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Identifying and assessing critical risk factors for BIM projects: Empirical study

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ABSTRACT

Building information modelling (BIM) technology exhibits strong potential to become the core technology used in the construction industry. However, the process of implementing new technology involves numerous challenges, and the performance of new technology can be impaired when unidentified risk factors are present during implementation. A complete understanding of the risk factors can enable BIM users to execute early responses to the potential risks, thus increasing the possibility that BIM is implemented successfully. In this study, 13 risk factors related to the technical, management, personnel, financial, and legal aspects of BIM adoption were identified. Based on the results of a questionnaire survey distributed to architects, engineering consultants, academics, and construction companies in the architecture, engineering, and construction industry in Taiwan, relationships between risk factors were identified using the decision-making trial and evaluation laboratory method. This study identified the critical risk factors of BIM projects at various levels and proposes relative risk-response strategies for a case study project.

1. Introduction

1.1. Background of building information modelling implementation

Building information modelling (BIM) is an emerging technology in which digital information models are employed in a virtual space to achieve high-quality and efficient construction and management throughout the life cycle of a facility. Several general construction projects worldwide, such as the EMP Museum at Seattle Center, Walt Disney Concert Hall, Shanghai World Expo Cultural Center, Shanghai World Expo China Pavilion, Washington National Park, the Bird's Nest and Water Cube constructed for the Beijing Olympics, and Shanghai Tower, have been successfully completed by implementing BIM technology. The digitized and parameterized characteristics of BIM enable project designers to fully analyze the influences of the environment and energy, and the parametric design facilitates the production of highly accurate results and instant feedback to changing variables when construction personnel encounter complex geometric designs. By implementing a three-dimensional (3-D) visual BIM model platform, project construction teams can assess clash detection in advance and adopt four-dimensional (4-D) information to facilitate construction management when facing tight deadlines.

Using BIM tremendously benefits construction projects in various aspects. By analyzing 32 major projects, the Stanford University Center for Integrated Facility Engineering revealed that using BIM yields numerous benefits, including an up to 40% elimination of unbudgeted change, cost-estimation accuracy within 3%, an up to 80% reduction in cost estimate generation time, savings of up to 10% of the contract value through clash detection, and an up to 7% reduction in project time [13]. Suermann surveyed 105 people in the Facility Information Council National BIM Standards Committee at the National Institute of Building Sciences to understand the effects of BIM on construction and obtained the following responses: 76% of the respondents indicated that BIM can facilitate reducing unit labour hours, 70% stated that BIM can facilitate reducing unit costs, 84% reported that BIM facilitates reducing project costs, 90% stated that BIM facilitates the timely completion of projects, and 94% reported that BIM facilitates ensuring that the quality of project designs is high [42]. In four detailed case studies, Kaner et al. observed apparent improvements in engineering design quality, including error-free drawings and steadily increasing improvement in labour productivity, when BIM was applied [28]. Barlish and Sullivan also indicated that there is a high potential for BIM benefits to be realized in RFIs (requests for information), change orders, schedule and cost savings [6]. Giel and Issa researched case studies that indicated that the return of investment of BIM varied greatly from 16% to 1654%. In addition, the total number of requests for information in a small tilt-wall project, a three-story assisted living facility project, and a midrise commercial condominium project decreased by 34%, 68%, and 43%, and the number of change orders decreased by 40%, 48%, and 37%, respectively [22].

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1.2. Challenges of building information modelling risk assessment

Zavadskas et al. (2010) mentioned that the size and complexity of construction projects are increasing, thus increasing risks [50]. BIM projects are often the largest investments or the most prominent projects undertaken in the construction industry. However, although most construction organisations are highly experienced in managing traditional construction projects, BIM projects may involve new challenges and risk factors that must be managed differently from those of traditional construction projects. Thus, risk management is more complex and crucial in BIM construction projects than in conventional construction projects.

Insufficient risk management knowledge and techniques are the primary barriers to risk management [43]. Several public BIM publications have emphasized the potential risks of BIM implementation. For example, the BIM Handbook (2011) described the barriers associated with work process changes and technological risks in implementing BIM [16]; the architecture, engineering, and construction (AEC) (UK) BIM Protocol (2012) provided guidance for BIM interoperability problems [1]; the BIM Planning Guide for Facility Owners presented a structured approach for effectively planning the integration of BIM into an organisation's ownership of model, data reuse, and data security [7]; and the Singapore BIM Guide v. 2.0 provided a reference for risk allocation and intellectual property rights [41].

