STUDY ON BIM-BASED TECHNOLOGICAL SCHEME DESIGN SYSTEM

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ABSTRACT

With the constant emergence of high-performance equipment, the current ruptured pattern of design, construction, and management has failed to meet standard and efficiency requirements in industrial construction. Building information modeling (BIM) can better create, share, and manage project information. BIM also integrates design, construction, and operation management in managing the life cycle of industrial construction projects, by changing the original cooperation design pattern. Besides, the BIM-based design process provides guidance for construction and simulation analyses, consequently reducing unnecessary design changes and waste of resources. Based on industrial construction engineering, the use of BIM in industrial construction work is examined and studied in this study.

Keywords: BIM, parametric design, industrial construction

1. INTRODUCTION

Industrial construction involves various production activities for buildings or structures. Some builders use one or more sets of equipment depending on the production process. Unlike ordinary construction, the technological process design must be determined prior to the building design. Technological processes directly affect the order of relationships of functional areas in industrial buildings. Furthermore, specific requirements of temperature, humidity, illumination, water supply, and drainage conditions are essential relative to the usage and characteristics of the workshop. These specific conditions are necessary in a workshop because of the possible production of acid, alkali, and other corrosive substances or the emission of flammable and explosive gases. With product development directed toward the attainment of highly critical standards, a number of particular requirements for workshop working conditions and norms become essential as the technological process becomes more complex and as the compatibility of workshops demands full consideration. Thus, a high demand for industrial building design is present, while a traditional two-dimensional design for an industrial building is far from meeting this new situation. Building information modeling (BIM) is an important information technology process in the construction technology field, which emerged after AutoCAD. The theory of BIM is based mainly on the concept of computer-integrated manufacturing system (CIMS) and of product information model that is based on product data management by PDM and STEP standards(Yu Jian 2012). In BIM, all architectural elements are combined into an information model, with the data stored in a consolidated database. BIM not only shows the physical and geometrical characteristics of a building, but it can also integrate building components and engineering information. Theoretically, BIM provides an independent, logical, and coherent data source that contains all construction project information.

This paper primarily explores the use of BIM technology in the life cycle of industrial construction, and based on API provided by Autodesk Revit Architecture 2013, secondary development technology is applied. Subsequently, the BIM parametric design for industrial construction is introduced, and the parametric 3D modeling platform based on BIM for industrial building is implemented. In the design process, parameters that generate a special technological style for industrial construction and other technological conditions, including temperature, humidity, illumination, corresponding power, ventilation, water supply, and drainage requirements, are automatically recorded and considered. The room and the equipment are also linked simultaneously, and all engineering information, such as equipment and facilities, is unified and associated organically. Using the IFC interface, the technological scheme design phase modeling can be shared with BIM at different phases of preliminary design, construction design, project construction, maintenance, and so on. Thus, a new way of using BIM technology in building the life cycle of industrial construction is explored in this paper.

2. RESEARCH FOUNDATION

2.1 The technological scheme design processes of industrial construction

Unlike ordinary engineering, industrial buildings must identify the workshop type, style, quantity, size, equipment, and layout during the technological scheme design phase. As far as the technological scheme designer of the industrial construction is concerned, the type, style, and space size of a workshop must be ascertained according to a given performance criterion and to the function requirements of industry construction.
The technological design scheme process is shown in Figure 1.

