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Building information modeling as a risk transformer: An evolutionary insight into the project uncertainty

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ABSTRACT

Building information modeling (BIM) is a promising technology for the construction sector, as it addresses multiple risks, supports decision-making and enhances value. However, its technological and contractual novelties introduce some new risks. To observe the BIM-driven risk transformation, this paper performs a thorough analysis involving international experts and practitioners. Data is collected in the form of open-ended interviews and typeset questionnaire along with case studies of running projects. Results reveal that BIM eliminates a majority of significant risks. Further, the findings fuel a new research problem; the lack of a dedicated BIM plugin for risk management. Responding to it, a theoretical framework is developed to automate the risk management process and improve overall project management practice. It is concluded that construction projects can greatly benefit from an automated risk management system and investment in developing a dedicated plugin is recommended, ensuring an effective penetration of BIM in the construction industry.

1. Introduction

Construction projects are unique in their nature [1], their process is complex from beginning to end, and they are characterized by uncertainty [2]. Since uncertainty and risk are unavoidable in such projects, they should be managed, minimized, accepted, shared and transferred, but should not be ignored [3]. The concept of risk and its management is not new. Various studies have maintained that proper risk management is advantageous to construction projects and industry [4]. Risk management is generally considered a critical part in the overall process of construction management and is practiced using tools like spreadsheets, brainstorming, strengths-weaknesses-opportunities-threats (SWOT) analysis [5,6], and risk registers [7,8] to name a few.

Despite the use of such systematic tools and techniques, information on the existence of risk has remained challenging owing to its evolving, subjective, emerging, nonlinear and behavioral characteristics which result in the escalated criticality of risk management [9–11]. Also, the traditional approaches are usually manual, with marginal reliance on software solutions and automation [12]. The majority of analysis is based on mathematical calculations and expert judgments. Thus, the practice of such a manual system for risk appraisals throughout the project progress reduces overall productivity [13]. This lack of information, it's automation and modeling in construction projects enhances the uncertainties, fueling the quantum and intensity of risk, paving a way towards project failure [14].

With a rapid advancement in information and communications technologies (ICT), Building Information Modeling (BIM) has emerged as an information source and a core data generator to support the decision-making [13,15]. Inputting huge amounts of data helps BIM to see through various complexities and uncertainties [16–18]. Risk management in construction projects applying BIM is highly significant [13], as the implementation of BIM introduces a major sway on standard level of risks due to the emergence of newer opportunities [18,19]. The application of BIM eliminates some fundamental risks such as those related to design and construction drawings [17,20–22]. It also assists designers by removing clashes, improving visualization and prefabrication process [17,23,24], and modeling sustainability simulations [25,26]. BIM also improves communication between project stakeholders [17,27], enhances coordination, and reduces the risk of variation and reworks. Further, it reduces safety risks by developing site safety plans and layouts [17,19]. The list of various advantages of BIM can be further enhanced by its risk mitigation capability [17,18].

Though positive, innovation in construction has its cost in the form of rapidity, uncertainty and lack of standardization [28–31]. This

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innovation comes in many forms, such as technical [32], contractual [33], managerial or organizational [34–36]. An example in this context is the modular construction technique which is prone to trial and error strategies for dimensional and geometric variability [37]. Similarly, cost and effort of data acquisition are crucial in sensor technologies and robotic applications in construction [32] which are further exasperated by the limited mobility, weight, size and even accuracy of automated construction systems [38]. Based on the similar line of argument on innovation [29], BIM brings some new risks of its own [18,39,40]. These include risks of liability, copyright and ownership due to weakening concept of responsibility [29,39–41], un-generalized impacts on individual projects [42], and numerous other technical, financial and legal risks [28–31,39,40].

Despite these new risks due to its implementation, BIM has the capability to reduce the intensity of threats [13,16–19], making the tradeoff between elimination of existing risks and formation of newer ones positive, with a greater portion of them being opportunities. In contrast to computer-aided design (CAD), where negative risks outweighed the opportunities [43], BIM is a better risk transfer system. Regardless of the significance of new risk introduced by BIM, a proactive approach is needed to further enhance its value proposition [18,44].

This proactive approach comes in the form of 'BIM-based risk management', which is an emerging process in the construction industry with a number of new openings for further development. According to Araszkiewicz [19], there does not exist a proper analysis of systematic integration of various areas of construction project management in BIM processes, procedures and methods, and techniques of risk management. Further, except for some theoretical attempt [45], the integration of traditional risk management with new technologies is largely missing [13]. The evolution of pre- and post-BIM risk, in the form of elimination and transformation of existing risks, and creation of newer ones, is yet to be investigated.

