Application of BIM Technology for Risk Mitigation in Design and Build Projects in Bali

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Abstract. Building Information Modelling (BIM) technology in construction project management has proven to be effective in identifying and reducing risks. This research aims to apply BIM technology in risk mitigation of Design and Build projects in Bali. With this approach, the study identifies the key risks in the Design and Build project in Bali, investigates the factors that influence those risks, and develops effective mitigation strategies using BIM. Data is collected through surveys, in-depth interviews, and analysis of project documents. The results show that using BIM improves risk management efficiency, especially in terms of communication between stakeholders and early detection of potential problems. This study contributes to the field by demonstrating the applicability of BIM technology in a unique regional context, emphasizing its role in enhancing risk management practices and stakeholder coordination in environments with specific local challenges. The findings have significant implications for improving construction project efficiency in Bali and similar contexts, where adapting technology to local conditions is crucial.

Keywords: Building Information Modelling (BIM), risk mitigation, Design and Build, technology.

1. Introduction

1.1. Background

Design and Build projects offer efficient integration between design and construction execution, which can save time and money. This method allows one party to be responsible for the entire process, from planning to execution, thereby reducing potential conflicts and improving coordination between stakeholders [1], [2] [30]. However, this method also carries several risks that require effective mitigation. Risks in Design and Build projects can include design errors, non-conformance of specifications, regulatory changes, and material availability [29]. [36].

In Bali, construction projects often face unique challenges related to different local conditions and regulations. For example, frequent changes in zoning laws and environmental regulations can delay projects and increase costs. Additionally, Bali's tropical climate poses specific challenges, such as heavy rainfall and humidity, which can affect construction schedules and material durability. Furthermore, the island's cultural heritage requirements often necessitate designs that preserve traditional architectural styles, adding complexity to the design process [1] [3] [36]. In this context, the use of Building Information Modeling (BIM) technology can be a solution to increase efficiency and reduce risks in Design and Build projects.

BIM technology has been applied in various construction projects around the world with positive results in risk management. BIM enables the creation of digital models of construction projects that cover various aspects such as design, structure, and mechanical-electrical, thereby facilitating early detection of potential problems and improving coordination between stakeholders [4], [5], [6]. In Bali, the adoption of this technology is still in its infancy, and this study aims to explore the potential of BIM in risk mitigation specific to Design and Build projects in this area.

The urgency of this research lies in the need to improve the efficiency and success of construction projects in Bali through the use of advanced technology. This research not only focuses on risk identification but also on the development of technology-based mitigation strategies, which are specifically adapted to Bali's local conditions. Thus, this research is expected to make a significant contribution to improving project management practices in Bali and become a reference for the implementation of BIM in other regions with similar conditions.

The formulation of the problem is (1) How can BIM technology be specifically adapted to identify and reduce risks in Design and Build projects in Bali, considering the unique regulatory and environmental landscape? (2) What are the novel factors that affect the effectiveness of BIM in risk mitigation of Design and Build projects in Bali, and how can these be leveraged to improve project outcomes? and (3) What innovative and context-specific risk mitigation strategies using BIM can be developed to address the unique challenges faced by Design and Build projects in Bali?

Meanwhile, the objectives of this study are: (1) To identify and evaluate the novel factors that influence the effectiveness of BIM in risk management within Bali's construction sector, such as stakeholder engagement, technological infrastructure, and cultural considerations, (2) To identify and evaluate the novel factors that

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influence the effectiveness of BIM in risk management within Bali's construction sector, such as stakeholder engagement, technological infrastructure, and cultural considerations, and (3) To develop innovative, context-specific BIM-based risk mitigation strategies tailored to the unique challenges of Design and Build projects in Bali, including strategies for enhancing local capacity and overcoming infrastructure limitations.

This research offers a new approach to the application of BIM technology for risk mitigation in the Design and Build projects in Bali. This approach focuses not only on risk identification but also on the development of technology-based mitigation strategies that are specifically adapted to Bali's local conditions.

