BIM-Based Framework for Creating Automated Construction Schedules: A Proposed Solution in Vietnam

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Abstract. In recent years, Building Information Modeling (BIM) has garnered a great deal of interest due to its benefits in design, generating construction schedules, and monitoring of the building process. In Vietnam, the creation of a construction plan depends on the knowledge and experience of designers, and typically these schedules are created manually. This study proposes a framework for developing a tool with features that suggest construction schedules based on created 3D-BIM models to achieve a fully automated and efficient design process. The framework integrates digital graphic information of building information modeling (BIM) with construction and schedule data, producing construction activity sequences pertinent to each other and the proposed building design. The expected results of conducting research according to this framework are the visible geometric representation and engineering data are merged into a single database that project managers can use to examine and modify the schedule effectively. As a result, resource-intensive activities can be reduced and productivity can be increased.

Keywords: Building information modeling · Construction schedule · Automation generation · Optimization algorithms · IFC standard classifications

1 Introduction

The industry of architecture, engineering, and construction (AEC) have seen a significant increase in projects, particularly in developing nations like Vietnam. This industry has contributed significantly to each country's gross directed product (GDP). Besides that, the construction section, which consumes many workers and resources, has been facing potential problems regarding wasting time and cost if construction managers cannot control construction projects effectively.

Building Information Modeling (BIM) has been developed and applied in various aspects of the construction industry with many clear benefits. In addition, BIM contributes throughout the life cycle of construction projects, from initial planning to project

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completion. Although most respondents viewed BIM as a multidisciplinary tool, their remarks indicated that interoperability concerns between the different BIM platforms in the industry still remain [4]. The majority of survey respondents (91%) felt that the best stages for adopting BIM in sustainable design and construction were schematic design (40%), predesign/program (31%), and design development (20%).

Planning and scheduling play crucial roles in the delivery of a project by optimizing the time and cost components of project management. Specifically, these tasks take a great deal of time and frequently relies on the knowledge and experience of schedulers to generate schedules for construction activities. However, most schedulers generate construction schedules manually, and it takes time to create and adjust them to achieve expected needs. Besides, schedulers conduct construction sequencing design in separate steps, or even other individuals generate it. As a result, there is a need to consume more time to finish them under pressure from relevant parties. Therefore, this study is conducted to present a framework to create a process of automated generation of construction schedules based on 3D Revit models via industry foundation classes (IFC) standard classification and optimization algorithms.

2 Literature Review

Decades of research have gone into the development of automated schedule generation; some of these methods are as follows: knowledge-based, algorithm-based, and model-based approaches.

2.1 Knowledge-Based Scheduling Approach

Several studies were conducted on generating construction schedules; the knowledge-based scheduling approach was designed based on sharing and reusing successful project templates from the past to avoid scheduling difficulties that may arise with repetitive projects [10]. In addition, a system designed to demonstrate the feasibility of producing project schedules from construction templates [6].

2.2 Algorithm-Based Scheduling Approach

Various strategies were employed to address scheduling issues. In the construction industry, the most prevalent algorithm is the Genetic Algorithm (GA). In the 1970s, John Holland developed the Genetic Algorithm, an enhanced heuristic search strategy [9]. It is very beneficial for solving dynamic construction schedule issues. This method is, in principle, inspired by the evolution of natural population genetics, in which it selects the most compatible chromosomes and causes them to mate and cross-pollinate proportionally to form new generations. Selvam and Tadepalli [12] utilized Genetic Algorithm, a programming-based meta-heuristic that modifies methods for scheduling the critical path.

2.3 Model-Based Scheduling Approaches

Widespread adoption has occurred for model-based procedures, which often relate to using model information to carry out advanced operations [5]. This category of techniques enables users to study and manipulate model data to create a schedule and 4D views. This approach may be divided into Computer-Aided Design (CAD)-based methods and BIM scheduling components. On the basis of the integration of a product model, a process model, and complementary information technology (IT) solutions, conducted research is to develop viable new approaches for modeling scheduling activities in the context of building [11].

CAD allows rapid model creation, modification, and analysis. It also has advanced features like 3D visualization, basic calculations, and recording the building's materials, measurements, and positions. CAD-based scheduling methods were developed from these skills. BIM systems feature more advanced functionality like conflict detection, cost calculation, energy analysis, and quantity take-offs than CAD platforms because they contain data-rich, object-oriented models. BIM systems can also integrate with other applications or include add-in tools.

2.4 BIM Technology for the Design Stage

Various studies have researched different benefits of BIM technology and indicate the effectiveness of BIM tools applied in many aspects of construction projects. Typically, designers use Revit to create 3D building models and generate construction schedules related to 3D models in Naviswork. Many studies are conducted to indicate the advanced applications of these tools; however, there is a need for automated generating construction planning.

Moreover, industry foundation classes (IFC) models define geometric shapes, relationships, processes, materials, performance, and other attributes essential for the design, production, construction, and maintenance of buildings using attribute, relationship, attribute set, and quantitative parameter definitions [2]. IFC model libraries are digital representations of standard design components like beams, plates, and columns and resources like steel bars, sand, and building equipment. In addition, IFCs make models reusable, portable, and interoperable [3], and provide a plausible foundation for mapping and exchanging design and construction data within the context of BIM.

2.5 Related Work

The construction industry is rapidly advancing, particularly in the use of Building Information Modeling (BIM) and optimization algorithms. BIM provides a digital representation of a building, and optimization algorithms can help find the best scheduling solution while considering constraints. Several academic studies have been conducted to explore the potential benefits of using BIM and optimization algorithms to generate construction schedules, but there are also limitations and challenges to address as Table 1.

Table 1. Summary of several academic studies

No	Title	Author (Year)	Highlights	Limitations	References
	Multi-objective genetic optimization for scheduling a multi-storey building	Agrama (2014)	– The study proposes a multi-objective genetic optimization algorithm for construction scheduling – Project scheduling is more comprehensive because the optimization process can consider multiple objectives, such as project duration and cost – The study includes sensitivity and trade-off analysis to understand better how variables affect scheduling results	– One case study may not represent all construction projects – The study's optimization algorithm is limited to scheduling multi-storey building projects – Weather and resource availability can significantly impact construction schedules, but the study does not consider them	[1]
	Integrating building information models with construction process simulations for project scheduling support	Wang et al. (2014)	– The study suggests integrating BIMs with construction process simulations for project scheduling – BIMs' rich data can improve construction scheduling – The study analyzes the results and shows how the proposed framework for construction scheduling support may benefit	– One case study may not represent all construction projects – The study's framework relies on BIM data, which may be inaccurate or unavailable – Weather and resource availability can significantly impact construction schedules, but the study does not consider them	[13]

(*continued*)

Table 1. (*continued*)

No	Title	Author (Year)	Highlights	Limitations	References
	BIM-based integrated approach for detailed construction scheduling under resource constraints	Liu et al. (2015)	– The study proposes a resource-constrained BIM-based integrated approach for detailed construction scheduling – BIMs' rich data can improve construction scheduling – The study analyzes the results to show how the proposed approach for construction scheduling under resource constraints may benefit	– One case study may not represent all construction projects – The study relies on BIM data, which may not always be available or accurate – Weather and resource availability can significantly impact construction schedules, but the study does not consider them	[8]
	Framework for automated generation of constructible steel erection sequences using structural information of static indeterminacy variation in BIM	Kim et al. (2020)	– The study introduces a BIM-based framework for automating constructible steel erection sequences – Structural information of static indeterminacy variation improves schedule accuracy in the proposed method – The study analyzes the results to show how the proposed method could improve construction project efficiency	– The study only covers construction project steel erection – A small number of case studies may not be representative of all possible applications – Weather and construction site changes, which can affect results accuracy, are not considered in the study	[7]

3 Methodology

This study proposes a research framework to develop a construction schedule recommendation tool based on the 3D BIM model and IFC classification, as shown in Fig. 1, and detailed described as follows.

