

Article

# Research on Lean Construction Management Mode of EPC Project Based on BIM

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**Abstract:** In view of the low production efficiency, backward information level and rough project management of the traditional construction industry, it is necessary to introduce a construction model that can efficiently achieve the project construction goals. Taking EPC projects as the research object, building information modeling (BIM) as the technical means, and lean construction (LC) as the management model, this paper constructs a lean construction management model for EPC projects based on BIM, the "BIM-LC" model. From the perspective of the general contractor, the lean construction implementation mechanism of EPC projects using BIM technology is proposed, and the research is combined with EPC project examples. The results show that through the practical application of this model, the characteristics of BIM technology and lean construction refined management can be brought into play, the EPC project management process can be simplified, and the efficiency of project management can be improved.

**Keywords:** Building Information Modeling; EPC project; lean construction; informatization

## 1. Introduction

As the scale of China's construction industry continues to expand, in 2015, the total output value of the national construction industry reached 18.08 trillion yuan, accounting for 26.71% of the gross domestic product (GDP) of that year, and the added value of the construction industry in the whole society was 4.65 trillion yuan [1]. This data shows that the construction industry plays an important role in China's national economy. However, the domestic construction industry generally faces the problems of low profit margins and insufficient competitiveness despite the large overall scale of the industry. These problems have long restricted the development of the construction industry and construction companies. The root cause lies in the backward management concept and loose management model of construction projects. In recent years, Building Information Modeling (BIM) and Lean Construction have been widely used in construction projects, providing the construction industry with efficient information technology means and advanced construction management concepts, and improving the industry's production efficiency and project management level [2].

Lean construction management is a new project management model that can accelerate project progress and save costs and construction time. Building Information Modeling (BIM) is a digital tool used for engineering design and project management. It can improve project construction efficiency and realize online communication and real-time control, which is highly consistent with the goals of lean construction management [3]. By applying the new tools and methods introduced by BIM and lean construction, the project management model can be improved, the operating costs of construction projects can be reduced, and the goals under the principles of lean construction can be achieved [4-5]. In addition, the implementation of lean construction based on BIM technology can help all parties involved in the construction project to manage and control the design, production,

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construction and other processes through the visualization function of BIM, and realize the integration of design and construction [6]. Therefore, studying the integrated management model of lean construction and BIM technology is of great significance to improving the current situation of project management.

Domestic research on BIM technology and lean construction started late, focusing more on the construction of basic concepts and technical frameworks, and less on its specific application in EPC project design and construction, especially from the perspective of lean construction. In response to the above problems, this paper deeply studies the implementation mechanism of the lean construction model based on BIM technology from the perspective of project construction general contracting, and discusses the lean construction management model of EPC projects based on BIM technology in combination with actual project cases. It is expected to provide valuable experience for the subsequent lean construction practice of similar EPC projects.

## 2. EPC Project Lean Construction Management Model

EPC project management is a management model that entrusts the overall design, procurement, and construction to the management subject, in which all engineering construction activities are carried out under the organization of the subject until the project is completed and delivered. Specific work includes taking design as the guide, integrating project procurement, construction production, material procurement and other links, and formulating plan management for each stage in the early stage of the project, as well as building construction document processes, such as contract details, design review, design documents, bidding technical documents, material and equipment review and other documents. This model is based on lean thinking and aims to achieve an overall delivery method for construction projects with high quality, optimal construction period and minimum resource consumption.

In the lean construction model of the project, the smooth flow and efficient transmission of information are the basis for ensuring that all parties in the project have timely grasp of information and realize comprehensive sharing. With the continuous development of engineering projects, the traditional data expression methods in China's construction industry have been unable to meet the management requirements of modern large-scale EPC projects. BIM technology can optimize the planning process of the project construction system through centralized access to information and diversified file interaction, thereby achieving high-quality and high-standard project construction.

## 3. Analysis of Lean Construction Relationship Based on BIM

### 3.1. Main Principles of Lean Construction

Through the study of relevant books on lean thinking and lean construction and domestic and foreign literature, this article summarizes the main principles of lean construction as follows:

- 1) Reducing cycle time. In construction projects, reducing cycle time should focus on the following aspects: project construction cycle, construction phase, material transportation, etc.
- 2) Select appropriate production control methods. In a push production system, production behavior is driven by production plans; in a pull production system, production behavior is driven by production demand in downstream links. Pull production systems help achieve precise production and reduce waste, which is consistent with lean thinking [7].
- 3) Standardized management. Standardized management can reduce the probability of accidental errors and the variability of product characteristics. It can also prevent workers from relying on their personal experience, which helps improve the stability of work quality.

