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Simulation of labor evacuation: The case of housing construction projects

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Abstract Construction sites occupy of the labors who are engaged in many different activities that can expose them to dangerous conditions. During emergencies and extreme events of natural or manmade origin in construction sites, saving labors lives is the primary objective. Therefore, the contractors are required to establish effective emergency plans which have to be improved to aid for rapid egress from construction sites. To support emergency evacuation planning, it is critical to estimate labor evacuation times during project execution. This paper presents a framework that utilizes building information modeling (BIM) and computer simulation to plan the evacuation of labors in construction sites during project execution and to visualize evacuation times of labors at emergency conditions at any time from project duration. The proposed framework utilizes Mass-Motion software as the simulation platform that enables predicting the labor evacuation times under various conditions. In addition, the evacuation time calculated from computer simulation is used to develop and evaluate the plan. A case study is worked out to demonstrate a simulation of emergency evacuation from a housing building during its construction to demonstrate the use of the proposed framework. Finally, the paper presents the simulation results of labors evacuation in the housing building construction sites.

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Introduction

Construction sites are subject to a wide way of emergencies and hazards. Structural collapse, fire, act of violence, explosion, earthquakes, and unexpected weather condition are among the many kinds of emergencies that may require a construction site to be safety evacuated. As such they may be seen as an example of a complex environment. Construction sites have the potential to accommodate hundreds of occupants, especially in high-rise building projects where contractors and workers carry out their activities. The occupational safety and Health Administration (OSHA) and other agencies require written emergency plan and safe means of egress on

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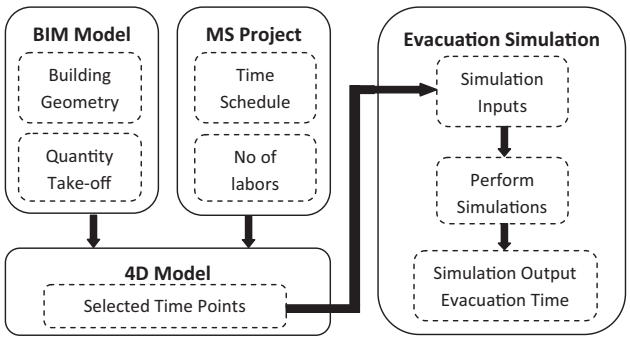

Fig. 1 Main components of evacuation framework.

construction sites. Accordingly, the contractors need to apply an effective emergency plan to prevent emergencies from occurring on construction sites.

However, many researchers have focused on the evacuation of the large population in public environments, such as malls, stadiums, airports, libraries, and metro station [1–4]. These environments have fixed spatial and occupants. Construction site environment changes continuously that which means the number of occupants, spaces and evacuation routes change from one day to another. Evacuation conditions for occupants that work in construction sites could be very different from the conditions that can be expected in public buildings [5]. Although evacuation models have been used in studying emergency evacuation for decades, little research has been done on construction sites. This paper presents a framework which helps the contractors to develop effective rescue and evacuation plan when an emergency or disaster happens and investigate the emergency evacuation time of occupants over the different points of time during project execution.

In this paper, the methodology contained three steps. The initial step involved an exhaustive review of the literature on emergency evacuation models. In the next step, a framework is developed using the integration of Building Information Modeling and computer simulation. The model uses Building Information Modeling (BIM) to build an adaptable 3D virtual reality environment. Computer simulation is adopted using agent-based simulation to model the behavior of labors in evacuation situations. The proposed simulation model utilizes MassMotion software, as a simulation engine to implement agent-based simulation. Finally a case study is worked out to illustrate the use of the proposed framework.

The remainder of the paper is organized as follows: Sectio n 'Emergency evacuation models' introduces related work in the field of evacuation simulation. Section 'Proposed framework' describes the proposed framework evacuation simulation using building information model and MassMotion software. Section 'Case study: evacuation simulation' provides the evacuation simulation of a case study: finally, Section 'Results and discussion' represents results and discussion.

Emergency evacuation models

Modeling of occupants' evacuation simulation from a building has been studied over the past years. Many evacuation simulation models have been established and applied to simulate occupant evacuation and evaluate the evacuation efficiency for buildings. These models can be classified in two main approaches: the macroscopic approach and the microscopic approach [6]. The first model focuses on crowd behavior as a whole and ignores the local dynamics of individuals and interactions between pedestrians. In the second model, the pedestrians are considered individually focusing on the local interactions of the pedestrians with their immediate environ-

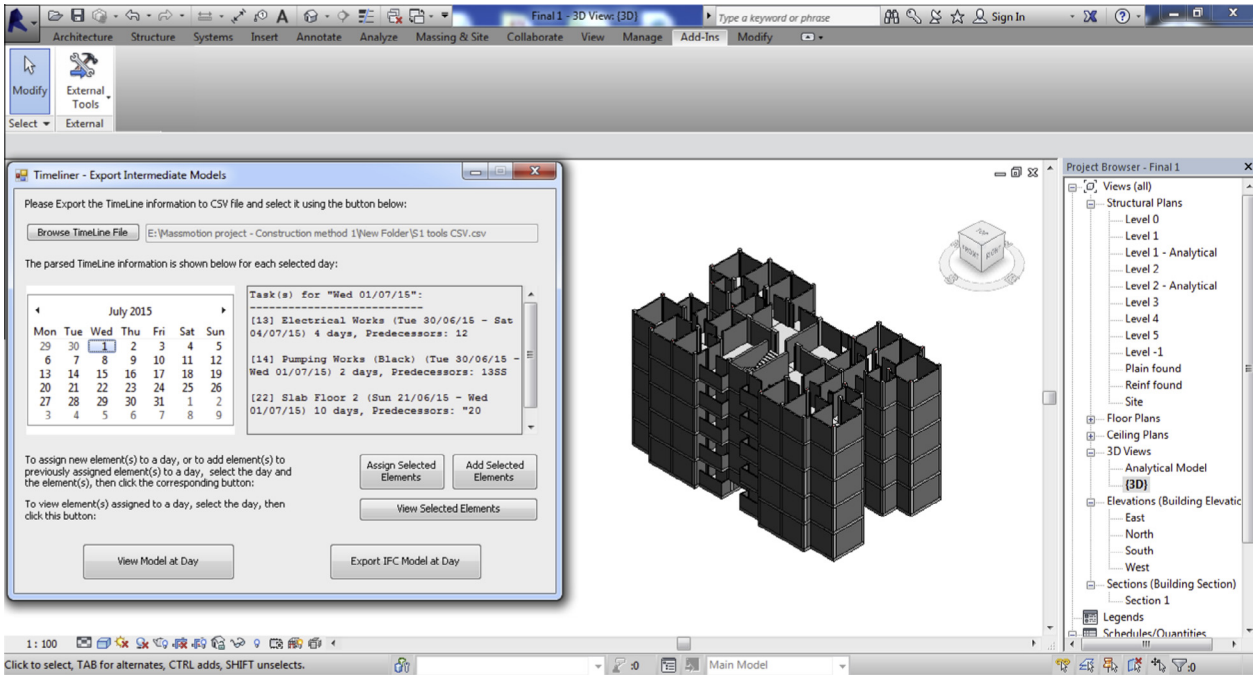

Fig. 2 Additional tool image in Revit Software.

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