2. Literature Review

2.1. Risk Management in Design and Build Projects

Design and Build (D&B) projects are an increasingly popular procurement method in the construction industry due to their ability to integrate design and execution into a single contract. The main advantage of this method is the existence of a single point of responsibility, which can reduce the potential for conflict between designers and contractors, as well as speed up the project execution process [7], [8], [9], [10]. However, D&B also presents several risks, including design errors, non-conformity with specifications, and regulatory changes [29], [36].

Risk management in D&B projects includes the process of identifying, analyzing, and mitigating risks that may affect the success of the project. According to [11] risk management must include a systematic approach to identifying risks, assessing their impacts, and developing appropriate mitigation strategies. Some of the methods that are often used in risk management include SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, FMEA (Failure Mode and Effects Analysis), and risk matrix.

2.2. Use of BIM Technology in Construction Project Management

Building Information Modeling (BIM) is a digital technology that allows the creation and management of digital representations of the physical and functional characteristics of a construction project. BIM has been shown to improve project management efficiency through various features such as 3D visualization, interdisciplinary coordination, and conflict detection [12], [13], [14].

BIM provides a platform that allows all project stakeholders to collaborate effectively. Using integrated 3D models, designers, contractors, and project owners can visualize and manage every aspect of a project in real time. This not only improves coordination but also minimizes errors and costly changes during the construction phase [15], [16], [17], [18]. Research by [19], and [20] shows that the use of BIM can reduce project costs by 5-20% and accelerate project completion time by 7-10%.

However, while these studies highlight the general benefits of BIM, they often focus on developed regions with advanced technological infrastructures and do not sufficiently address the unique challenges faced in developing regions like Bali, where local regulations, environmental conditions, and cultural considerations may significantly impact BIM's effectiveness. The existing literature lacks a comprehensive analysis of how BIM can be specifically adapted to regional contexts with unique challenges. This study addresses this gap by examining the application of BIM technology in the Design and Build projects in Bali, where the regulatory and environmental landscape presents distinct risks that are not commonly encountered elsewhere. Additionally, while previous research primarily discusses the theoretical benefits of BIM, this study diverges by providing empirical evidence on the practical implementation of BIM in Bali, highlighting both its advantages and limitations in this specific context. The study aims to provide a clearer justification for the adaptation and integration of BIM in regions with unique local challenges, thereby extending the scope of current research on BIM and risk management.

2.3. Risk Mitigation Using BIM Technology

Previous research has shown that BIM technology can significantly improve risk management in construction projects. With the ability to detect potential conflicts and problems early on, BIM allows for the development of more effective mitigation strategies (Eastman et al., 2011). In addition, BIM also allows the simulation of various project scenarios, which can be helpful in proactively identifying and managing risks.

Research by [21]suggests that BIM can improve communication between stakeholders, which is crucial in reducing project risk. For example, through BIM models, all stakeholders can see and understand the design in detail, thereby minimizing miscommunication and increasing transparency. Hillson (2002) also emphasizes the importance of communication in risk management, stating that effective communication can reduce uncertainty and increase trust between stakeholders.

2.4. Case Studies and Previous Research

Several case studies have shown the effectiveness of BIM in risk mitigation. For example, research by Hardin (2009) shows that projects that use BIM have experienced a significant decrease in the number of design changes and construction claims. Another study by [22], [23] found that BIM helps in identifying and managing risks related to project schedules, thereby reducing delays and improving budget adherence.

In addition, [19], [24] in their research on D&B projects in Bali found that the use of BIM can help manage risks associated with changing local conditions and regulations. They concluded that BIM can improve risk management efficiency through early detection of potential problems and improved coordination between stakeholders.

3. Research Methods

This study uses a mixed methods approach that combines qualitative and quantitative analysis to obtain a comprehensive understanding of the application of BIM technology in risk mitigation in Design and Build projects in Bali. This approach allows researchers to collect and analyze data in depth and breadth so that it can identify factors that affect the effectiveness of BIM and develop appropriate risk mitigation strategies. The choice of a mixed-methods approach is particularly suited to this study's aim of addressing the unique challenges in Bali's construction projects, where both contextual understanding (qualitative) and empirical validation (quantitative) are crucial. By integrating surveys, in-depth interviews, and document analysis, the study captures a holistic view of stakeholder perspectives and real-world applications of BIM, ensuring robust and replicable findings. The combination of methods allows for triangulation, which strengthens the validity of the results and provides a more nuanced understanding of how BIM can be effectively applied in a regional context with distinct regulatory and environmental challenges.