- 4) Visual management. Visualization of production methods can clarify construction standards and help implement standardized management; visualization of production processes can help workers perceive process status and improve methods [8].

### 3.2. Main Functions of BIM Technology

Through the research and analysis of BIM technical guidance books and domestic and foreign literature, this paper summarizes the key functions of BIM technology, including editing, evaluation and reporting.

- 1) Ensure the accuracy and integration of project information and design models. In a BIM model, all data originates from a comprehensive database. Changes in any view will directly update the database, thereby automatically updating other views. Information based on a BIM model will not be stored multiple times, while in the traditional design process, information is often saved repeatedly in multiple views. The automatic collision detection function of BIM software can identify conflicts between different parts of the model, optimize the design, and achieve the integration of different professional models [9].
- 2) Automatic generation of drawings and documents. Currently, various BIM software provide different levels of automatic generation of drawings and documents, including floor plans, elevations, sections, 3D views, and detailed drawings. These can be automatically generated from the BIM model and associated with the main model, automatically updated as the main model changes [10].
- 3) Rapidly generate and evaluate multiple construction plans. This is mainly reflected in the automatic generation of project tasks, plan changes, resource demand plans, construction simulation of engineering plans, and 4D visualization of construction progress.
- 4) Online communication and exchange. The BIM database platform enables project participants such as builders, constructors, and designers to communicate online, put forward opinions or suggestions on various aspects of the project, improve the information flow in the production system, and enhance the project management awareness of various personnel.

### 3.3. Analysis of the Relationship between BIM Technology and Lean Construction

By summarizing the main principles of lean construction and BIM technology, the interaction between the two in each stage of the project is discussed. In the design stage, the visualization function of BIM makes it easier for project participants to understand the design intent and to more clearly grasp the comprehensive needs of the construction project. In the design refinement stage, since the design of complex building models is difficult to be completed independently by a single professional designer, multi-party collaborative design is required to achieve accurate model design.

During the construction phase, BIM technology can automatically generate project task compilation, plan changes, and resource demand plans, which is consistent with the principles of increasing flexibility and shortening cycles in lean construction. By integrating suppliers, supply chains, and manufacturing equipment systems in engineering projects, the cooperation of all parties can be strengthened and a win-win situation can be achieved [11].

## 4. Implementation Mechanism of Lean Construction in EPC Projects Based on BIM

### 4.1. Interaction between BIM and LC

The interactive relationship between BIM and lean construction (LC) refers to the support role of BIM technology in achieving LC goals. Through qualitative analysis of the interactive relationship between BIM usage functions and LC goals, it can be concluded that the role of BIM technology in lean construction is mainly concentrated in information

integration, collaborative design, 4D progress management, 5D investment control and operation and maintenance assistance. In project practice, create conditions to promote the support effect between the two, thereby maximizing project value.

#### 4.2. Implementation Mechanism of BIM Supporting LC

In EPC project management, the management scope covers multiple professional fields such as civil engineering, steel structure, pipelines, decoration and renovation, and involves frequent cross-operation and complex construction processes. This makes management in information integration and communication, progress management, cost control and contract management more difficult. However, under the lean construction model, the general contractor can use refined management concepts and methods based on project management policies and goals at all stages of project implementation, combined with advanced information technology and management methods to improve the operational efficiency of the project.

At present, the application scope of the combination of BIM and lean construction (LC) is mainly concentrated in the information storage, transmission and sharing of EPC projects, as well as the construction of comprehensive project management models and the establishment of sub-databases, including contract management, progress management and change management. These applications provide support for all parties to make project decisions and work collaboration. BIM technology can promote the implementation of lean construction, while lean construction provides BIM with a more advanced construction system and application space, further exerting the role of BIM technology, thereby promoting its promotion and application in the construction industry and improving the industry's information level [12]. Through a comprehensive analysis of the relationship between lean construction and BIM, the interaction mechanism between BIM and lean construction can be summarized as shown in Figure 1 .