To fill these research gaps, the current study examines the performance of risk management in both traditional and BIM systems. In doing so, the evolution of risk is traced using published works, expert opinion and case study based data acquisition through systematic literature review, BIM practitioners and institutional buildings, respectively. The risk transformation helps practitioners in appreciating the value proposition of BIM in the context of project risk management. This paves the way for the development and integration of dedicated tools in BIM environment for an enhanced productivity.

2. Literature review

Since an attempt is made to study the evolution of project risk in the face of information systems, specifically BIM, the reviewed literature encompasses the major areas of risk management and ICT based information modeling solutions in the construction sector.

2.1. Project risk management

Risk is an uncertainty that impacts the project objectives [46]. Every activity in a construction project involves risks of varying degree which need to be managed to keep the project under control [3]. According to Frimpong et al. [47], a successful project is characterized by its achievement of a set objectives and goals with regard to its technical aspects, and time and budget constraints. But it is not so simple in construction projects; risk can negatively influence the project success by diminishing its performance, resulting in cost and time overruns, and quality decline, causing the failure of the project [48–50].

A number of studies have discussed the impact of risk on construction projects in terms of success parameters. For example, in Saudi Arabia, 70% of projects suffer time and cost overruns due to 73 multiple risk factors [51]. Similarly, Odeyinka and Yusif [52] found that 7 out of 10 Nigerian construction projects suffer delays and cost overruns due to various uncertainties. Also, Mansfield et al. [53] identified 16 major risk factors behind project failure. Frimpong et al. [47] identified causes of project delay and cost overrun in Ghana based on 26 critical uncertain factors. They found that payment delays, stakeholder management, material procurement, inadequate technical performance and price escalation are the major factors. Also, Sambasivan and Soon [54] identified 10 significant risk factors causing delays in construction projects and quantified that almost 17% public projects in Malaysia fail to meet their timeline due to such factors. These studies assert the criticality of risk management process for achieving project success in all of its dimensions including cost, time, quality of work, safety and sustainability [1,55].

Risk management is a holistic process of identifying, analyzing and responding to project risks [56,57]. Identification of risk factors, which may positively or negatively influence project outcomes, is the first and most crucial part of an effective risk management process [29]. Further, after the identification of potentially influencing factors, they are analyzed for categorization based on their criticality [2]. According to ISO [3] there are a number of techniques for identification, analysis and evaluation of risk. The assessment techniques can be classified into qualitative and quantitative categories, with some semi-quantitative techniques [29]. These techniques are supported by various tools such as checklists, spreadsheets, Delphi method, SWOT analysis [5,6], risk ranking, risk registers [7,8], environmental risk assessment, row tie analysis and risk incidences to name a few [13]. However, the subjective and nonlinear nature of risk, and limited statistical information obtained from these techniques, makes them inefficient in practice [58].

To make matters worse, these analyses are manually carried out with marginal dependence on ICT tools. Thaheem and De Marco [12] found that only 21% of global construction industry uses risk assessment software. The traditional manual risk assessment practices are largely based on statistical and mathematical calculations, and expert judgments. Similar is the case with the decision-making. This leads to a decrease in efficiency in a real environment, especially in the developmental phases of projects where it is essential to properly keep updated risk registers [13]. Likewise, the construction projects experience a proprietary transformation from planning to operating phases. In this context, the onus of responsibility shifts from one party to another during the project progression. It is tantamount to an assembly line where every operative completes their job and gets contractually entitled to leave from the project. Though this is an efficient system in terms of optimum utilization of resources, it results in loss of information about any occurred risk and its mitigation strategy if not recorded properly or shared with other participants [59]. Ideally, most of the risks are identified during the planning phase and the remaining ones during execution and succeeding phases. But the transactional nature of construction projects leads to a lack of information and ineffective communication which fuels uncertainties and triggers project failure [13].

It is evident from the literature that this lack of automation and information management practices is at the core of underperformance of risk management in the construction industry. Any construction business will need to incorporate better ICT tools for explicitly or implicitly improving the state of project management.

2.2. Role of ICT in risk management – A view on BIM

With rapid advancement in ICT, such as CAD, BIM [17–19,29], virtual [60,61] and augmented realities [62], risk management has been strengthened. These tools indirectly support decision-making in construction projects. BIM is defined as "*a shared digital representation of a built object to facilitate design, construction and operation processes to form a reliable basis for decisions*" [63]. It has emerged as a recent development in ICT for the construction industry. It is an information and data generation source aimed at facilitating critical decision-making.