The data for this study was collected through several methods, namely surveys, in-depth interviews, and analysis of project documents. Each of these methods has specific data collection goals and techniques. First, the survey was conducted to collect quantitative data on the views and experiences of project stakeholders on the use of BIM technology in risk mitigation. The sample taken includes project owners, contractors, and consultants involved in Design and Build projects in Bali. The questionnaire is designed to measure various aspects of BIM use, including adoption rates, perceived benefits, and challenges faced. These questionnaires are distributed via email and online survey platforms such as Google Forms or SurveyMonkey.

Second, in-depth interviews are conducted to collect in-depth qualitative data on stakeholder perceptions, experiences, and opinions regarding the use of BIM for risk mitigation. The sample was selected by purposive sampling based on their involvement in the D&B project in Bali. Interviews are conducted face-to-face or through online communication platforms such as Zoom or Microsoft Teams, using a semi-structured interview guide that includes open-ended questions about the experience of using BIM, the types of risks faced, and mitigation strategies implemented.

Third, the analysis of project documents is carried out to identify and evaluate the application of BIM in a real context. The documents analyzed include risk management plans, project progress reports, and relevant BIM models. These documents are collected from construction companies, project owners, and consultants who are willing to share data.

The data collected through surveys, in-depth interviews, and analysis of project documents were analyzed using statistical methods and content analysis. Survey data were analyzed using descriptive and inferential statistical methods, using statistical software such as SPSS or R to process the data, including calculation of mean, median, standard deviation, and regression analysis. The goal is to identify patterns and relationships between variables related to the use of BIM and risk mitigation.

Meanwhile, interview data was analyzed using content analysis. Qualitative analysis software such as NVivo or Atlas.ti is used to code and categorize interview data. The purpose of this analysis is to identify emerging themes and patterns related to the use of BIM, the types of risks faced, and the mitigation strategies implemented.

To validate the research findings, data triangulation was carried out by combining data from various sources. This technique involves comparing and contrasting the results of quantitative and qualitative analysis to obtain a more comprehensive and valid picture.

4. Results and Discussion

The results of this study show that there are several main risks faced in the Design and Build project in Bali. These risks include design errors, non-compliance with specifications, and changes in local regulations. In addition, the study also identifies the dominant factors that affect this risk, namely the quality of communication between stakeholders, the availability of materials, and the technical capabilities of the contractor.

4.1. Major Risks in Design and Build Projects

1. Design Errors: Design errors are one of the most common risks in Design and Build projects. These errors can occur due to a lack of coordination between the designer and the contractor or due to incomplete or inaccurate information. Design errors can lead to project delays, increased costs, and decreased quality of the final result [20].

2. Specification Non-Conformity: Specification non-conformity occurs when the final result of the project does not conform to the approved specifications. This can be due to a variety of factors, including changes in the construction process, ambiguity in contract documents, or failures in quality control. Non-conformity of specifications can result in construction claims and conflicts between project stakeholders [23].
3. Changes in Local Regulations: Changes in local regulations are a significant risk in construction projects in Bali. Changing regulations can affect various aspects of a project, including design, construction, and licensing. This regulatory uncertainty can lead to project delays and increased costs [20], [25].
4. Quality Communication between Stakeholders: Effective communication between stakeholders is essential to reduce risk in Design and Build projects. The study found that poor communication quality can lead to design errors and non-conformity with specifications. BIM helps improve communication by providing a collaboration platform that allows all stakeholders to share information and coordinate effectively[26].
5. Material Availability: Material availability is an important factor that affects project risk. Material shortages or delivery delays can result in project delays and increased costs. This study found that the use of BIM can help manage material inventory and monitor material availability in real-time, thereby reducing risks associated with materials [19], [27].
6. Contractor's Technical Ability: The contractor's technical ability has a significant effect on project risk. Contractors who are less experienced or do not have the necessary skills can lead to errors in construction and non-conformity with specifications. BIM can help reduce this risk by providing clear and detailed information about the project, making it easier for contractors to carry out their duties [26], [28].