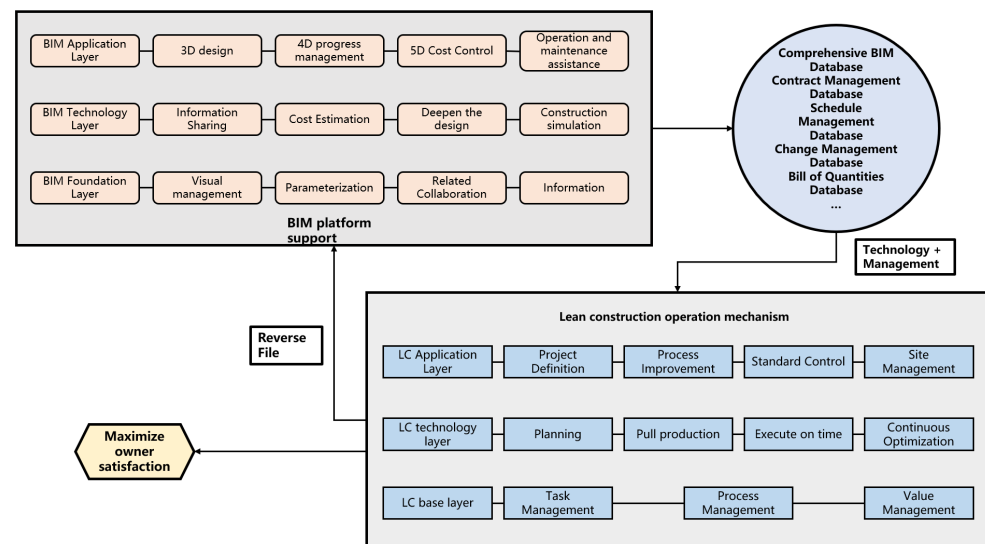


Figure 1. Interaction between Lean Construction and BIM.

#### 4.3. BIM-Based Lean Construction Management Model - "BIM-LC "

By outlining the main principles of lean construction and the core functions of BIM technology, the support role of BIM technology for lean construction and its interactive mechanism are analyzed. BIM technology can provide support for lean construction at multiple stages of project implementation. In the process of lean construction implementation, integrating BIM technology helps achieve project goals, such as reducing waste, improving efficiency and increasing value [13-14].

Based on the above analysis, this paper attempts to establish a BIM-based lean construction management model - "BIM-LC", as shown in Figure 2. This model studies the implementation methods and processes of BIM-based lean construction management from multiple perspectives such as lean design, lean construction and lean supply of "BIM-LC" to promote the maximum satisfaction of owner needs.

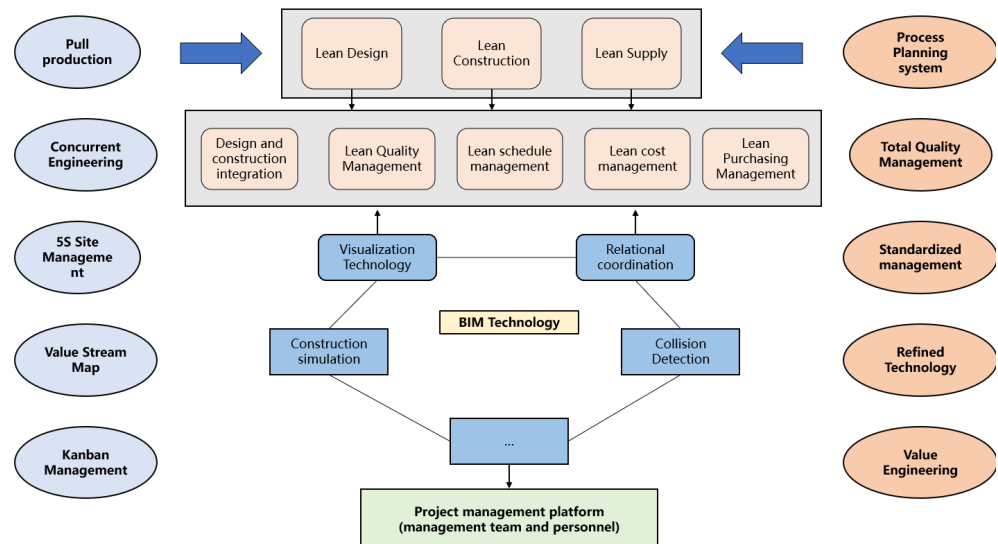


Figure 2. BIM-LC" joint model.