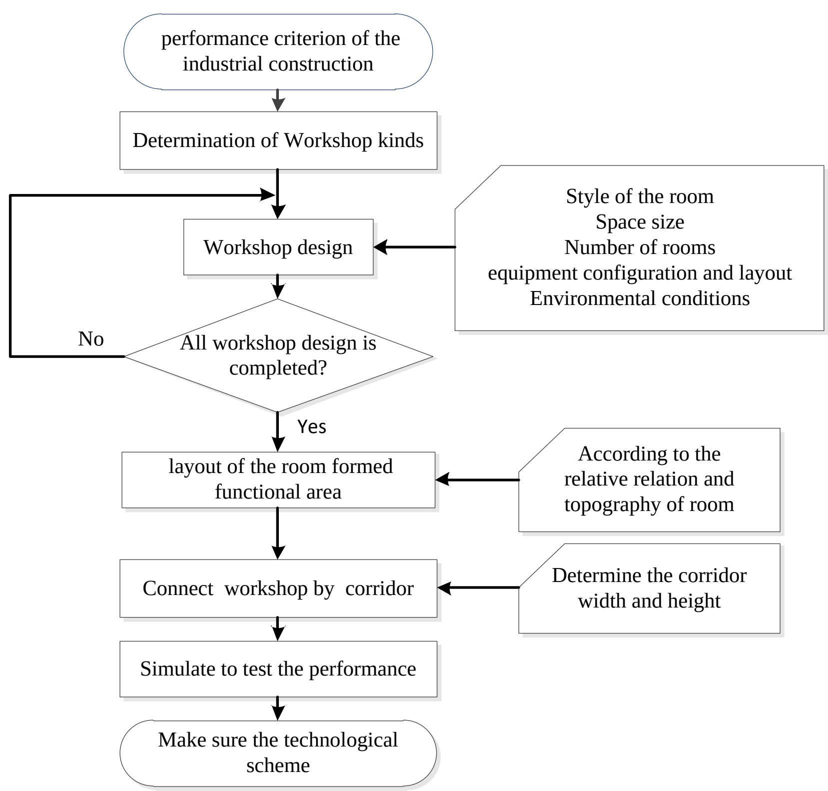

Figure 1: The technological scheme design process

2.2 The secondary development of Autodesk Revit

Revit, BIM introduced a new concept of architectural design, which is applied in one of the most innovative construction products at present. The object of the design includes a professional door, window, and wall, among others, rather than purely geometric elements. Object parameter is driven by the knowledge of the industry. For example, a concrete iron bar should be embedded in concrete, doors and windows should be embedded in the wall, and power distribution cabinet should be placed on the floor. The Revit API provides the Revit function expansion interface, allowing the user to implement functional extension and customization through programming. Consequently, the second development of Revit has become a research field in which major software firms here and abroad cannot ignore(Xu Di 2012). At present, the second development of Revit has two main aspects(Lin Jiarui et al. 2012). One is the development of parametric family necessities to the professional application, such as sofa, bed, and tea table. The designer can then focus on the design instead of the uninteresting modeling creation work. The other is the development of plug-in components and the interface program, such as the interface plug between Navisworks and Revit software programs. These components are mainly used for model conversion or for improvement of the function steps in the Revit design flow. The technological scheme design system introduced by this paper is an industrial construction-oriented system based on the study of Revit SDK platform and is not a simple function improvement of the Revit or parametric family development to the industrial construction.

2.3 Interface conversion technology

To verify the rationality of the technological scheme design, its model of industrial construction should be converted into the simulation model to be applied in the workflow simulation. The situation about personnel, equipment, and products working on the formulary route can then be displayed clearly. The occupancy rate of resources and the working position, as well as the completion quantity of products in each workflow, can also be achieved. The result of the simulation calculation (personnel, equipment idle time, efficiency, utilization rate, equipment residence time in each working position, and equipment blocking time in the operation), in which the technological scheme is analyzed and evaluated, is shown in Figure 2.

