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Review

Visualization technology-based construction safety management: A review

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ABSTRACT

Construction safety management has been a popular issue in research and practice in recent years due to the high accident and death rates in the construction industry. The complexity and variability of construction sites makes safety management more difficult to implement than in other industries. As a promising technology, visualization has been extensively explored to aid construction safety management. However, a comprehensive critical review of the visualization technology in construction safety management is absent in the literature.
This paper provides a comprehensive review to investigate research and development, application methods, achievements and barriers to the use of visualization technology in safety management, and suggests possible future research directions to extend its application. It is found that visualization technology can improve safety management by aiding safety training, job hazard area (JHA) identification and on-site safety monitoring and warnings, but there are barriers or limitations involved. Existing location technologies, for instance, can perform well only in relatively small areas due to their generally poor penetrating performance. Finally, possible future research directions are proposed to benefit the extensive application of visualization technology for construction safety management in both theory and practice.

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1. Introduction

Construction has become one of the most dangerous industries due to the harsh work environment and high risks involved [1]. In China alone, there was an average of more than 2500 annual accident deaths accompanied by serious safety accidents in the construction industry from 1997 to 2014 (see Fig. 1) [2]. In addition to developing countries, the construction industry is also recognized as dangerous in developed countries such as U.S. and U.K. [3]. According to global statistical data, its accident death and injury rate is three and two times higher respectively than the average of other industries [4]. In spite of more attention being paid to safety management in recent years, the accident rate of the construction industry continues to be high [5].

Construction safety management can be divided into the pre-construction stage and construction stage [6]. In pre-construction, potential safety hazards are normally identified based on the safety officers' or project managers' experience and eliminated via safety training and safety planning. During construction, accidents are prevented by monitoring workers and the environment on site [7]. However, some problems still exist in construction safety management, summarized as follows (see Fig. 2):

- *Insufficient safety training*. Safety training is regarded as a useful safety management method [8], but is traditionally based on indoor teaching, which lacks interaction, intuition and hands-on training, and therefore does little improve the safety consciousness of workers [9].
- *Incomplete safety planning*. Failing to identify safety hazards is a major cause of construction accidents [10] and the identification of a job hazard area (JHA) can significantly improve safety and decrease associated costs [11,12]. Traditionally, safety planning is based on a team meeting [13] in which JHAs are identified by imagining construction processes with the aid of 2D drawings, schedules, safety rules and experience, but lacking an intuitive method of representing the construction process. A large number of JHAs also go undetected because of the uniqueness, dynamism and complexity of the construction environment.
- *Invalid site monitoring*. Site monitoring is currently the key to safety management [9]. Safety officers often use a checklist to manage construction safety by identifying and recording violations [14]. In the absence of technological support, however, it is impractical to monitor the whole of sites at once in this way due to their large size and dynamic environment [15].

The above problems derive from the information level. Fig. 2 shows the features of construction information, which is abstract, dynamic and massive. These features of construction information impede construction training, planning and monitoring, since workers and safety officers have to imagine what the construction site would be like according to construction drawings and documents, which are not intuitional and efficient enough.

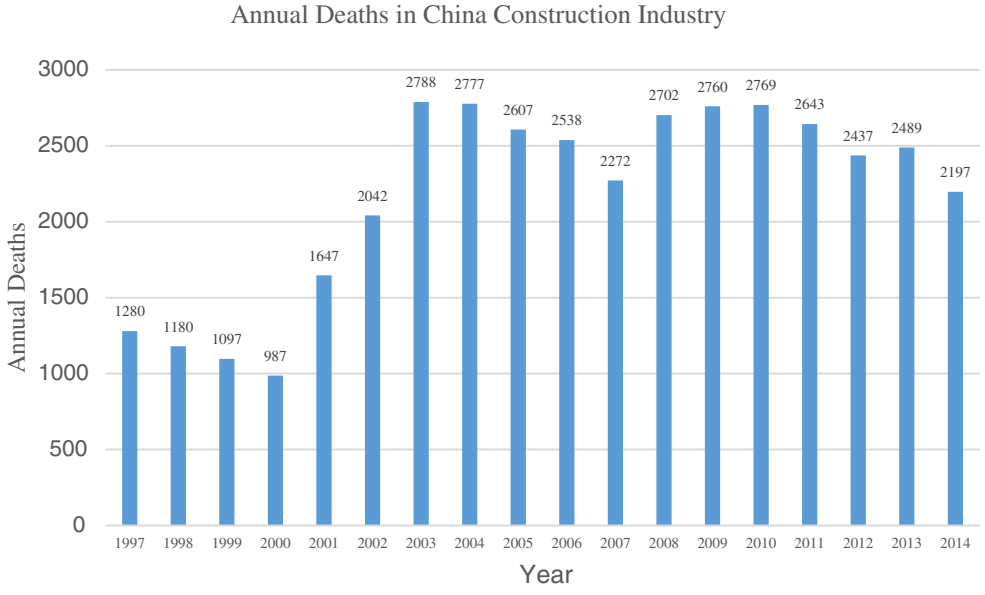

Fig. 1. Annual deaths in the China construction industry from 1997 to 2014.

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