannot be done simultaneously due to the limited number of concrete pump and tower crane. In BIM, the sequence of work and its duration can be visualized. Normally, the work schedule is modeled using bar chart and PDM in Ms. Project. However, in BIM the work schedule can be linked with 3D model and visualized according to the implementation stages. Therefore, the 4D Modeling and 3D coordination took the main role in this proposed system.

Resources in construction activity such as labor, equipment, and material are unique depending on the method. The user should determine type of the resources and its volume. A task work cannot be carried out until all resources are ready in the site project. A delay in one resource, for example material, will resulted an idle for labor and equipment. Idle is accounted as waste which can result in delays in schedules and cost overruns. Thus, the availability of resources in the right particular time, amount, and specification is also one of the prerequisite activities that must be properly prepared [5], [15], [8]. In traditional project planning, the resources in each construction activity are usually stored in a privately owned database by the planner and are not well documented. As an improvement, a database information management in BIM software will accommodate the database storage of required resources in each activity.

In addition to the literature review on previous research, interviews with experts stated that approval documents are also needed to start a project activity. The shop drawing must be produced by the drafter, checked by the contractor's engineer and then approved by the supervisor. This process takes several days from drawing to approval. Therefore, document approval is also an essential aspect for pre-acquisition activities planning. The duration of each document approval can be stored as a database in BIM database information management. As we understand the intersection between BIM use and construction prerequisite activities, the proposed matrix was developed in Table 1.

Table 2. Matching process between prerequisite activity features and BIM uses

| Prerequisite activity features                  | Sources       | BIM Use                                    |
|------------------------------------------------|---------------|--------------------------------------------|
| Construction Method                            | [5], [15]     | Phase planning (4D Modeling), 3D coordination |
| Resource (materials, machine, manpower)        | [5], [15], [8]| 3D control and planning, Phase planning (4D Modeling) |
| Related sub process and its dependencies       | [5], [15]     | Phase planning (4D Modeling)               |
| Duration of subprocess                         | Interview     | Phase planning (4D Modeling)               |
| Document approval                              | Interview     | 3D control and planning                    |

As the matching process has been conducted, the proposed system is established. It consists of three stages as shown in Error! Reference source not found. Each stage describes the process of the development of the system as elaborated as follows.
3.3.1 Initiation

Initiation as shown in Figure 1 highlights the first step of research development in which the basic knowledge of prerequisite activities is initiated. The process is started with the intensive literature review to develop an extended list of prerequisite activities. The features and related factors of prerequisite activities are created through previous study through journal paper, books, and related articles. In this phase, the boundaries between the main activities and prerequisite activities are clearly drawn based on the literature through brainstorming process. The criteria are quite simple, the main activities usually appear on the contractors’ schedule quite often such as concrete work, wall work, or floor works. This support the limitation and definition of prerequisite activities in this study which are document preparation, resource procurement, and completion of the predecessor activities.

The extended list of prerequisite activities is later verified by selected expert from different field of expertise such as contractors, consultants, and owner. The semi-structural interview aims to confirm the list of prerequisite activities along with the duration. It also helps collect additional prerequisite activities that may not in the list. Questionnaire is also prepared to complement the interview to gather the detailed feature of prerequisite activities. The result of the interviewed is later used to form the new list of prerequisite activities which is stored into a databased which is used in the next stage.

During this stage of the research, the investigation on several BIM software is performed. It aims to select some potential software which is able to support the implementation of the proposed system. The pros and cons of several available BIM software along with its features are identified. The selection process is based on criteria such as the ability to handle geometric and non-geometric information and the ability to integrate with another software especially programming system.

Figure 2. The framework of the proposed system
3.3.2 Workflow
The aim of this stage is integrating between the prerequisite activities database into BIM model. This stage is started by authoring of a BIM model which represent the actual condition of the building. It also aims to develop an automated assignment so that the user who made a 4D BIM model, can automatically obtained a list of prerequisite activities along with the time according to their schedule and BIM model. The proposed system is supposed to reduce a repetitive and tedious work by developing a database and then later recalled based on the activities listed in the 4D BIM.

3.3.3 Application
The application stage describes the manufacture process by turning the concept into a platform which can be used by the user. The user-friendly interface is created to facilitate the user to use the proposed system. An interactive method to assign the prerequisite activities and 4D BIM shall be performed automatically. As the user update their 4D BIM by inputting the construction progress, the proposed system is able to identify the critical and upcoming prerequisite activities. This identification process is later be transformed into a pop-up notification. This notification is an early warning notification so that the risk of delay causing by unprepared trivial yet important activity such as document process can be mitigated.

4. Conclusions
The semi-systematic literature review shows the potential benefit of integrating BIM and prerequisite activities. The lack of focus on the detailing schedule was found to conclude that the prerequisite activities are substantial. Several BIM uses are identified and selected to be implemented such as Phase planning (4D Modeling), 3D control and planning, and 3D coordination. These selected BIM uses are matched with the features of prerequisite activities to identify the potential improvement of current practice. The matching process between the prerequisite activities and BIM uses also shows that the development of the proposed system is potentially feasible.