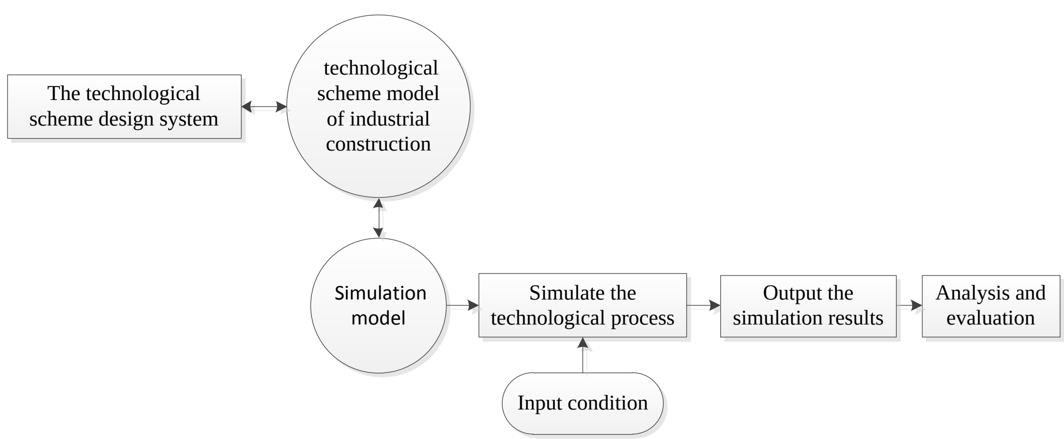

Figure 2: Work flow of the system

In this process, the industrial construction BIM model for the technological scheme must be converted to become the simulation model for the process simulation. As shown in Figure 3, the model has two main aspects:

(a) A three-dimensional model of the DXF format, which can be utilized by the workflow simulation software, is converted from the BIM model and imported into the simulation environment.

(b) According to the data file provided by the simulation system, the existing BIM is optimized and modified in the technological scheme design system. As a result, the engineering data are ensured congruously.

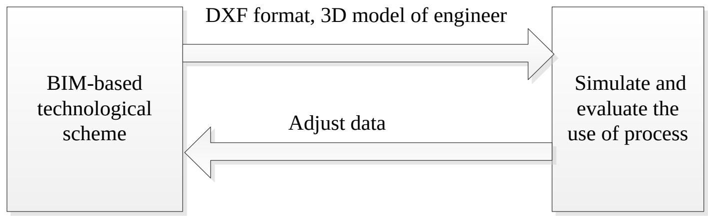

Figure 3: Interface conversion

3. THE OVERALL FRAMEWORK OF THE SYSTEM

3.1 The technological scheme design processes of industrial construction

According to the technical scheme of the industrial building design process, the process of combining the functions required by the system to ascertain the workflow of the system is composed of five main steps. These steps are shown in Figure 4.