However, the implementation of BIM in Bali faces several limitations and challenges that impact its effectiveness in managing these risks. One significant challenge is the need for specialized training for local stakeholders, many of whom may lack familiarity with digital modeling tools and processes. Additionally, there is often resistance to adopting new technologies due to entrenched traditional construction practices and scepticism about the benefits of BIM. Furthermore, the limited availability of technological infrastructure in certain areas of Bali can constrain the use of advanced BIM features such as real-time data sharing and 3D visualization. These challenges need to be addressed to optimize BIM's potential in managing risks specific to the context of Bali.

4.2. Benefits of Using BIM in Risk Mitigation

The study found that the use of BIM has proven to be effective in improving communication and coordination between stakeholders. BIM provides a platform that allows all parties to collaborate in real-time, thereby increasing transparency and minimizing miscommunication. Additionally, BIM enables early detection of potential problems through features such as 3D visualization and scenario simulation, which helps in identifying and addressing risks before they become larger problems [26], [29].

A study by [20] shows that projects that use BIM have experienced a significant decrease in the number of design changes and construction claims. This research supports these findings, showing that BIM can reduce overall project risk by improving design quality and ensuring that project specifications are met appropriately.

In addition, the study also found that BIM helps in managing changes in local regulations. By using the BIM model, stakeholders can quickly adjust construction designs and plans to comply with the new regulations, reducing the risk of delays and claims related to regulations.

While the study demonstrates that BIM significantly improves risk management through enhanced communication and early detection of potential problems, the unique context of Bali presents certain barriers to its full implementation. Cultural considerations, such as the necessity to integrate traditional Balinese architectural elements, may complicate BIM modeling and require advanced software adaptations. Additionally, stakeholder resistance and infrastructural limitations highlight the need for a phased approach to technology adoption. Future research should focus on developing tailored training programs and creating partnerships to improve infrastructure support, ensuring that BIM can be effectively utilized in regions with unique local conditions

5. Conclusion

This study concludes that the application of Building Information Modeling (BIM) technology in Design and Build projects in Bali has proven to be effective in identifying and reducing the risks faced. By using BIM, various risks such as design errors, non-compliance with specifications, and changes in local regulations can be better managed. BIM provides a collaborative platform that improves communication and coordination between stakeholders, allowing for early detection of potential problems and the implementation of more effective mitigation strategies.

To enhance the practical application of BIM in similar contexts, it is recommended that stakeholders invest in tailored training programs to improve local expertise in BIM tools and practices. Moreover, fostering collaborative environments where stakeholders can share their experiences and challenges with BIM can help develop localized best practices. Future research should focus on developing specific BIM adaptation strategies that consider local regulatory, environmental, and cultural conditions. Additionally, exploring partnerships to build technological infrastructure in regions with limited access can support more widespread and effective use of BIM. Further studies could also investigate the long-term cost-benefit analysis of BIM implementation in contexts similar to Bali to better understand its potential impacts on project efficiency and risk management.

The use of BIM helps in identifying risks in the early stages of the project through 3D visualization and scenario simulation. This allows all stakeholders to clearly understand the project design and plan, reduce miscommunication, and increase transparency (Eastman et al., 2011). BIM also provides detailed and real-time information, which is very helpful in managing material availability and ensuring project specifications are met [20].

The study found that the dominant factors influencing risk in Design and Build projects in Bali include the quality of communication between stakeholders, material availability, and the contractor's technical capabilities. BIM helps in improving the quality of communication and coordination between stakeholders, monitoring material availability, and providing the necessary information to improve the contractor's technical capabilities (Succar, 2009).

With risk mitigation strategies developed using BIM, projects in Bali can be more efficient and successful. The use of BIM has been shown to reduce the number of design changes and construction claims, as well as improve compliance with local regulations. This shows that BIM not only helps in risk management but also improves the overall efficiency of the project.

This research makes an important contribution to the development of risk management theory in the context of construction, especially in the application of BIM technology. This research adds to the literature on the effectiveness of BIM in risk mitigation and offers a new approach to the risk management of Design and Build projects, adapted to the local conditions of Bali. These findings can be a reference for the implementation of BIM in other regions with similar conditions, as well as provide valuable insights for construction project stakeholders in Bali.

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