Scenario simulations for improved production planning in construction engineering using standard simulation software

Immo Feine¹, Kay Smarsly² and Hans-Joachim Bargstädt³

¹) PhD Candidate, Chair of Construction Engineering and Management, Bauhaus University Weimar, Germany.
   Email: immo.feine@uni-weimar.de
²) Professor, Chair of Computing in Civil Engineering, Bauhaus University Weimar, Germany.
   Email: kay.smarsly@uni-weimar.de
³) Professor, Chair of Construction Engineering and Management, Bauhaus University Weimar, Germany.
   Email: hans-joachim.bargstaedt@uni-weimar.de

Abstract

In construction engineering, scenario simulations can be used for improving process chains of technical as well as logistical processes. While the utilization of simulation tools is widely accepted in academia, there is a considerable lack of acceptance in construction practice. The lack of acceptance is particularly obvious in small and medium-sized construction companies, due to the need for qualified personnel and the time (and cost) required for getting familiar with simulation tools. Focusing on scenario simulations for production planning, it is evident that using simulation tools would substantially contribute to improved planning results. This paper presents concepts and strategies for using of simulation tools in production planning in order to increase process efficiency, thus facilitating the level of acceptance of simulation tools in construction practice.

Keywords: Scenario simulations, construction processes, production planning, work preparation, process simulation.

1. INTRODUCTION

A common challenge in production planning within construction engineering is the determination of an efficient set of processes that transform the planning results, i.e. the design, into the actual building. To give an example, the set of processes (or, more precisely, the set of technological processes) may include certain production technologies or methods, such as pouring of concrete using special equipment (e.g. mobile pumps). The set of technological processes is supplemented by another set of processes, the logistical processes, which ensure the execution of technological processes. Logistical processes can thus be understood as a basis for the technological processes. In practice, the planning of these processes takes place in construction companies and is determined by the characteristics of the available material and machinery as well as the experiences and knowledge of the individuals involved.

Production planning is frequently built upon experiences gained from similar projects or from assumptions (Berner et al., 2013). Apart from the experiences and assumptions, analytical methods are increasingly used for production planning, i.e. a specific order of processes as well as the process characteristics are derived from calculations based on specific planning algorithms (conducted either manually or using planning software). However, it is well known that planning problems in practice, due to their complexity, soon reach the limitations of analytical approaches. In these cases, the application of scenario simulations has proven a suitable alternative to support decision making in production planning (Galić et al., 2015; Marx & König, 2010; Weber, 2007; Xu et al., 2003). In this context, scenario simulations describe the approach to run a simulation model, which reflects the characteristics of a construction site or a part of it (“real-world system”), under different sets of parameter values. A set of parameter values represents a certain scenario to be analyzed. Contributing to an improved construction planning, the goal of scenario simulations is to assess changes of a target value depending on the sets of parameter values.

2. APPLICATIONS OF SCENARIO SIMULATIONS AND RESEARCH OBJECTIVES

As opposed to the utilization of simulations in academia, which is widely accepted, simulations have not yet found their way into the engineering practice of construction companies (Bargstädt & Feine, 2015; Kordi et al., 2011; Halpin, 1998). It should be emphasized that this is in particular contrast to different other branches, such as stationary industry, where simulation tools are inherent part of production planning. Several studies have been conducted investigating the obstacles preventing construction companies from using simulations (Kochkine, 2014; Kugler, 2012; Lu & Wong, 2007; Shi & AbouRizk, 1997). Main obstacles are

- a lack of expertise of the companies in using simulation tools,
• inadequateness of tools if being adopted from other branches, such as stationary industry, according to the specific requirements of the construction industry,
• considerable efforts needed for developing adequate simulation models in the construction industry,
• time needed for adaptation of the simulation model to changes in the real-world system (e.g. a construction site) being modeled, and
• a lack of valid input data for the simulation.

In this paper, the dualism between the acceptance of simulations in academia and in construction practice is investigated. Furthermore, this research provides an analysis of how construction companies may advantageously use standard simulation software tools in production planning in order to achieve improved planning results for the execution of construction works. In this context, standard simulation software, as opposed to branch-specific special simulators, is defined as generally applicable simulation tools available on the market that are adaptable to different applications (Pitch, 2011).

3. PRODUCTION PLANNING

From a project management point of view, construction projects can be separated into different phases, the development phase, the realization phase, and the operation phase (Figure 1). The realization phase of a construction project consists of a planning phase (design) followed by a production phase. The planning phase is related to the product (i.e. to the building) and contains all information needed to describe the outcome in form of the building. The production phase includes all tasks to be performed for transforming the planning outcome into the physical building, which involves practical works, usually executed by the different construction companies. The production phase, as shown in Figure 1, is further subdivided into production planning and production execution.