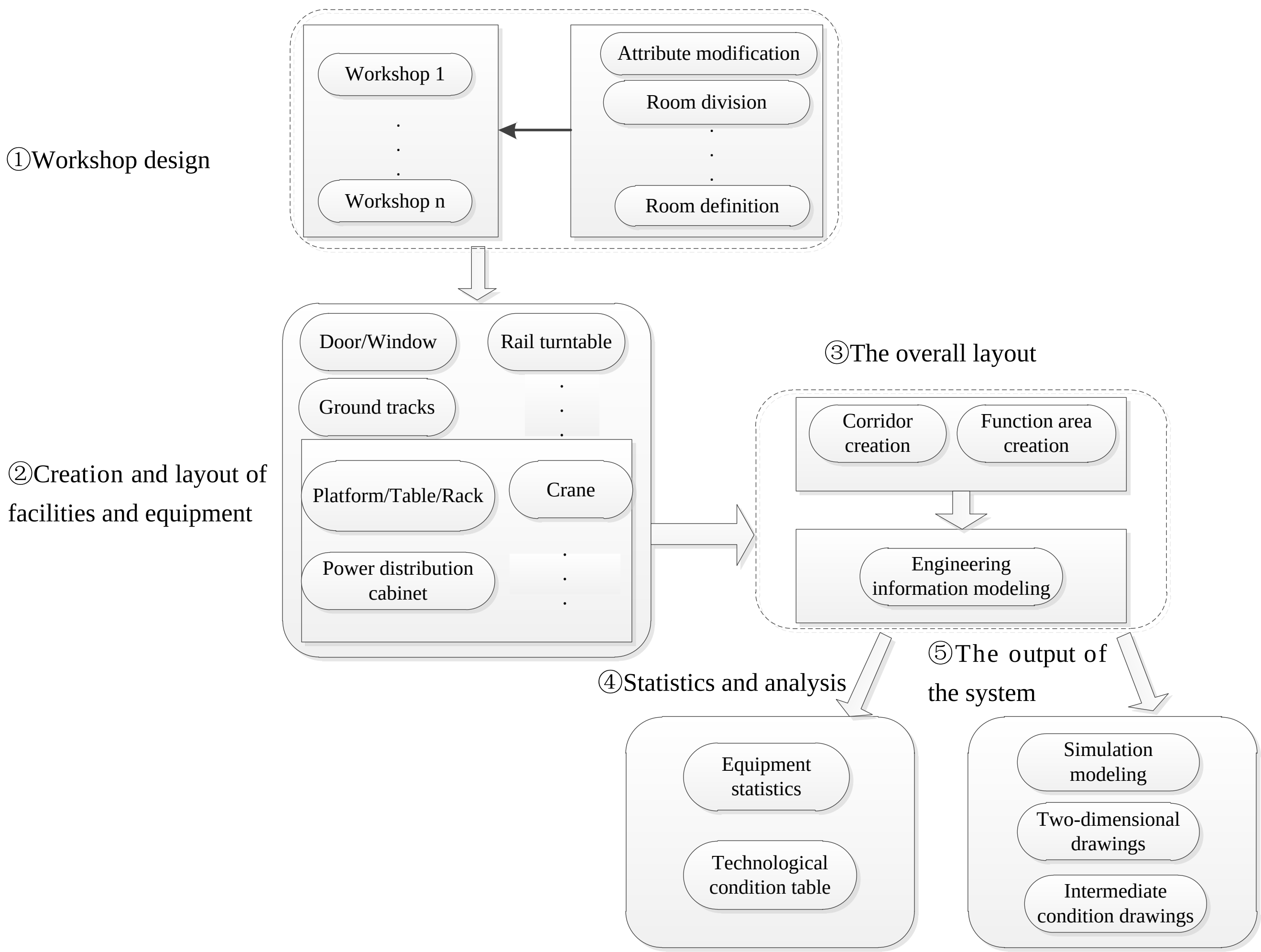

Figure 4: System workflow

(a) Workshop design

By selecting from among different types of workshops and by inputting the necessary design parameters, such as the spatial size of a room according to the preset wall thickness, slab thickness, wall material, and so on, the workshop is generated. If crane attributes are detected, the crane track that is ready for the configuration of the crane will be generated automatically at the same time as the workshop. For non-standard workshops, the user can utilize the function of modification to divide or to combine the standard room, allowing the room to adapt to various actual situations.

(b) Creation and layout of facilities and equipment

In confirming the selected arch, door/window, crane, ground track, and equipment types, among others, the system can automatically call the corresponding parametric modeling module. This module will create the monomer information model of the building components and the equipment according to predefined rules and will allow the user to modify and to layout the prescribed constraint conditions. Subsequently, the standard BIM that contains all the content elements of the room is generated.

(c) The overall layout

According to the function of the technological room association and the use process, all technological rooms are carried out by geographical layout. The connecting corridor is then automatically created based on the style and routing design. Finally, the information model of the whole project is formed.

(d) Statistics and analysis

After establishing the information model of the entire project, the system provides statistics and analysis functions to actualize the room's name table, assorted equipment table, decoration sheet, and technological condition table, among others in the prescribed area. Thus, the designer can be aided in deciding the scheme for the project.

(e) The output of the system

Based on BIM of the project, the system can output a series of results. These results include a simulation model that uses the process simulation for the functional verification, two-dimensional drawing for maintenance of the archives, sectional view, and the intermediate conditional drawing in cooperation with other professional designs.

