1. Introduction

The AEC (Architecture, Engineering and Construction) industry has witnessed a rapid development all around the world, especially in developing countries, during the last few decades – large-scale projects have become widespread and international, new project delivery methodologies are being adopted, design theory and tools are constantly improving, creative and new approaches, methods, and materials of construction are being introduced (Bryde et al., 2004). AEC projects such as buildings, infrastructure systems and plants are part of the scope of urban spatial planning and design, and have an immediate impact on and a direct relation to the accommodation of land use for the future growth of cities (Colding, 2007). However, high accident rates and hazardous activities in the AEC industry not only lead to a poor reputation but pose a threat to its future innovation and evolution. The scope of a risk is very broad and consists of issues such as damage or failure of structures, injury or loss of life, budget overruns, and delays to the construction schedule, which are caused by various reasons such as design deficiency, material failure, inexperienced operatives, and weak management. For instance, in the United States, 503 bridge collapses were reported between 1989 and 2000 (Wardhana and Hadipriono, 2003), and according to official records over 26,000 workers lost their lives on construction sites from 1989 to 2013 (Zhang et al., 2013). It was estimated that over 60,000 on-site fatal accidents happen every year globally (ILO, 2005). In China, though the number of construction supervision companies has increased from 52 in 1989 to 5123 in 2000 (Liu et al., 2004), unwanted hazards related to safety, time, and cost were observed frequently due to poor risk management (Tam et al., 2004).

An AEC project starts with planning and design followed by the construction stage lasting for months or years, and eventually the project will come into the operation period that may last for decades before demolition. Different risks may be present in each of the different stages of the project and product lifecycle. There are a wide range of risks that may lead to hazards. In recent years, with the rapid development of society, risks are gradually growing because of the increasing structural complexity and project size,
and the adoption of new and complex construction methods (Shim et al., 2012). To reduce the possibility of these hazards occurring and to achieve project goals successfully, there is a high demand for managing risks effectively throughout a project’s life cycle. However, the implementation of traditional risk management is still a manual undertaking, and the assessment is heavily reliant on experience and mathematical analysis, and decision making is frequently based on knowledge and experience based intuition, which leads to decreased efficiency in the real environment (Shim et al., 2012). In response to these problems, there is currently a new research trend of utilising Building Information Modelling (BIM) and BIM-related tools to assist in early risk identification, accident prevention, risk communication, etc., which is defined as “BIM-based risk management” in this paper.

The paper conducts a critical and extensive review on these new developments. It firstly presents an overview of the fundamentals, process, and challenges of the traditional risk management. This paper further moves on to discuss the state-of-the-art of the use of BIM and BIM-related technologies for risk management and outlines the existing challenges and gaps that slow down or prevent its broad adoption. The last part of the paper discusses combining traditional methods with new technologies and identifies research areas where additional research is needed in the future.

2. Research approach

2.1. Motivation and aim

The literature includes numerous studies describing the development of BIM and BIM-related technologies for managing particular risks (Chen and Luo, 2014; Hadikusumo and Rowlinson, 2004; Zhang and Hu, 2011; Zhang et al., 2013). Nearly all reviews (Bryde et al., 2013; Eastman et al., 2009; Forsythe, 2014; Hartmann et al., 2008; Zhou et al., 2012) partially summarise the application area, development and shortcomings of applying these technologies, and cover only one or several aspects separately. Many papers (Ahmed et al., 2007; Jannadi and Almishari, 2003; Vrouwenvelder et al., 2001; Zou et al., 2007) concentrate on reviewing traditional risk management methods and other publications (Azhari, 2011; Eastman et al., 2011; Tomek and Matějka, 2014) partially summarise the benefits and risks of implementing BIM in projects. However, to the authors’ knowledge there is no comprehensive overview of recent research on BIM-based risk management as a comprehensive whole and no studies focusing on the relationship between digital technologies and the traditional methods for managing risk. The aim of this review is to close this gap, identify the obstacles of BIM-based risk management as well as foster research interests for the future.

