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Building information modeling and discrete event simulation: Towards an integrated framework

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ABSTRACT

The development of a realistic Discrete Event Simulation (DES) model needs the complete specification of the interdependencies between activities and resources. Also, the maintenance of an existing DES model is challenging especially when changes in the logical relationships between activities, resource allocation and design need to be considered. The process of development and maintenance is time-consuming, error-prone and it restricts the application of DES within the construction industry. In this research, a Building Information Modeling (BIM) and DES framework is proposed to enable the implementation and integration of DES in the planning and follow-up of construction activities. The framework consists of: (1) A building information modeling process that exports material quantity take-offs, schedules and required resources to a relational database and (2) an intelligent simulation engine that automatically reads information from the database at the start of each simulation run. This implies that changes in the building information modeling process, such as design modification, different resource allocations and alternative construction methods can be explored without manually checking and re-formalizing the simulation model. A preliminary prototype has been developed by using the proposed BIM–DES framework. The initial results show that the proposed BIM–DES framework reinforces both elements by providing valuable additional information. BIM provides the product and process information to DES, facilitating the building and maintenance of the DES model; the DES model evaluates the construction performances and provides valuable feedback to the BIM process for decision support.

1. Introduction

Construction projects are usually delivered within an uncertain environment in which resources and activities interact with each other in a complex manner. The uncertainty that exerts tremendous influence on project performances stems from the inherent variations in activity duration, delivery of material, machine failure and workforce productivity, which are often attributed to the temporary nature of the project organization, on-site production and loosely-coupled supply chains [1,2]. Traditional deterministic methods cannot model and manage the level of uncertainty involved in construction projects. Discrete event simulation (DES), which explicitly incorporates uncertainty, has been used as an effective approach to better capture the complicated interactions and uncertainties found in construction operations [3]. While the benefits of using DES as a decision support tool have been recognized, it has not been widely adopted by the construction industry [4]. One of the reasons for this lack of implementation is the amount of manual work needed to specify and maintain the interdependencies between activities and resources in the construction supply chain [5,6]. In particular, when there are changes to logical relationships, resource allocation or design, the simulation model has to be updated and re-formalized to accommodate the new conditions. Small changes to the input of the simulation model often lead to extensive manual modifications [7]. This process is time-consuming, error-prone and restricts the application of DES to the construction industry. A possible solution for improving the flexibility of a simulation model is to make the necessary input data variable by linking it to a database [8].

On the other hand, as will be discussed later, the data captured by Building Information Modeling (BIM) can be used further by other applications [9]. BIM represents the processes and activities of development and uses a computer-generated model to simulate the planning, design, construction and operation of a facility [10]. The resulting model, a building information model, is a data-rich parametric digital representation of a facility, from which relevant data needed to support construction, fabrication and procurement can be extracted and analyzed [11]. Thus, BIM has the potential to provide a simulation model with design and planning data [7,12].

In this study, a BIM and DES framework is proposed that enables the implementation and integration of DES in the planning and follow-up of construction activities. The purpose of the integrated BIM–DES framework is twofold: BIM provides the product and process information for the DES, which facilitates the building and maintenance of the DES model; the DES model evaluates the construction performance and

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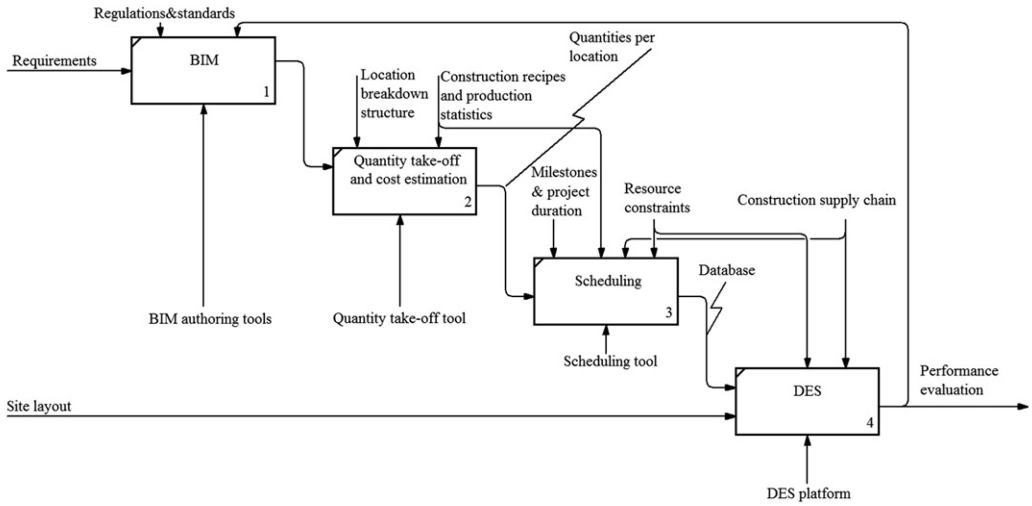

Fig. 1. The integrated framework of BIM and DES.

provides valuable feedback and decision support to the BIM process (the processes of Building Information Modeling).

The remainder of the paper is structured as follows. In Section 2, the authors review previous studies of DES and BIM related to the research work and describe the necessary steps for an integrated framework. In Section 3, the integrated framework between DES and BIM is proposed and modeled with function model methodology (IDEF0) [13]. In Section 4, a preliminary prototype of the proposed BIM–DES framework is developed. A summary of the contributions of the proposed framework and discussions about future research are presented in the final section of the paper.

2. Related research

2.1. DES in construction

DES is the modeling of systems in which the state variable changes at a discrete set of points in time [14]. It has been adopted as an effective technique in understanding the behavior of systems and evaluating various strategies for their operation. Since the development of CYCLic Operations Network (CYCLONE) [15], DES has been used to develop computer-based simulation models of construction projects in order to analyze and optimize their behaviors [16]. After the introduction of CYCLONE, a number of construction simulation systems were developed, such as STROBOSCOPE [17], Simphony.net [3], RiSim [18], and SDESA [19]. These simulation systems provide useful tools for project managers to replicate the dynamic interactions between resources and activities in order to evaluate overall performances and to produce a more reliable prediction of a construction system, taking into account the presence of inherent uncertainty and unforeseen conditions [20].

Despite its advantages, the practical applications of DES in construction are limited. The large number of input data required to build a simulation model has been one of the reasons restricting the use of DES in the construction industry [21]. Manual data entry is not only time-consuming but also an error-prone process [22]. A study from the National Institute of Standards and Technology (NIST) reported [23] that the lack of interoperability between individual systems accounted for a substantial increase in construction costs. Some approaches have

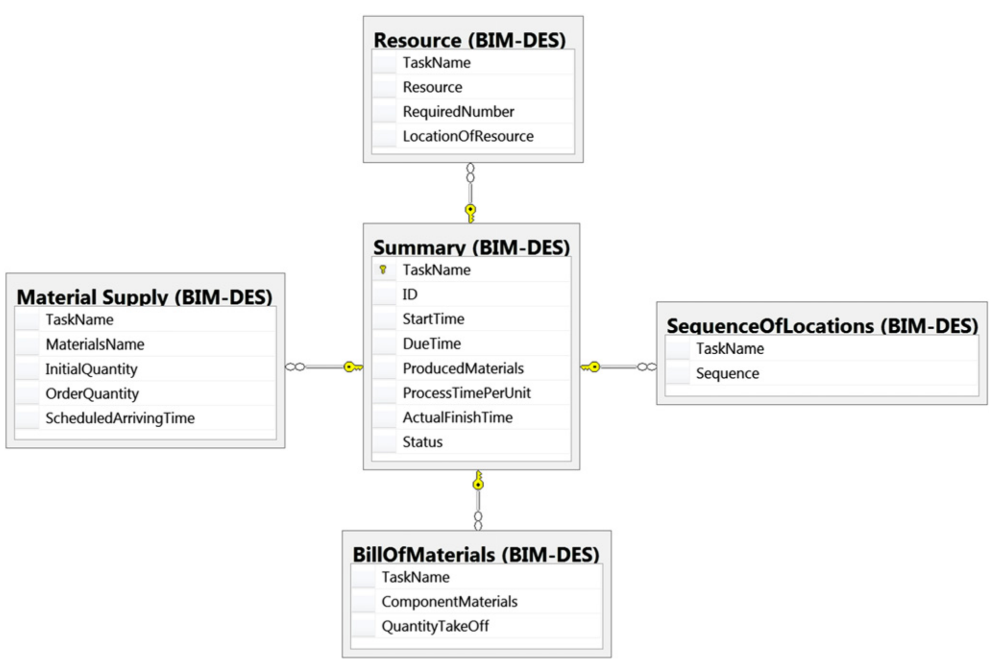

Fig. 2. The relational database diagrams.