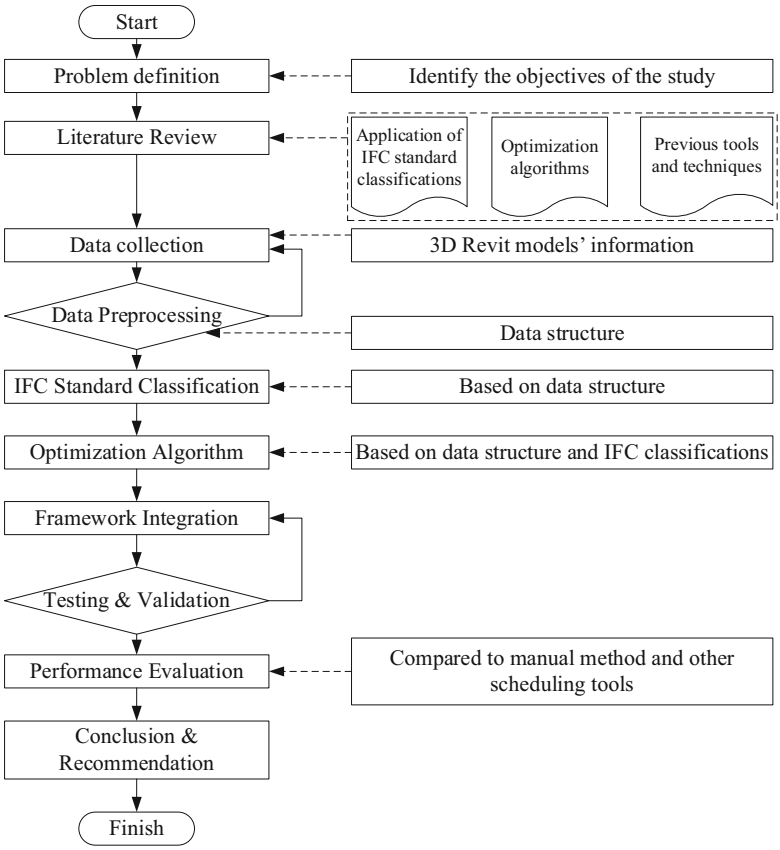

Fig. 1. Flowchart of the research methodology

Step 1: Problem Definition: Define the problem and the study's objectives precisely. This includes knowing the construction schedule's needs, such as the required level of detail and the limits that must be considered.

Step 2: Literature Review: Conduct a literature review to obtain information on comparable studies and to establish the current state of knowledge in this field. This includes investigating the application of IFC standard classifications, optimization algorithms, and other pertinent tools and techniques.

Step 3: Data Collection: Collect data from the 3D Revit models that will be used in the research. This data should include information about the models' items, including their location, size, and purpose.

Step 4: Data Preprocessing: Prepare a data structure that may be used for optimization by preprocessing the data received from the 3D Revit models. This may require converting the data into a format compatible with the optimization algorithm and cleaning or altering the data to eliminate any flaws or inconsistencies.

Step 5: Implementation of IFC Standard Classifications: Implement the IFC standard classifications on the data structure to be compatible with other building information models and can be readily connected with other systems.

Step 6: Development of the Optimization Algorithm: Based on the data structure and IFC classifications, develop an optimization algorithm to determine the construction schedule. The optimization method should take into account the restrictions and objectives specified in the requirements and employ heuristics to create a schedule that satisfies the project's objectives.

Step 7: Framework Integration of the Optimization Algorithm: Integrate the optimization method and any extra tools or modules required to build the final schedule into the framework. In addition to a user interface for inputting data and limitations and reviewing the schedule, the framework should also have a user interface.

Step 8: Testing and Validation: Test and verify the framework to ensure that it provides accurate and reliable schedules that fulfill the criteria. This may involve comparing the framework-derived schedules against those generated manually or by other scheduling tools.

Step 9: Performance Evaluation: Evaluate the performance of the framework by comparing its generated schedules to those prepared manually or by other scheduling tools. This may involve testing the framework's precision, dependability, and effectiveness.

Step 10: Conclusion and Recommendations: Summarize the study's findings and provide suggestions for further research or framework enhancements.

4 Results and Discussion

Based on the above literature review, one common limitation among these studies is the lack of integration of the generated construction schedules with other relevant project information, such as resource availability, cost and safety constraints. These limitations hinder the practical application and acceptance of the generated schedules by construction professionals, as they require a comprehensive and integrated view of all aspects of the project. Moreover, it is crucial to consider other factors that may impact the construction process, such as site conditions and changes in the project scope, to ensure the accuracy and reliability of the generated schedules. The algorithm-based techniques are capable of math-based searching strategies capable of discovering optimum solutions for dynamically resource-constrained scheduling situations. The algorithm-based scheduling approaches function as a complement to conventional scheduling techniques.

Knowledge-based approaches may sometimes be prone to inaccuracy, particularly when the templates search engine is poorly built. Consequently, many engineers choose model-based scheduling approaches, comprising one of the following technologies: CAD-based and BIM-based. Design, visualization, and simulation may be simplified by both technologies. However, parametric modeling in BIM is significantly more capable than CAD.

BIM has several novel capabilities that may be used in the context of autonomous schedule creation. Besides, the application of optimization algorithms to solve technical problems is an inevitable trend in the construction industry today. Therefore, integrating optimization algorithms and BIM models to generate construction schedules helps designers save a lot of time and minimize human errors.

The study outcomes are expected to be possible highlight the performance improvements, such as increased schedule quality, reduced creating time, and provide statistical analysis to support these findings. The results section could also present visual representations of the schedules generated by the framework, such as Gantt charts, and compare them to existing schedules for the same projects to demonstrate the improved accuracy and efficiency of the proposed framework. This paper presented a method for developing an add-in for Naviswork that generates the construction schedule automatically based on 3D Revit models. Figure 2 is provided as an illustration of the expected results of this study of conducting research according to Fig. 1.

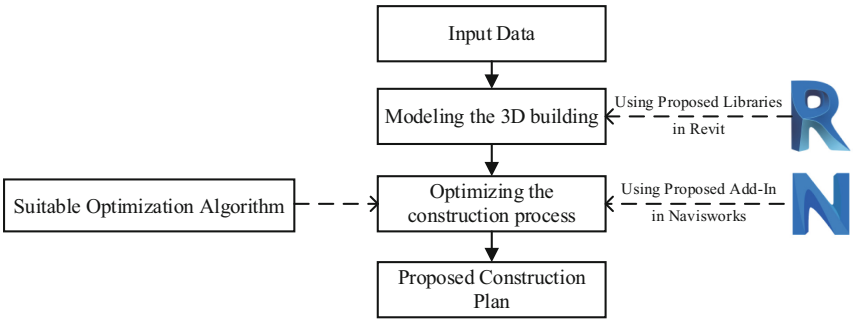

Fig. 2. An illustration of the process of automated generation of construction planning

5 Conclusion

BIM technology has altered the conventional project planning methods used by engineers. BIM enables a more visible and transportable information platform throughout a project's duration, resulting in increased collaboration between all project participants. These capabilities have boosted the job efficiency of AEC industry personnel. In addition, BIM is interoperable with software and plug-ins from other disciplines. Despite these benefits, the BIM's schedule creation capabilities are nowhere near their full potential. The method of data transmission inside BIM systems remains challenging. In addition, it is necessary to discover a strategy to employ 4D BIM effectively. By merging 3D models

and optimization algorithms, it can suggest a project's schedule effectively. Therefore, the proposed framework aims to generate construction schedules based on necessary sources as data, the optimization algorithm, and the simulation model. Finally, it will is tested and validated with an actual construction project to conclude the effectiveness of the proposed framework. Expected results and recommendations related to the proposed framework can be used to further studies.

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