2.2. Methodology

To review BIM-based risk management critically, a three-step approach was conducted. The topic of “risks of implementing BIM” and papers that are not published in English are not within the scope of this review.

In the first step, the fundamentals, general process, and main challenges of traditional risk management are summarised through an extensive literature review and several expert interviews for comprehensive understanding of the relation between the traditional methods and BIM-based risk management. The process identifies a set of keywords for data collection as the basis for the next step. The main keywords are, for example, “BIM”, “building information model”, “risk”, “risk assessment”, “risk analysis”, “risk management”, “knowledge management”, “safety”, “quality”, “time”, “cost”, and “budget”. In the second step these keywords were applied to a web search in online academic publication databases, i.e. “Web of Science”, “Engineering Village”, “Scopus”, and “Google Scholar”, for collecting academic and applied publications related to this topic. Then the state-of-the-art of these technologies is classified and surveyed as follows: (1) BIM, (2) automatic rule checking, (3) knowledge based systems, (4) reactive IT-based safety systems (i.e. database technology, VR, 4D CAD, GIS), and (5) proactive IT-based safety systems (e.g. GPS, RFID, laser scanning). The scope of the survey includes articles in leading journals of this area (e.g. Safety Science, Automation in Construction, International Journal of Project Management, Journal of Computing in Civil Engineering, Information Technology in Construction, Reliability Engineering & System Safety), publications from conference proceedings and other sources of professional associations, standard committees (e.g. HSE, ISO) and authorities. In the third step, all publications are analysed critically and compared with the traditional risk management methods to identify current obstacles and future work to close these gaps.

3. Background

3.1. The fundamentals of risk management

The term “risk” was known in the English language from the 17th century and was derived from an original meaning to run into danger or to go against a rock (McElree, 2007). Today the concept of risk is adopted in many different fields and with a variety of different words, such as “hazard”, “threat”, “challenge”, or “uncertainty”. In the AEC industry, risks have a two-edged nature, e.g. “the likelihood of unwanted hazards and the corresponding consequences” (Zou et al., 2007), “the likelihood and consequence of risks” (Williams, 1996), “a combination of the likelihood and consequences of the hazard” (Vrouwenvelder et al., 2001).

Risk management is a system aiming to recognise, quantify, and manage all risks exposed in the business or project (Flanagan and Norman, 1993). PMBOK® (Project Management Body of Knowledge) describes it as a process in relation to planning, identifying, analysing, responding, and monitoring project risks and one of the ten knowledge areas in which a project manager must be competent (PMI, 2004). The International Organization for Standardization (ISO, 2009) defines the process of risk management involving applying a systemic and logical method for establishing the context, creating a communication and consultation mechanism, and constructing risk management identification, analysis, evaluation, treatment, monitoring, and recording in a project. In accordance with these definitions, risk management in the AEC context is a logical, systematic, and comprehensive approach to identifying and analysing risks, and treating them with the help of communication and consultation to successfully achieve project goals. The systematic process includes risk identification, analysis, evaluation, treatment, monitoring and review (Banaitiene and Banaitis, 2012; ISO, 2009; Zou et al., 2007), where risk identification aims to find out the range of potential risks and risk analysis plays a core role in the whole process. When risks cannot be eliminated, early and effective identification and assessment of risks become necessary for effective risk management in a successful project (Zou et al., 2007). All activities of a project involve risks (ISO, 2009) and there is an immediate and direct relationship of objectives between the whole project and risk management.

A set of techniques has been developed to identify, analyse and evaluate risks. The techniques, according to ISO (2009), can be divided into qualitative and quantitative analysis. The former includes Delphi, check lists, strength–weakness–opportunity–threats (SWOT) analysis, risk rating scales, etc., while the latter includes environmental risk assessment, neural networks (NN),
دریافت فوری
متن کامل مقاله
امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات