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A BIM-based Dynamic Model of Site Material Supply

Qunzhou Yu, Kaiman Li, Hanbin Luo

School of Civil Engineering &Mechanics, Huazhong University of Science & Technology, Wuhan 430074, China

Abstract

Construction site material supply is one of the major issues in construction planning. Due to the space inadequacy of construction site in downtown area, material supply problems exist in almost every construction site regarding how to manage material amount, approach time and stack positions in construction activities, thus lead to low construction efficiency, high project cost and other problems. Moreover, the current material supply scheme is designed only once before construction without consideration of the dynamic nature of the supply problems. With the development of BIM technology, it provides a potentially valuable tool for these problems. This paper presents the development of a BIM-based dynamic model of site material supply that is capable of identifying optimal dynamic scheme for site material supply —what (material), how many, when, and where. The method of 4D modeling is investigated, as well as the acquisition method of site information, and the optimal scheme generation method. Contributions include the development of the BIM-based site material supply management system, and a case study for the process of the site supply scheme implementation.

Keywords: BIM; dynamic model; material supply; construction site

1. Introduction

In official records, there were 46,456 million yuan value-added of construction industry in China in 2015, which is an increase of 6.8% over the previous year [1]. With the increasing of construction scale, a large number construction sites have sprung up in city, such as Wuhan city has more than 10,000 construction sites [2]. For the sake of inadequate spaces for construction site in congested urban areas, every construction site has the material supply problems [3] (material amount, approach time and stack position [4] [10]). For example, inappropriate stack position will take more time to re-position the material, low construction efficiency, high project cost and the like. Therefore, a good material supply scheme is required. Presently, the material supply planning for construction site is based upon the personal experience [5], and it is designed only once before construction without considering the dynamic nature of the supply problems, including dynamic changes of the material demand and the site information in different construction phase.

A number of scholars have carried out relevant research on the above problems. Aiming at the dynamic problem of material demand, Ju Hyun Lee [6] used the RFID technology to track the site material to confirm the demand of material; Jongchul Song [7] developed a RFID and DPS based construction material management system, and realizes the material management in real time. About the dynamic problem of site information, IK Brilakis [8] identified a method of image retrieval in construction, and it can obtain site information through recognizing materials. To generate the optimal layout scheme, Khaled El-Rayes [9] presented the development of an Approximate Dynamic Programming (ADP) model that is capable of globally optimizing dynamic site supply plans of construction projects in order to minimize overall site supply costs; Xing Su [10] proposed a material layout evaluation model (MLEM) based on the material accessibility grade concept to integrate space and time in order to improve material accessibility and reduce time waste; Hisham Said [11] presented the development of a new congested construction logistics planning (C2LP) model that is capable of modeling and utilizing interior spaces of buildings under construction to generate optimal logistics plans.

However, on one hand, existing studies are all focusing on one or two problem such as stack position only. Though they proposed the solutions, a proper scheme requires a comprehensive consideration of these issues. On the other hand, the solutions are one-time optimization of the scheme without considering the dynamic change with construction schedule. Construction site conditions are dynamic in nature, involving numerous activities and resources scattered on a usually congested site [12]. The reason for these difficulties lies in the fact that there is no information integration tool as the basis of information sharing in site material supply management.

With the development of BIM technology, it provides a potentially valuable tool for the site material supply problems. BIM is a highly integrated project information tool, it is mainly to build a data model with a variety of project information, and then use the information model to support the project design, construction and operation [13]. A suitable site supply model can realize the reasonable arrangement of materials, and help to improve the production efficiency. This paper uses the BIM technology to establish a dynamic model of site material supply about the material amount, approach time, and stack position on the basis of construction schedule.

2. Research methodology

The objective of this research is to develop a comprehensive, informative and practical BIM-based application for the purpose of BIM-based dynamic model of site material supply. Fig. 1 illustrates its framework, in which the model integrates Material Demand Dynamic Model, and Site Layout Dynamic Model, and generates Site Drawing with respect to site-level and floor-level and Material Supply Plan Table in terms of Name, Amount, Time, and Position.

Information about material demand dynamic model (4D model) is extracted from the construction schedule and the building design. The construction schedule, the core of the whole model, is required to determine the material approach time. At the same time, it can support the building design in order to confirm the name and the quantity of the required materials in each construction phase.