In the "BIM-LC" model, the relevant management technologies of lean construction mainly include pull production, concurrent engineering, 5S site management, value stream mapping and Kanban management. These technologies can facilitate the implementation of process planning systems, total quality management, standardization management, refined technology and value engineering. In the specific implementation process, the main implementation stages of lean construction management and the application of BIM technology platform constitute the main content framework of the "BIM-LC" model. The BIM platform is not only a cooperation platform for all project participants, but also serves as a communication and collaboration platform between project participants such as owners, construction parties, and designers.

The "BIM-LC" model aims to achieve the goal of "maximizing customer value" by optimizing the implementation methods and processes of project management. The model is committed to completing project delivery at the lowest cost, optimal construction period and highest quality by continuously reducing waste, improving efficiency and continuous improvement. This not only maximizes the needs of the owner, but also improves the benefits of the general contractor, achieving mutual benefit and win-win results for both parties.

#### 4.4. Applied Research - Taking the Phnom Penh International Airport Project in Cambodia as an Example

The project is located in Kanrasden County in the south of Phnom Penh, the capital of Cambodia, covering an area of about 2,600 hectares and a total construction area of about 210,000 square meters, including the terminal building, north concourse, energy center, viaduct, outdoor roads and parking lots. Taking the lean construction management of the Phnom Penh International Airport project in Cambodia as an example, explore the full life cycle process management of such EPC projects combined with the lean construction model. From the design, planning, construction, procurement and other aspects of lean construction, the airport project management process and integration are efficiently promoted.

As the general contractor of the project, China Construction Third Engineering Bureau No. 1 Company established a design management system of "Design Management Department + Local BIM Engineer" in the project, and used the 4D-BIM collaborative work platform as a carrier. Through process organization and technical management in technology, progress, quality, safety, business, operation and maintenance, it carried out general contracting lean construction process management such as parallel engineering, pull production, standardized control, value management, and teamwork in the three aspects of design and construction, procurement and supply, and delivery and operation.

By applying the "BIM-LC" model, the ultimate goal is to deliver engineering construction products that can be maintained in the later stage, while improving the level of project performance, and providing owners with lean and intelligent building products. The "BIM-LC" model application framework for the airport project is shown in Figure 3 .

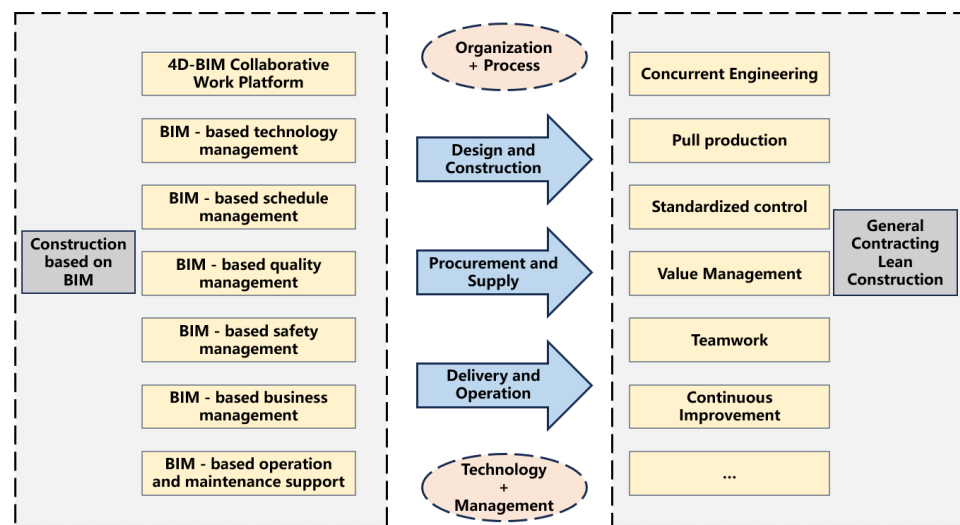


Figure 3. Application of "BIM-LC" model in Phnom Penh Airport Project, Cambodia.