Projects are commonly influenced by multiple risk factors. To systematically manage large and complex BIM projects, the potential risk factors must be identified during the risk-management process. Because of the limits on project resources and awareness of suggested BIM risks, new questions have arisen among adherent BIM practitioners: “What are the major risk factors associated with BIM projects?”, “Is every level of the AEC industry facing a similar risk situation?”, and “What are the risk-response strategies used for addressing BIM risks associated with BIM projects?”

1.3. Research objectives

To provide a broader context in which to investigate these questions, this paper introduces a comprehensive risk-factor identification and assessment method for BIM construction projects. First, we reviewed the literature to identify the risks affecting general construction projects, information technology (IT) and software projects, and BIM projects as well as the risk factors associated with BIM projects. Second, the decision-making trial and evaluation laboratory (DEMATEL), an effective risk-factor assessment method, was applied to determine the critical risk factors (CRFs) in BIM projects. Finally, a case study was conducted, and risk-response strategies for BIM projects that involve allocating risk among project partners were proposed.

2. Literature review

2.1. Risk management

Ghosh suggested that risk is a factor that can jeopardize the successful completion of a project by causing cost overruns, time overruns, and underspecification [23]. Chapman and Ward noted that project risk implies the existence of substantial uncertainty regarding the level of achievable project performance [10]. Wang et al. indicated that a systematic approach to risk management in the construction industry consists of three main stages: risk identification, risk analysis and evaluation, and risk response [45]. The risk-management process begins with identifying the relevant and potential risks associated with the construction project; this stage is crucial because the processes of risk analysis and response management are applied only to the potential risks identified. Risk analysis and evaluation is the intermediate process between risk identification and management in which uncertainty is measured quantitatively and qualitatively to assess the potential impact of the risk. The evaluation should generally focus on risks with high probabilities, high financial consequences, or combinations thereof. Once the risks of a project have been identified and analyzed, an appropriate method for eliminating risks must be adopted.

Al-Bahar and Crandall stated that the risk analysis and evaluation process is the vital link between the systematic identification of risks and the rational management of the key risks, and that the process forms the foundation of decision making regarding the various management strategies that should be used. Risk analysis and evaluation is defined as “a process which incorporates uncertainty in a quantitative manner, using probability theory to evaluate the potential impact of risk.” [2].

Risk analysis generally includes qualitative analysis, semiquantitative analysis, quantitative analysis, common construction engineering risk analysis, and methods of operation (Table 1).

Zhi noted that the level of risk is evaluated according to several criteria, such as the probability of an undesirable occurrence, the degree of severity, and the subsequent impact of an undesirable event [51]. Williams suggested that a risk can be expressed as $R = P \times I$, where R is the degree of risk (between zero and one), P is the probability of the risk occurring (between zero and one), and I is the degree of impact of the risk (between zero and one) [46].

Risk probability can be assessed using two methods: subjective judgment and objective analysis. Subjective judgment involves estimating the probability that a risk factor is present directly; this is simple and practical for construction projects, but requires experience. Subjective judgment can be used to assign probability to certain risks that appear frequently and for which numerous comparable experiences exist. Objective analysis is used widely to estimate the probability of a risk factor. However, to use this approach, historical data are required, occasionally rendering the application of this method impractical in construction practice; this is especially true for BIM projects because BIM projects are often new and unfamiliar, and comparable information required for undertaking such projects is not easily found.

The ranking of risk factors provides a basis for prioritizing responses to various risks in a construction project. Several methods can be used to assess risk impact. In this paper, we suggest using the DEMATEL method.

2.2. Decision-making trial and evaluation laboratory method

The DEMATEL method, which was created by the Geneva Research Center of the Battelle Memorial Institute [18–20], is practical and useful for visualizing the structure of complex causal relationships by using

Table 1
Construction risk analysis methods.

	Qualitative analysis	Semi-quantitative analysis	Quantitative analysis
Description	Using the text or the descriptive classification level to describe the extent and the impact of risk that may affect the probability of risk occurrence.	Using actual values to determine the level, but each level is not equal to the actual value that directly affects risk impact and probability.	Using actual data (rather than the semiquantitative analysis used for descriptive classification) to describe risk impact and probability.
Analysis method	Checklists, influence diagrams, hazard and operability analysis, brainstorming, cause and effect analysis, risk breakdown structure, failure mode and effects analysis, SWOT analysis, and the Delphi method.	The matrix method, fuzzy analysis method, connection method, and statistical inference.	Fault tree analysis, hierarchical or network analysis, event tree analysis, the Monte Carlo simulation, sensitivity analysis, DEMATEL, and the Poda equation.