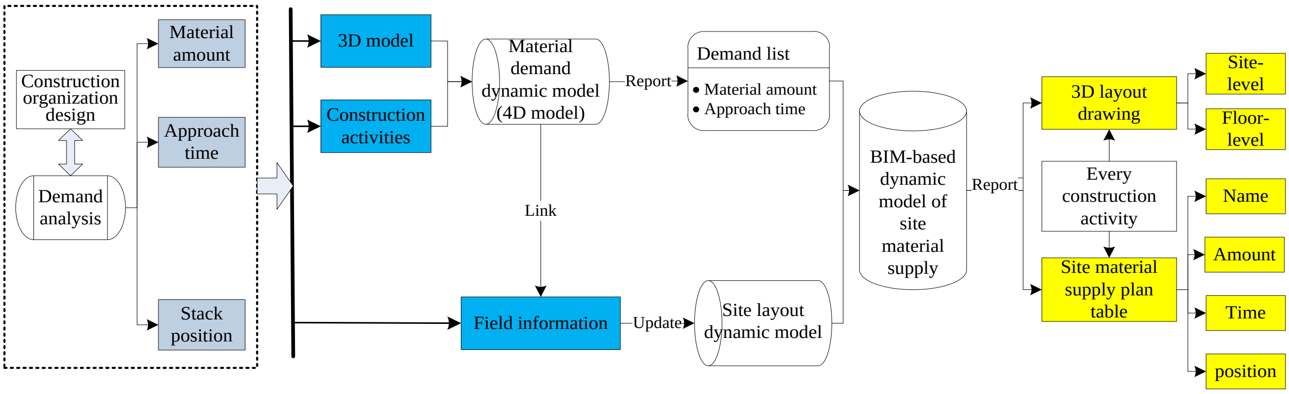

Figure 1. The framework of BIM-based dynamic model of site material supply

Site layout model comes from the link of 4D model and field information. The site information included static information and dynamic information is the basis of confirming the material storage location. Static information mainly refer to site drawings (includes building location, access ways, major equipment location, and work spots, etc.) of each phase generated by building design, and It converts the site drawings into polygons to represent the total site area. Dynamic information needs to collect the dynamic site information through the image acquisition technology corresponding to construction schedule.

3. The demand analysis of site material supply management

3.1. *Function analysis*

Site Material Supply Management is mainly for the management of supply situation contains the time when to approach, the position where to stack, and how many amounts of the material. The main function of the site material supply management includes the following parts:

- Material approach time management: according to the construction schedule, determining the material approach time of each construction stage, and allocating materials in an orderly approach;
- Material amount management: according to the building design and construction schedule, determining the amount of material used in each construction phase, and supplying a certain amount of material into the site;
- And material stacking location management: after a certain amount of material approaching at a certain time, the position of the material can be arranged according to the site condition.

3.2. *Information analysis*

The basic information of site material supply management in the completion of various functions as shown in table 1:

Table 1. Required information in site material supply management

Function	Information	Remarks
Material approach time management	Scheduling information	Construction activities；duration
Material stack position management	Static information in site	Site division; region number; region size
	Dynamic information in site	Region status（whether or not to be occupied），other location
Material amount management	Design information	Material name、name、amount of each phase

4. BIM-based dynamic model of site material supply

On the basis of demand information analysis about the site material supply management, this paper presents BIM-based dynamic model of site material supply comprised all the required information. The dynamic model is shown in Fig 2. The dynamic model mainly includes material demand dynamic model and site information dynamic model.

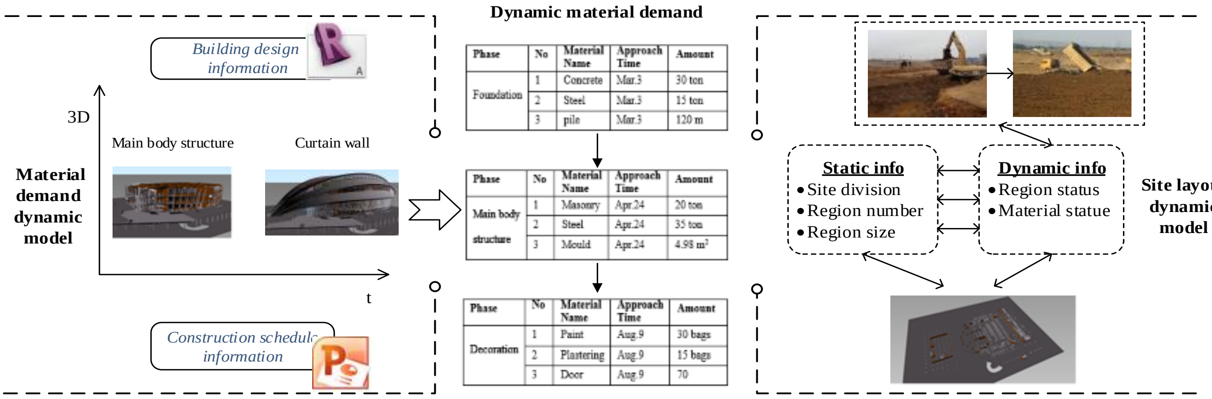

Figure 2. The dynamic model of site material supply

Material demand dynamic model is the foundation of the material layout scheme. The model consists of building design information and construction schedule information. Site layout dynamic model is divided into static information and dynamic information included region status and material status.