#### 4.4.1. Lean Design Management Based on BIM

Lean design management adopts the concept of concurrent engineering and integrates the design and construction stages [15]. In the DB model, the general contractor is responsible for the design and construction of the project; in the EPC general contracting model, the general contractor is responsible for design, construction and procurement. In both models, the general contractor can independently coordinate the design and construction process. Based on the BIM model, the designer uses BIM technology to design the project and opens the BIM model to the owner and the construction party, so that the construction party can view the model. The design plan is reviewed from the construction perspective, and the construction party can raise possible problems based on the actual situation [16]. After receiving the feedback from the construction party, the designer should attach importance to it and discuss and modify the plan with the construction party. Throughout the process, the owner is mainly responsible for contact, coordination and supervision, and does not directly intervene in the specific work.

#### 4.4.2. Lean Construction Management Based on BIM

In the "BIM-LC" model, lean construction management is at the core. Before starting construction, the project department technicians use BIM software to draw a 3D comprehensive plan layout of the site. By drawing the project construction plan, the locations of the construction area, material processing area, office area, living area and other areas are reasonably planned. Combined with the actual size parameters of the construction site, the BIM three-dimensional model is used to display the layout of the construction site. At

the same time, the plan layout planning of the foundation pit construction stage and the ground main structure construction stage can be carried out. In addition, the construction plan layout and the traffic organization of the construction site can also be managed and analyzed.

During the EPC project design phase, the general contractor needs to participate in the process of project drawing design. Therefore, the project department technicians can use software such as Revit and Navisworks to virtualize various plane drawings into three-dimensional models to preview the entire construction process. At the technical briefing meeting, the construction process is displayed through 3D models to help people with less professional ability and experience understand the construction technology process.

#### 4.4.3. Lean Construction Quality Management Based on BIM

In the early stage of the project, the owner formulates the quality objectives and quality management plan of the project, and sets the overall standards for the contractor's construction. During the construction stage, the contractor further prepares a specific project quality implementation plan based on the relevant construction standards and quality management plan. Professional consultants will supervise the construction process on site, including inspections of the parts, processes and sub-projects that use new technologies and materials. The consultants are responsible for timely discovering and reporting various problems that arise during the construction process.

The key to quality control during the construction phase lies in the degree of conformity between the design plan and the actual construction. First, in some EPC or general engineering general contracting projects, the construction unit may not be involved in the project design phase. This situation will result in the designer being unable to promptly resolve problems that may be encountered during the construction process, such as complex shapes of certain parts in the design, excessive construction difficulty, or insufficient depth of the design drawings to meet construction requirements. In addition, the construction unit's misunderstanding of the design plan may also cause quality problems [17]. Secondly, some construction personnel may cause project quality defects due to their lack of technical skills, inaccurate grasp of quality specifications, or misunderstanding of the design drawings. At the same time, it is difficult for the construction unit to determine the specific responsible individuals who caused the project to fail to pass the acceptance inspection, which makes it impossible to promptly eliminate the individuals or factors that caused the quality problems, resulting in the need for repeated quality inspections and acceptance of the project [18].

In order to improve the quality control level, it is necessary to improve the traditional quality control model. Quality management based on lean construction theory and BIM technology can start from two aspects: standardized management and BIM-based Kanban management, clarify the project construction process and quality standards, strengthen the pre-construction and process control of construction quality, and thus comprehensively improve the quality of engineering projects [19]. Among them, it is crucial to formulate and implement the 5S site management system, which can reasonably arrange the construction site layout, improve work efficiency, and ensure the quality of construction products [20]. In addition, it is necessary to supervise equipment maintenance and material management to ensure the normal operation of equipment and the safety of employees.

In process planning management, the Kanban management system is used to formulate and implement process plans, which mainly include four levels of plans: overall schedule, stage schedule, visual schedule and weekly schedule [21]. These schedules are imported into the BIM model, the BIM4D model is constructed, and specific arrangements are made based on the weekly schedule and daily schedule. The material information required for each day and the tasks to be completed by each construction team can be



quickly and accurately calculated. The BIM-based lean construction Kanban quality management process is shown in Figure 4 .

