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Interactive simulation modeling for heavy construction operations

K.J. Kim [a,*], G. Edward Gibson Jr. [b]

[a] *Department of Civil and Environmental Engineering, Chung-Ang University, 211 Heuksuk-Dong, Dongjak-Ku, 156 756 Seoul, South Korea*
[b] *University of Texas at Austin, Austin, TX, USA*

Abstract

With all the benefits of discrete event simulation, the field application of simulation has been limited in the construction industry. The principal reasons for the limited field application include the complexity of simulation system itself and the amount of time and cost to develop the simulation model. To support the utilization of discrete-event simulation in the planning and the analysis of heavy construction operations, this paper proposes an interactive simulation modeling approach that will allow, with step-by-step guidance, the project manager to build a simulation model through interaction with a computer. To evaluate this modeling concept, this paper presents a framework for an information system that is called *K*nowledge-embedded, *MO*dularized *S*imulation system (KMOS), and then applies to a real project.
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Keywords: Discrete event simulation; Construction operations; Construction management; Object-oriented simulation modeling

1. Background

Since Halpin [5] developed cyclic operation network (CYCLONE) for construction simulation, a number of researchers have extended the capabilities and the sophistication of CYCLONE [18]. Some of these systems include INSIGHT [17], RESQUE [3], UM-CYCLONE [7], MICRO-CYCLONE [11], and so on. These simulation systems allow the project manager to evaluate complex construction operations under different conditions to produce a more reliable (accurate) prediction of the operation performance and achieve a more efficient operation design. The use of construction simulation has high potential as a construction management tool.

With all the potential benefits that simulation can bring to the project, its application has been limited in the construction industry. The principal reasons for the limited field application of simulation in the construction industry include the complexity of simulation system itself, the lack of familiarity of simulation to practitioners, and the amount of time and cost to develop the simulation model. [14,20,22]. The simulation model building process using most computer simulation packages requires considerable time with which to gain expertise and proficiency. There has also been a lack of training about simulation in most undergraduate and graduate engineering curricula which have restricted the use of simulation as a management tool for construction projects [14].

In addition to the difficulty of the simulation modeling process itself, the unsteady state characteristics of construction operations also require more user-friendly environments in which a project manager responds easily and rapidly to the changes encountered on the job site such as space availability, and resource availability. To meet this requirement,

* Corresponding author.
E-mail address: kjkim@cau.ac.kr (K.J. Kim).

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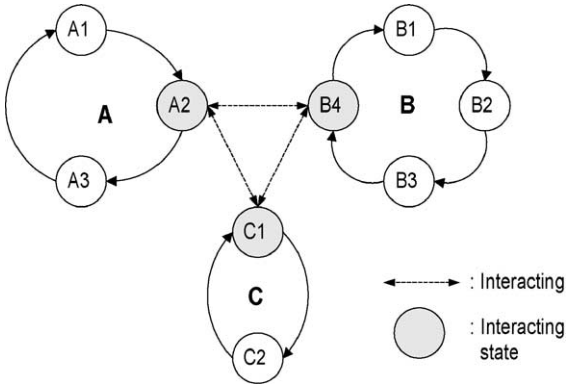

Fig. 1. Abstract of resource operations and interaction.

many researchers proposed user-friendly simulation environments. The combination of simulation and artificial intelligence in object functions is suggested for more user-friendly environments [1]. Touran [22,23] investigated the integration of simulation with expert systems, which can be applied to a limited domain (truck-loader operation). Oloufa [13,14], Oloufa and Ikeda [15], and Oloufa et al. [16] proposed the formation of a library of object-oriented constructs representing construction resources. Shi and AbouRizk [19] and Hajjar and AbouRizk [4] also investigated a simulation system that generates a simulation model by reference to all involved resources and site conditions. For the simulation of construction operations, each resource is associated with its own "Model". The "Model" is essentially similar to the atomic component, which was theorized by Zeigler [24] and Luna [12]. A simulation model is constructed by a continuous coupling of these models. Both Oloufa [13,14] and Shi and AbouRizk [19] use the resource model library for automated simulation model building.

Huang and Halpin [6] added a graphical user-interface to MICRO-CYCLONE. This is called dynamic interface simulation for construction operations (DISCO), which allows the user to create the schematic model diagram, using CYCLONE standard building blocks. This eliminated the code generation process for the simulation model. The user can build a simulation model by simply clicking on the appropriate icon from the DISCO graphical menu bar and dragging it over to the drawing area [6]. These approaches still, however, require considerable time with which to gain proficiency in the simulation model building process.

To provide an ideal environment for easy simulation modeling, this paper presents an interactive simulation modeling approach that will allow, with step-by-step guidance, the project manager to build a simulation model through interaction with a computer. This approach will provide an environment in which field personnel with minimal training in simulation can easily use the simulation package.

2. Concept of the interactive modeling

To allow for this interactive simulation modeling, the simulation system needs to allow for modularized simulation model-building and to provide step-by-step guidance in model building for the construction operation. For this method, the simulation of construction operations can be represented by all involved construction resources and their interactions (Fig. 1). The behavior of each construction resource can be described by its operation cycle. The resource operation cycle, in turn, can be constructed of basic types of states with which each construction resource stays in the operation. Here, a state means any particular status of construction resources in the operation. For the modularized simulation model building, each resource model should be constructed independently, and then the independently developed resource model should be able to interact with other resource models [8].

For interaction among resources, each resource needs to identify its interacting resources and their

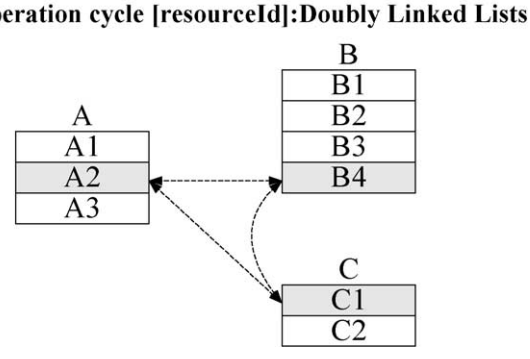

Fig. 2. Representation of operation cycle for each resource model.

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