![Figure 1. Production planning as part of the realization phase of projects derived from Kochendörfer et al., 2004](image)

Production planning includes, for example, work related to the order of tasks, to specific scheduling, and to the application of construction methods (“technology selection”). The overall goal of production planning is to provide a schedule that allows an efficient production of the building. The schedule has to consider time, cost and quality-related constraints as well as the unique conditions of the construction site in terms of location, size, weather condition, etc.

Typical application areas of simulations in production planning are site layout planning (including the localization of cranes, the dimensioning of storage areas etc.), planning of execution strategies (e.g. related to the selection of technologies or to the order of crafts), or logistics planning. The simulation models, depending on the application area and the processes to be modeled, significantly differ from each other. If simulating technological processes is of interest, logistical processes are assumed to be given, and vice versa (Beißert & Bargstädt, 2012; Weber, 2007). A combined consideration of both logistical and technological processes, which is required to establish an efficient process chain for production, can be found in recent publications, as proposed, e.g., by Heck & Habenicht (2015) and Voigtmann (2014).

4. APPLYING SIMULATIONS AS A PLANNING TOOL – CHALLENGES AND OPPORTUNITIES

Lu & Wong (2007), referring to Samuelsson & Gräns (2004) and Carr (2003), note that in practice a planning tool will be applied only if the planning outcome is expected economically viable, as compared to the outcome based on traditional planning methods. Furthermore, applying planning tools requires the individuals in charge to learn and to understand the tools quickly. Clearly, these two requirements are related to each other, because challenges in use will automatically result in increased planning costs. Thus, the main question is how to apply simulations cost-effectively?
To answer this question, the input data for the simulation model is considered, which can be divided into the following areas:

a. Construction site-specific data, e.g. size, location, and characteristics of site  
b. Construction task-specific data, e.g. product model  
c. Construction technology-related data, e.g. specifications of construction methods  
d. Company-specific data, e.g. resources and characteristics

The primary challenge when introducing simulation tools in a construction company the first time is that data of all areas listed above must to be available. However, once being used in a project, simulation may be of benefit for upcoming projects, because data of the areas c and d of the previous project(s) can be used. It can therefore be concluded that the economic viability of applying simulation should not been assessed based on single projects, but rather on a series of projects. This conclusion corresponds to the experiences made when introducing new software that should be used for the next years, which is not expected to be amortized after one single project.

5. CONCEPTS AND STRATEGIES TOWARDS INTRODUCING SIMULATIONS AS A PLANNING TOOL

Companies that are interested in using standard simulation tools in order to increase efficiency in production processes should consider the following strategies.

1. When introducing simulations as a planning tool, simple problems should be addressed and interfaces between the simulation tool and existing IT resources should be defined in order to facilitate a consistent data exchange. The provision of valid input data usually constitutes one obstacle for applying process simulation. Therefore, simulation should be embedded into existing IT resources (Figure 2).

![Figure 2. Simulation software as a part of the IT resources of construction companies](image)

2. Company-specific characteristics and parameters of machines should be identified to be easily included into the simulation model. For these characteristics and parameters, values based on experiences or existing guidelines are usually included into the simulation model. However, this will increase the time needed for the creation of simulation models in practice.

3. The re-use of simulation sub models should be organized. Typically, parts of construction processes, such as delivery of products or processing of ready-mixed concrete, are similar on different construction sites. These parts of the construction processes should therefore be separated into sub models and parameterized for re-use in different settings.

4. Typical planning problems that frequently occur, such as the establishment of a sound transport chain or the dimensioning and localization of storage areas, should be elaborated in detail in order to accelerate modeling by defining interfaces existing sources.

5. Analyzing the interrelationship between parameter changes and its effect on the target value of the simulation over a series of projects ("computational steering") may help to limit parameter ranges in simulations, thus enhancing the efficiency of the simulations. Last but not least, procedures for simulation knowledge management across projects should be implemented to enhance the reliability of simulation results.
6. SUMMARY AND OUTLOOK

In academia, a variety of research projects focuses on the development of simulation tools in order to solve real-world problems in construction engineering with scenario simulations. Nevertheless, simulation tools are rarely used in construction practice. As has been illuminated in this paper, this academia-to-practice gap should be reduced in order to increase the level of acceptance of simulation tools in construction practice and finally to contribute to an increased efficiency in production.

In this paper, concepts and strategies towards introducing simulations as a planning tool have been proposed for solving practical planning problems in the area of production planning. It has been demonstrated that many obstacles unveiled in recent studies can be overcome by a suitable integration approach in the construction companies. The integration approach includes, e.g. interfaces between the simulation tools and existing IT tools as well as an appropriate integration as into the process chain of production planning. A distinct benefit can be expected when coupling simulation tools with building information modeling (BIM) technology (Tauscher et al., 2015; Tauscher & Smarsly, 2016). The current BIM implementation into practice worldwide offers opportunities to establish BIM as technology for exchanging data and as a central data source for all activities, including scenario simulations, in construction engineering.

REFERENCES