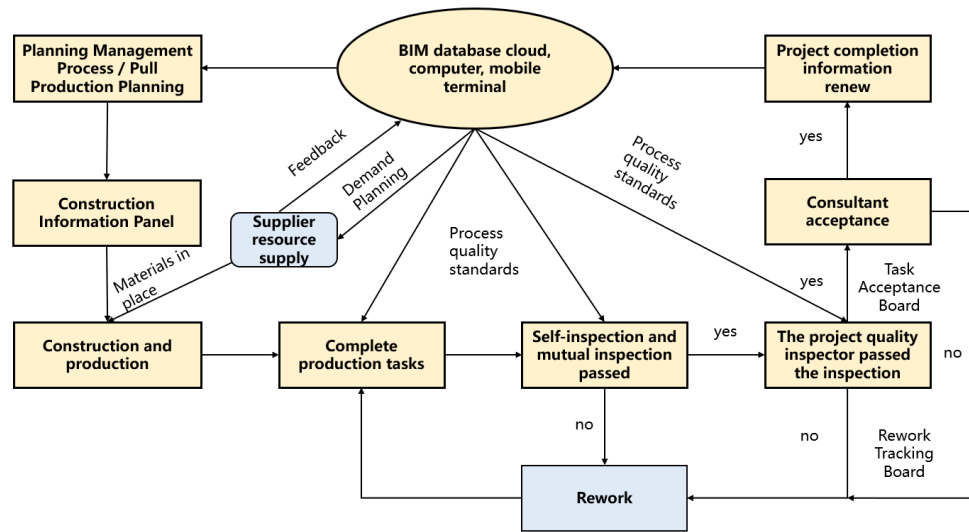


Figure 4. IM-based lean construction Kanban quality management process.

#### 4.4.4. Lean Construction Progress Management Based on BIM

In traditional project management, managers responsible for construction are involved in the preparation of project schedules. The Work Breakdown Structure (WBS) breaks down the overall objectives, scope of work, and contract requirements of the project into independent and interrelated work units according to system principles, and uses each work unit as an information carrier in the planning and construction process. This method helps project managers better grasp the implementation details [22]. An example of WBS work task decomposition is shown in Figure 5 .

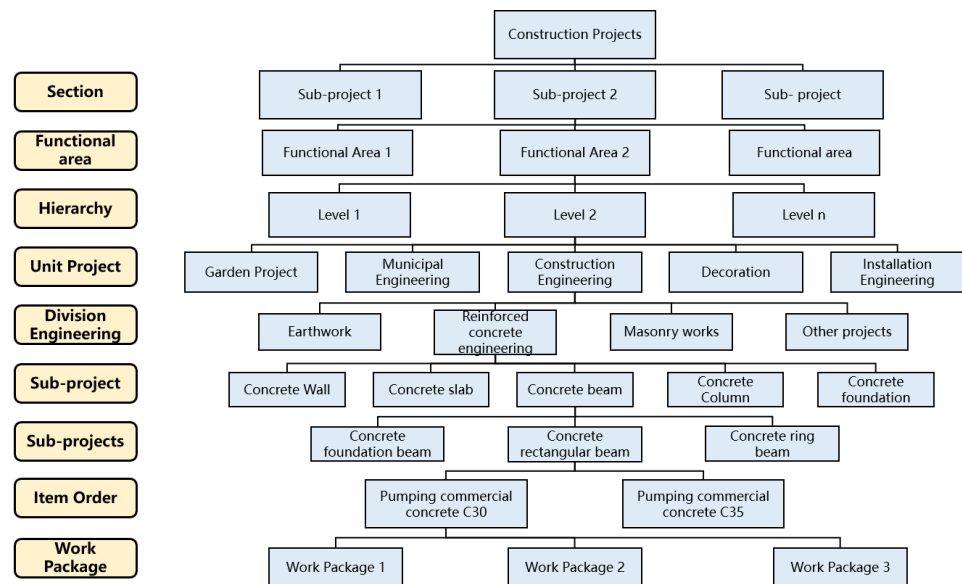


Figure 5. BS work task decomposition diagram.

During the project implementation process, the WBS coding system is used to collect and classify information such as personnel, materials, equipment, and construction progress. After the overlapping relationships and task names of work units at each level are input into the engineering management software, tools such as bar charts and network



plan diagrams can be automatically generated. These tools allow the project progress status to be viewed at any time, and the computer automatically generates periodic progress reports [23].