3.2 The overall structure of the system

According to the workflow and the demand function, the system is designed for the four-layer architectural model illustrated in Figure 5.

(a) Data layer: The data layer contains a data structure in which the system data are stored. The database storage forms and the documents are organized in this layer, including the equipment model library, civil model library, user data, and various documents.

(b) Interface layer: The interface layer provides and implements access control to the application layer. The layer serves as the data interactive intermediary between the application layer and the database or the disk file. The interface layer mainly solves the problem of data access by saving the data to the database, reading them, and then implementing the model modification or data statistics.

(c) Application layer: The application layer contains a series of algorithms and function modules and the integrated environment. The application of the system includes businesses related to the establishment of models, system management, and project analysis management. This layer is a core element for the system scheme and will be accomplished by Microsoft C# programming, combining BIM and database technologies based on Revit 2013 SDK platform.

(d) User layer: The user layer provides a friendly man-to-machine interface for use in the system and a seamless integration with the original interface of Revit 2013.

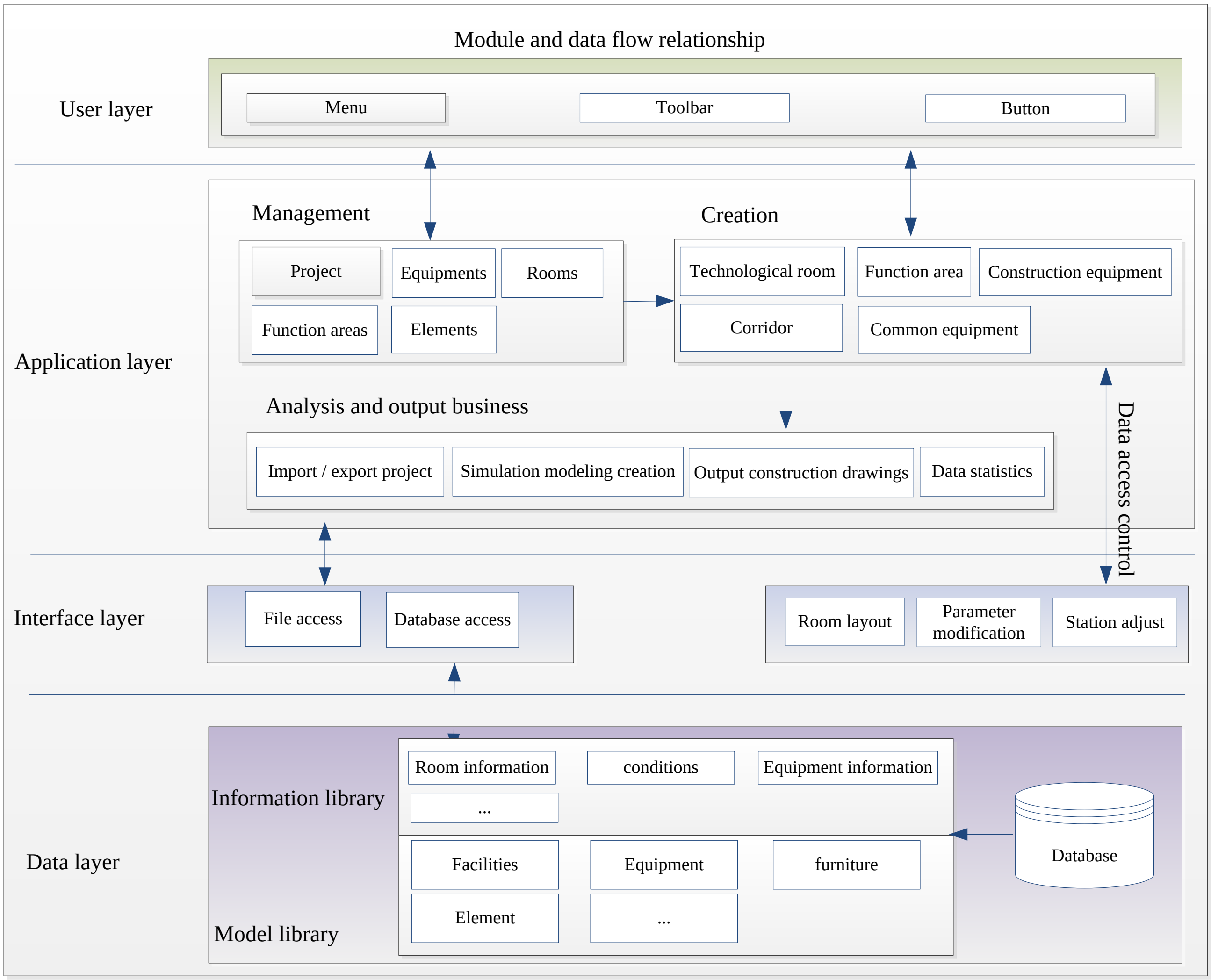

Figure 5: System structure diagram

4. THE KEY TECHNOLOGY

(a) Rapid modeling process of BIM for the technological scheme design of industrial construction