The proposal of implementation BIM for prerequisite activities has been elaborated. It consists of three main stage which are initiation, workflow, and application. Initiation take a role to prepare the basic knowledge of the system by provide the verified list of prerequisite activities. The list is created by extensive literature review and expert interview. The workflow aims to integrate the verified list into the BIM model and the project schedule. This workflow also aims to develop an automated assignment so that the user who made a 4D BIM model, can automatically obtained a list of prerequisite activities along with the time according to their schedule and BIM model. The last, application is creating a friendly user-interface so that when the user update their schedule by inputting their progress, the model will give a pop-up notification as a warning if there are any prerequisite activities needed to be accomplished.

The research is still a proposal, each stage needs to be accomplished in order to aim the main goal, which is developing a BIM-based prerequisite activity system. The future works consists of detailing the prerequisite activities for each activity in construction project. The expert interview is also needed to verify it. Lastly, the development of the proposed system in the current available BIM-based software is performed.

5. References
[1] N Ramlee, N J Tammy, R N H R M Noor, A A Musir, N A Karim, H B Chan, and S R M Nasir 2016 Critical Success Factors for Construction Project: Proceedings in International Conference on Advanced Science, Engineering and Technology (ICASET) December 21–22. (Malaysia: MARA University of Technology)
[2] C Eastman, P Teicholz, R Sacks, and K Liston 2008 BIM Handbook, A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors (New Jersey: John Wiley & Sons, Inc)
[3] S. Azhar et al. 2011 Building Information Modeling (BIM): Benefits, Risks and Challenges for
the AEC Industry J. Leadership and Management in Engineering. Vol 11 issue 3, pp 241-252

[4] A Ghaffarianhoseini, J Tokey, A Ghaffarianhoseini, N Naismith, S Azhar, O Efimova, and K Raahemifar 2017 Building Information Modelling (BIM) Uptake: Clear benefits, Understanding Its Implementation, Risks and Challenges J. Renewable and Sustainable Energy Reviews. Vol 75, pp 1046–1053

[5] I C Wu, A Bormann, U Beibert, M König, and E Rank 2010 Bridge Construction Schedule Generation with Pattern-Based Construction Methods and Constraint-Based Simulation J. Adv. Eng. Informatics. Vol 24, pp 379–388

[6] K Sigalov and M König 2017 Recognition of process patterns for BIM-based construction schedules J. Adv. Eng. Informatics. Vol 33, pp 456–472

[7] W C Wang, S S Weng, S H Wang, and C Y Chen 2014 Integrating Building Information Models with Construction Process Simulations for Project Scheduling Support J. Autom. Constr. Vol 37, pp 68–80

[8] M H Liu, Al-Hussein, and M. Lu 2015 BIM-Based Integrated Approach for Detailed Construction Scheduling Under Resource Constraints J. Autom. Constr. Vol 53, pp 29–43

[9] Z Wang and E R Azar 2019 BIM-Based Draft Schedule Generation in Reinforced Concrete-Framed Buildings J. Constr. Innov. Vol 19, pp 280–294

[10] C Chen and L Tang 2019 BIM-Based Integrated Management Workflow Design for Schedule and Cost Planning of Building Fabric Maintenance J. Autom. Constr. Vol 107

[11] V Likhitruangsilp, M J Malvar, and T Handayani 2016 Implementing BIM Uses for Managing Risk in Design-Build Projects Proceedings 16th Int. Conf. Comput. Civ. Build. Eng (ICCCBE) July 6-8 (Japan: Osaka University)

[12] R Kreider, J Messner, and C Dubler 2010 Determining the Frequency and Impact of Applying BIM for Different Purposes on Building Projects Proceedings 6th Int. Conf. on Innovation in Arch., Eng. and Constr. (AEC) June 9–11 (USA: Pennsylvania State University)

[13] H Wang and X S Song 2015 Research on BIM Construction Schedule Generating Algorithm Int. J. Simul. Syst. Sci. Technol. Vol 16, pp 10.1-10.7

[14] X Li, J Xu, and Q Zhang 2017 Research on Construction Schedule Management Based on BIM Technology J. Procedia Eng. Vol 174, pp 657–667

[15] A Benevolenskiy, P Katranuschkov, and R J Scherer 2011 Ontology-Based Configuration of Construction Processes Using Process Patterns Proc. of the 2011 EG-IC Workshop, Enschede, The Netherlands. July (Dresden: Dresden University of Technology)

[16] W C Wang, S W Weng, S H Wang, and C Y Chen 2014 Integrating Building Information Models with Construction Process Simulations for Project Scheduling Support J. Autom. Constr Vol 37, pp 68–80.

[17] R G Kreider and J I Messner 2013 The Uses of BIM: Classifying and Selecting BIM Uses (Pennsylvania: Computer integrated Construction Research Program)

[18] J Messner, C Anumba, C Dubler, S Goodman, C Kasprzak, R Kreider, R Leicht, C Saluja, and N Zikic 2011 BIM Project Execution Planning Guide - Version 2.2. (Pennsylvania: Computer integrated Construction Research Program, Pennsylvania State University)