4.1. *Creation of the material demand dynamic model*

Material demand dynamic model consists of two parts. The building design information is expressed by Autodesk Revit, and generates the 3D model [14]. Revit is development by Autodesk Revit Company and applicable to architectural, structural, mechanical and electrical modeling and software design. Using the Autodesk Revit can create custom site materials regional group, and add position number, length, width and other properties to a divided region, which is convenient for later identification and localization of the material regions. Finally, the 3D model is derived for a model file, and shared to the next phase.

Facilitating site material supply management processes with BIM, so that the supply scheme can be arranged and adjusted dynamically along with the actual construction process. Schedule information should be integrated with the 3D model, and form the 4D model. The construction schedule created in the MS Project is added to the 3D model by linking each component of the 3D model to the correlative work breakdown structure node [15]. The process is showed in fig 3. In addition, the construction process can be virtually presented in time sequence by attaching start and finish times to each construction activity [14]. According to construction contents, construction process can be divided into construction foundation, the main structure, building decoration, the roof of building, the drainage and heating etc. This is convenient for site material reasonable supply scheme according to different construction process.

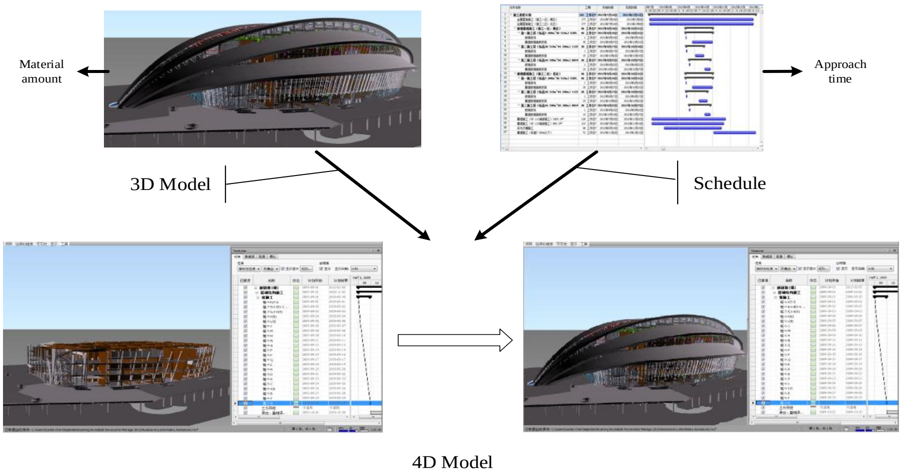

Figure 3. The process of material demand model

4.2. *Site layout dynamic model*

After confirming material amount and approach time, stack position of material is demanded to be determined. With the change of construction schedule, construction site information is constantly changing. So there are different optimal stack positions for the material in different construction phase. It needs support of site information in every construction phase. And site information includes static information and dynamic information.

Site division, region number and region size belong to static information. There has create site region attributes in the above 4D model, and every divided region has the specific size, position, application, and the like. Meanwhile, the region for stacking will have the number information. The information above is aggregated to generate the site basic model of each construction stage. To determine stack position also need site dynamic information such as region status (whether it is occupied), material status (type and position). Collect site information to obtain the region status and material status. Then, relating the status information to the site basic model as attributes [16].

4.3. *The generation of optimal material layout*

Genetic algorithm (GA) is used to assist the stack position on the basis of site basic model [17]. The essence of the problem is to build a relationship between the two parts. In the above model, site is divided into many appropriate regions except the build, facilities, road and other usage. And materials and regions have been assigned specific numbers. Using the permutation type as genetic coding and randomly generates initial population. Then, reproduce new populations through choose, crossover and mutation. Fig 4 reprents the Genetic Algorithms operation flow. The objective function and constraint condition are as follows.