Parametric modeling technology currently used by the BIM software on the market is the general and basic level method because it requires the engineering designer not only to demonstrate their professional knowledge, but also to exert effort in learning how to build the model. Applications of the BIM software, such as Revit, are limited. For example, in industrial construction, the project is basically in a plain, engineering-style room, and the corridor shape is relatively fixed. The model is mainly determined by the parameters of length, width, and height where the arch of the roof begins. The entire project is then formed by the corridor linking the layout of the rooms. Meanwhile, the equipment used in the project, such as cranes, shelves, and some operation platform, have a relatively fixed style. Therefore, this study can deeply examine the modeling technology to realize the rapid modeling process in industrial construction.

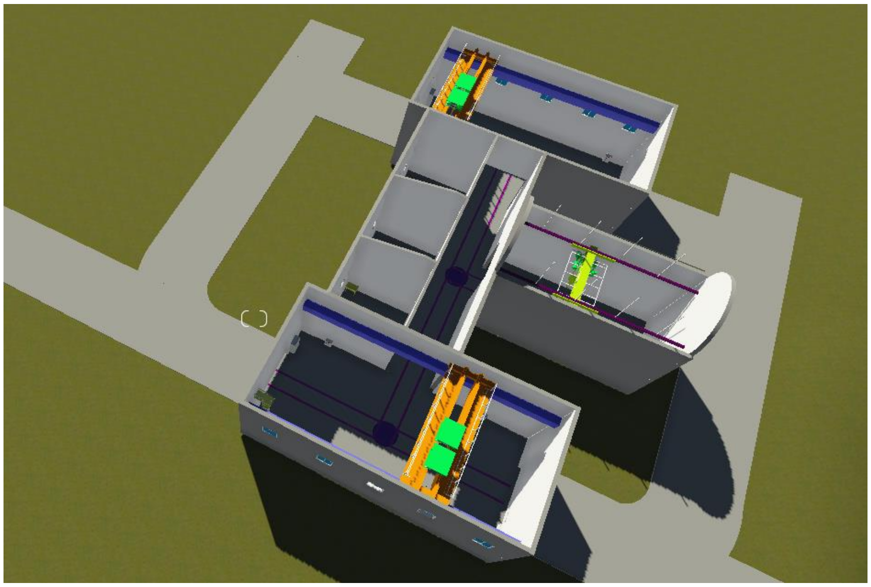

Figure 6: Basic industrial construction

(b) Automatic matching of the equipment and the space

Based on the BIM parametric design concept, the system automatically matches the equipment and the space, reducing the design mistakes and the engineering design staff. Simple matching, such as the power distribution box to be placed or embedded on a wall at a default height, also means that tables, shelves, and rails must be positioned on the floor. For complex matching, different types of cranes can equip the technical room to obtain the parameters at the placed height and track width. A suspension crane is also needed to calculate the distance between the arch roof and the track, generating booms at specific distances. The programming flow is shown in Figure 7.

