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A simulation-based approach for material yard laydown planning

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ABSTRACT

This paper describes a simulation-based approach for planning material laydown yards for steel fabrication projects. The classic approach to material placement is the "reactive approach," whereby as material arrives, the yard foreman decides, based on few rules and his/her past experience, where to place everything. It's often fraught with uncertainty resulting from imprecise and difficult-to-forecast construction consumption schedules, resource interactions, and supply chain issues, especially in material delivery. This paper outlines an approach to optimize reactive placement policy using heuristics, genetic algorithms and simulation to model material movement from laydown areas to the consumption unit. The novel approach combines analytical tools and heuristics to model the dynamic nature of material management. The paper compares this integrated approach with commonly-used optimization techniques which use weighted target functions based on rule of thumb. A case study demonstrates the suitability and efficiency of the proposed optimization method in reactive laydown yard management.

1. Introduction

Material handling is a part of the broader domain of material management. Material handling can be defined as "the art and science of conveying, elevating, positioning, transporting, packaging and storing of materials" [12]. Applying the right material handling methodology in construction projects would result in real savings in the project time and cost, improved labor productivity and reduced surplus.

Due to inefficiency of operations for places and methods that materials are handled and stored [14], researchers have, in the past, formulated material placement and handling approaches for planning construction yards. Crainic et al. [4] investigated space allocation by studying the space and time dependency of events. They proposed a space optimization method based on event handling of the incoming materials (container being the materials) on terminals. Gambardella et al. [5] addressed spatial allocation of containers on terminal yards, and presented a decision support system for the management of an intermodal container terminal. Zhang et al. [16] also studied the storage space allocation problem in storage yards of terminals. In another study, Shen and Khoong [13] established a decision support system to solve a large-scale planning problem concerning the multi-period distribution of empty containers for a shipping company. To improve material transportation cost on site, Cheung et al. [2] developed a genetic algorithm (GA) model to determine the near optimal layout of facilities on concrete precast yards.

Wenzel et al. [15] demonstrated that simulation can connect the planning stage to operation to reduce costs in production and logistic systems. Marasini and Dawood [8] developed a process model for evaluation of stockyard layouts for standard precast concrete products, and provided some promising results presenting reduced throughput times once they used GA in collaboration with simulation. Zhou [17] developed a GA-based site optimization algorithm and incorporated it in a simulation model which used the optimized site-layout as the starting point of simulation.

Despite the considerable number of studies conducted on construction material handling and layouts, organization of laydown areas, which directly affects material handling costs, remains a challenge in practice.

The goal of this study is to determine a dynamic, optimum storage yard layout for improving material handling cost and time using simulation tools integrated with an optimization engine. Our main focus is on utilizing a "reactive approach" strategy for allocation of incoming material. A comparison between the proposed methodology and the other existing approaches, which try to optimize material handling costs by reducing haulage distances, is presented.

2. Reactive placement approach

Material handling is greatly dependent on other processes such as planning, estimating, drafting, purchasing, installing and commissioning. Changes, disruptions and delays in any of the other processes naturally impact material management and handling. For instance, Fig. 1 demonstrates a typical drafting procedure and its interaction with purchasing and consumption of the material in a steel fabrication company. Once a steel fabrication company wins a job, it receives the design drawings from the client (IFC drawings). In most cases, after developing the reserved bill of material and preparing detail drawings, the approval