#### 4.4.5. Lean Construction Cost Management Based on BIM

From construction preparation to completion settlement, BIM technology and data support can be used to effectively control project cost targets [24]. Based on the project BIM model, the project progress and cost control are carried out around the project progress and cost control. The progress and cost dimensions are introduced on the basis of the 3D model to form a BIM5D model. Through BIM5D construction simulation, the layout of the construction site and the division of construction sections can be simulated and analyzed, thereby optimizing the construction process.

In schedule management, with WBS as the core, combined with BIM3D model, BIM5D information model is constructed, and conflicts in construction period, resources, cost and site layout are analyzed through virtual construction, so as to adjust the cost plan and reasonably formulate an implementable cost plan [25]. In the process of dynamic cost monitoring, the cost management department and relevant responsible entities input the project progress, resources and cost data into the BIM5D system in real time. The system will automatically calculate and issue an early warning immediately when the real-time cost exceeds the preset limit, requiring the relevant departments to deal with the cost problem in a timely manner.

#### 4.4.6. Lean Construction Procurement Management Based on BIM

The information platform based on the BIM5D model combines parameters such as the quantity of materials used and the time of demand with the project construction progress, and updates them in real time according to the progress of the project. This can be achieved by integrating the project's BIM5D database system with the supply chain database of the material and equipment supplier, so that the resource demand information can be transmitted to the supplier in a timely and accurate manner, forming a pull-type supply mechanism. The project's just-in-time procurement model is shown in Figure 6 .

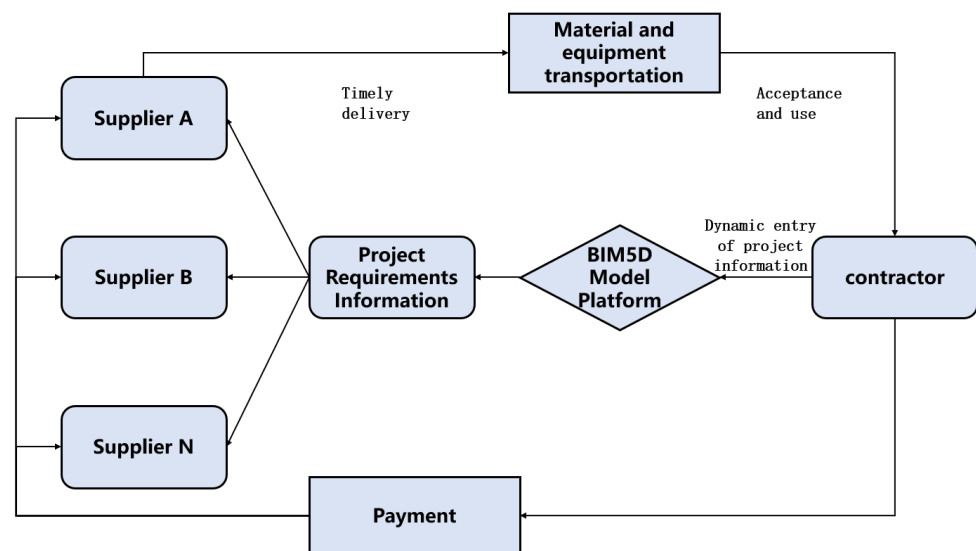


Figure 6. Just-in-time procurement model based on BIM.

In order to ensure that construction materials and equipment resources are delivered on time, the construction plan should be arranged scientifically and rationally, and construction organization and coordination should be carried out to control material demand.

At the same time, material input should be reasonably arranged according to the changes in construction nodes to avoid waste caused by errors or repeated construction, and ensure the stability and rationality of material use.

## 5. Conclusion

As an emerging construction management model, the lean construction management model based on BIM technology significantly improves the efficiency of the construction industry. At the same time, this model provides new ideas for project engineering management under the EPC model and promotes the informatization process of project construction. This paper takes the lean construction management in EPC projects as the research object, applies BIM technology for technical support, analyzes the lean management model of EPC projects, and draws the following conclusions:

(1) BIM, as an information technology, provides an information technology foundation for EPC projects from design, construction, and procurement. An information platform based on BIM technology can be built to provide a data carrier for the lean management of engineering general contracting projects and realize engineering information management under EPC or other modes.

(2) The "BIM+LC" model established by lean construction theory can integrate design and construction, procurement and supply, delivery and operation, and promote efficient project management. Among them, BIM technology and lean construction model, as the key content of construction project informatization and management integration, will be more widely promoted and applied in my country's construction industry and even the world's construction industry.

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