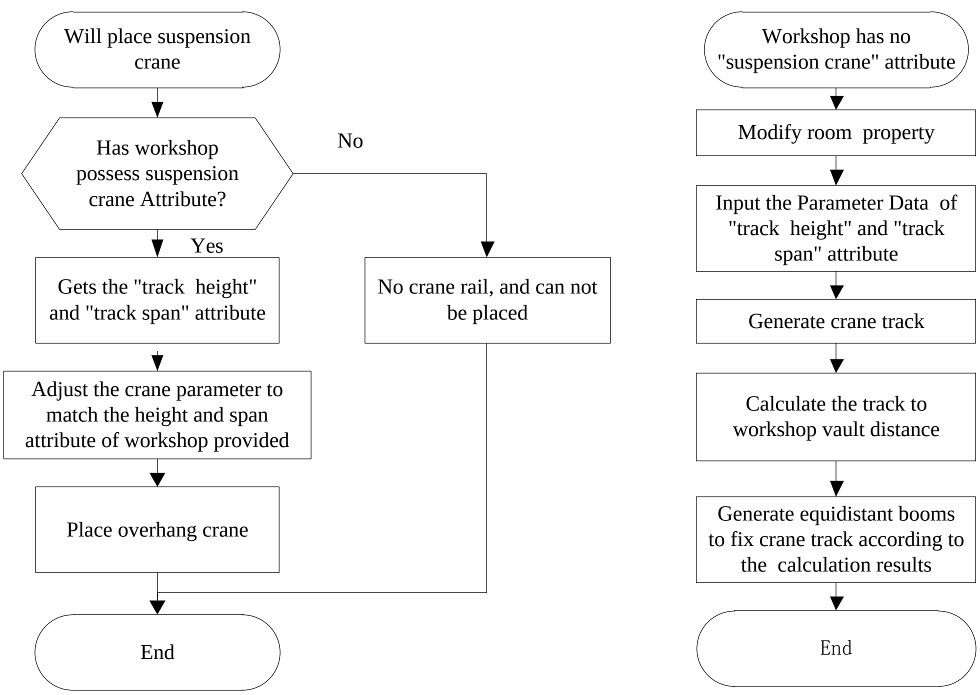

Figure 7: Create facilities and equipment

(c) The simulation technology based on technical process

The simulation technology based on the technical process demonstrates and validates the products used in the construction. Rationality, economy, the use process fluency of the technological scheme design, the matching of the workshop, and equipment used are scientifically assessed. The function of the simulation technology is to analyze the relationship between different functional areas of the project and identifies the relationship between each link in the process. Therefore, the technology can arrange the route and the timing reasonably to avoid a staggered, unsmooth, and inefficient operation. Finally, the work station, quantity, and space occupied are adjusted allowing the personnel, materials, and equipment to obtain the best operation method and relationship.