Minimum transport distance of workers [18]: MinisizeTD= $\sum_{i=1}^{n}\sum_{j=1}^{n}\delta_{ij}w_{ij}d_{ij}$, (1)

Constraint conditions: $\sum_{i=1}^{n}\delta_{ij}=1$, {i=1, 2, 3,…n} and {if $\delta_{ij}=1$ then ($i \notin R$ or $j \notin M$)} (2)

Where *n* is the number of materials; δ_{ij} is the permutation matrix variable. *w* is the priority weight of a material *j* relative to a region *i*. *d* is the distances between a region *i* and a material *j*.

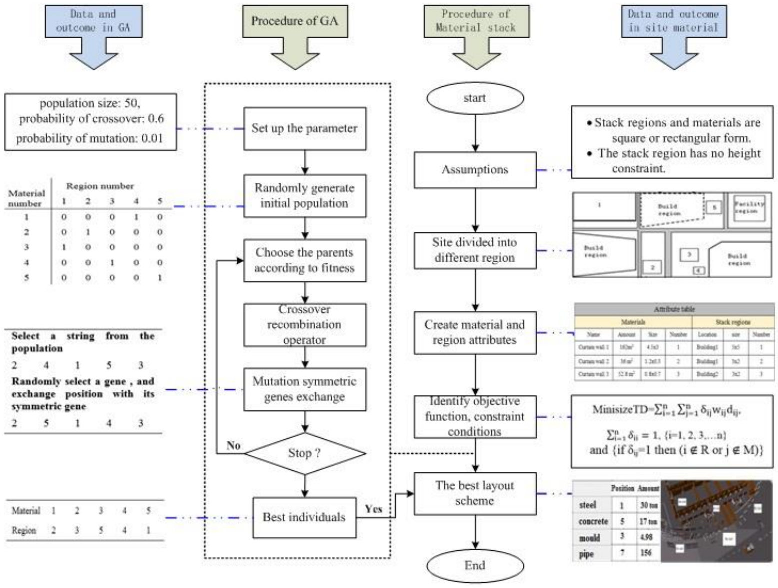

Figure 4. Optimal material layout operation flow

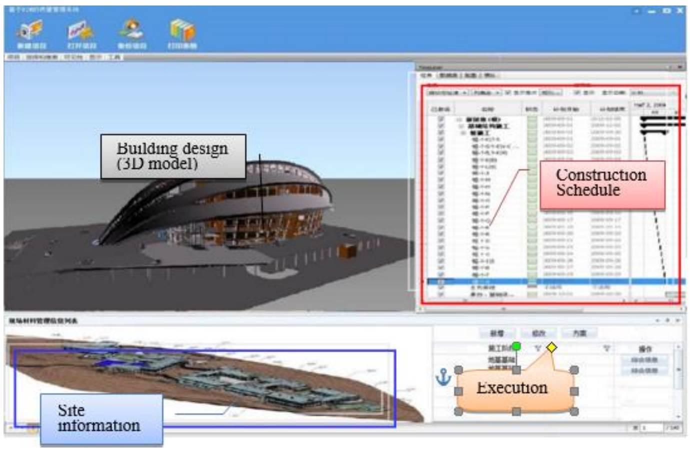

Figure 5. The system of site material supply management

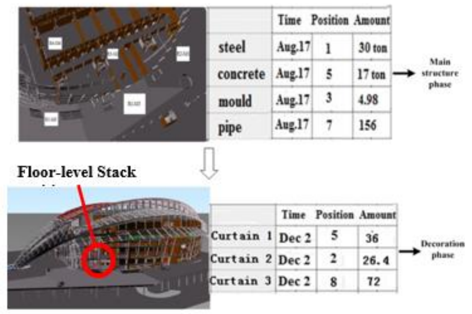

Figure 6. Layout drawing and plan table in two phase

5. Implementation

In order to verify the effectiveness of the BIM-based dynamic model of site material supply, a BIM based site material supply management system is developed. The system is shown as fig 5. And the outcome in two phase is shown as fig 6.

6. Conclusions and future work

On the basis of demand analysis about the site material supply management, this study presents BIM-based dynamic model of site material, and introduces the implementation process of the optimal supply scheme through a case study. The main conclusions are as follows.

- BIM technology is introduced into the construction site material supply management, the establishment of dynamic model is discussed, and it realize the value of BIM in the field of material supply management;
- The material demand dynamic determined the material amount and the approach time and the site information dynamic model determined the stack position are combined to achieve the integration of multiple information;
- 4D application ensures the timely scheme generation of the whole process, which helps the project participants to better solve the site material supply problem.

However, the research does have some limitations, such as the research is still in the stage of theoretical research. Future research will focus on the implementation of the model.

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