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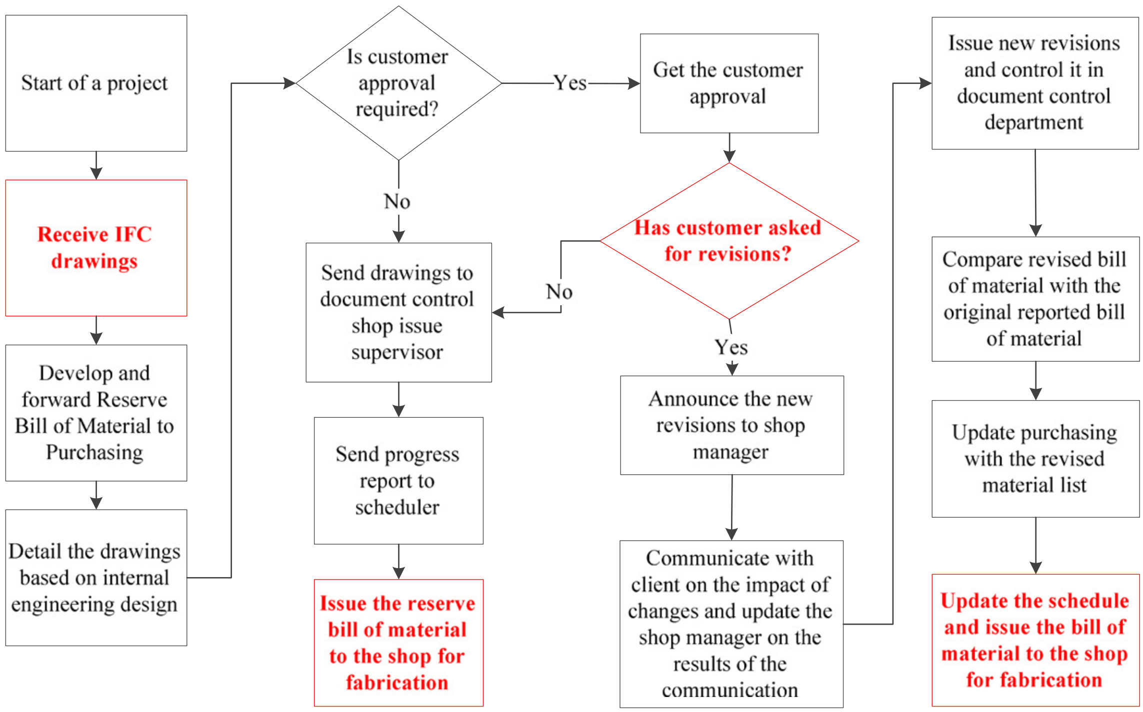

Fig. 1. Drafting procedure and its interaction with purchasing and consumption of the material.

of the customer (which adds several time-consuming activities when the customer asks for revisions, as shown in Fig. 1) is required. The incorporation of a customer's feedback time into the baseline schedule provides space for proactive material handling and management, in which purchase lists and pick lists are known in advance, and leaves room for further implementation of best practices to pursue continual improvement in a construction company. However, a slight change in meeting the milestones generally affects the predictability of the process. Some of these unwanted changes include: late delivery of design drawings and revised drawings, change orders, and mistakes and errors in drafting. In response to such changes, yard management policies, as part of the overall material handling program, react accordingly, and change reciprocally. The approach for dealing with this challenge is called 'reactive placement policy' in this study. In the reactive placement policy, the receiver (the person who receives the material from the supplier/vendor/mill or any other material provider) does not have the arrival schedule for a specific period of time informing him what material arrives at site on the days ahead. The receiver also does not know what material will be consumed and leave the yard in a timely manner (for a specific period of time). The only information the receiver has is the daily pick tickets from the consumption unit required for that day, and the material arrival list from purchasing containing what material is arriving that day. For these reasons, the receiver has to react to daily incoming batches for placement on the laydown areas. For placing the material, the receiver can be given a daily schedule in advance providing the information regarding which grid the material should be stocked. For example, if a batch of material arrives at the yard containing twenty different material types to place in twenty different laydown areas, the receiver knows where to place them on the yard grid network, as each material type has a tag with that information.

3. Research methodology

This research initially attempted to identify current practice of yard foremen when faced with daily incoming batches to the yard. As a result, the following factors were found to be involved in common practice of material laydown planning for steel fabrication projects:

- dynamism of the material flow in and out of the yard,
- material transfer time/distance from the yard to the consumption schedule,
- space availability of the laydown areas,
- special provisions such as laydown occupancy due to reserved spaces for special jobs,
- logistics of the yard (yard dimensions, transfer lines to consumption unit, permanent and temporary hauling equipment on the yard), and
- hard and soft yard constraints such as material compatibility constraints (materials of the same type can be stacked in one laydown area).

On steel fabrication yards, equipment units such as overhead cranes, forklifts and carts are deployed to transfer the key material from the laydown areas on the storage yard to the consumption unit. Under a tight schedule, it would be paramount that the right materials are delivered in a timely manner. Moreover, the use of equipment should be minimized to reduce costs as hourly rate of equipment use could be very high.

In the next step, efforts are made to help the yard foreman place the materials on the laydown areas in a more sophisticated manner considering the abovementioned factors.

Simulation, which is one of the mathematical tools that has been widely used in academia, and very recently in practice, can be of great assistance to serve this purpose, as it can model resource interactions intelligently. Pritsker [11] defines simulation as "the process of devising a mathematical model of an actual world system and experimenting with the model on a computer." Hence, the material handling process is modeled using a simulation tool to evaluate the efficiency of the material laydowns from the material handling time/cost point of view.

Moreover, to propose an optimum or near-optimum solution, all possible placement combinations must be examined, which is impossible due to the great number of laydown areas and variety of material types. As a result, genetic algorithm, which lends itself to examining cases and discovering the optimum or near-optimum solution through iterations within the algorithm, is implemented to determine the optimized layout. Another advantage of genetic algorithm is that it works