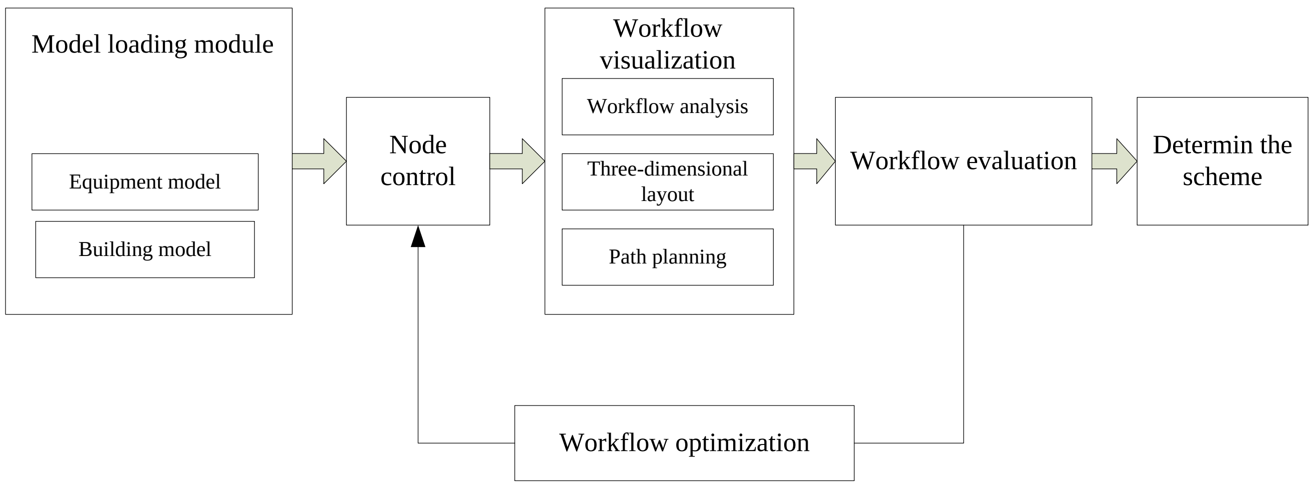

Figure 8: Simulation technology flow diagram based on the technological scheme process

(d) Input and statistics of the environmental conditions of the technological room

In the technological scheme design phase, the name and the number of the room are not the only aspects to be set, but also room conditions(i.e., environmental conditions) such as room decoration, ventilation circulation permit, temperature and humidity requirements, water supply and drainage requirements, and room illumination. Other developers can then design the project based on the condition requirements. Therefore, in defining the room, room conditions and the statistical descriptions of these conditions must be established.

5. SUMMARY AND OUTLOOK

The emergence of BIM technology provides timely, accurate, and sufficient information for different stages and participants in the life cycle of industrial construction. The technology likewise supports information exchange and sharing between stages of the project and between software applications. At the same time, BIM provides the information and technology foundation for the application of third party software programs such as the simulation software program for the engineering construction, operation, and maintenance phases. The introduction of BIM technology allows system integration of industrial construction to be possible. Integrated construction, in general, can be divided into horizontal and vertical integration(Xun Chen 2006). Horizontal integration implements information and resource sharing between different management subsystems at various stages of the construction life cycle. For example, in the operation and maintenance stage, information sharing and functional linkage among some subsystems, such as electrical and mechanical management, fire alarm, and security subsystems, are realized. Vertical integration implements information sharing and transfer between different stages of the project life cycle. BIM is constantly enriched and expanded at every construction stage, and all important information generated in the preview stage of the construction can be used easily in the next stage. In the early construction stage, the designer can also predict the information that will analyze factors, such as cost, energy, and logistics, in the late construction phase. Ultimately, engineering performance is optimized and energy consumption is reduced.

Based on BIM of the technological scheme, the following studies may be further carried out:

(a) Trafficability simulation in industrial construction

According to the information provided by the BIM model of industrial construction, engineering applications can be simulated to reduce the number of mistakes in the engineering design. For example, if there is a "T" shape curve and a crossing in the industrial construction, an obstacle can be anticipated by a passing vehicle. The vehicle model then must be established according to specific parameters such as width, vehicle wheelbase, wheel distance, approach angle, departure angle, and minimum turning radius. The situation of a vehicle running through the curve can be simulated by changing the radius of the turn road and the starting point of the curve based on the sweep width calculation of the vehicle.

(b) Assessment of the economy and the applicability of engineering

Although evaluation methods in some situations are provided(N.Thusen et al. 2010; WeilinShen et al. 2011), some studies evaluated these methods based on energy consumption in the engineering operation stage. As far as industrial construction is concerned, applicability must be evaluated. Thus, the evaluation criteria for engineering performance are necessary to be studied further.

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