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Development of mobile-based risk management application for construction companies: an extreme programming approach

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ABSTRACT

This research addresses the complexity and dynamics of risks in construction projects by developing a mobile-based risk management application with Extreme Programming (XP) approach. Critical issues in the construction industry involve high uncertainty, changing project conditions, and the need for adaptive risk management. The research method is structured in three stages, starting with Data Collection through literature studies, surveys, and expert interviews. The second stage involves Application Development with the application of XP, focusing on mobile device integration and continuous iteration. The final stage was User Acceptance Analysis to evaluate user response to the developed application. The results showed that the application effectively identified, assessed, and planned risk mitigation. Features like real-time monitoring, reporting, and analytics provide accurate information for quick decision-making. Although some areas have potential for further development, the User Acceptance Analysis gives an overall positive picture with scores above 80 on each feature. This research contributes to developing an application that can improve the responsiveness, flexibility, and quality of construction project risk management. Integrating mobile technology and the XP approach shows relevance and potential to be applied in the construction industry, hoping to provide practical solutions to unpredictable risk dynamics.

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INTRODUCTION

The construction industry plays a crucial role in development, a key pillar for a country's economic growth and infrastructure. Construction projects, which involve the construction of buildings, roads, bridges, and other critical infrastructure, not only create jobs but also significantly impact society's progress. Despite its highly positive role, the construction industry faces significant complexities and risk dynamics. These risks, including changing weather conditions, material delivery delays, and safety concerns, require effective risk management to ensure smooth and successful projects(Altaf et al., 2022; Brodskiy, 2022; Khodabakhshian & Re Cecconi, 2022; Serpell & Rubio, 2023; Tessema et al., 2022).

The challenges in construction risk management are further complicated due to the uncertainties inherent in the construction environment. External factors such as changes in government policies or fluctuations in building material prices can significantly impact

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project risk dynamics. In addition, changes in project conditions, such as delays or changes in specifications, can negatively impact the sustainability of construction projects(Boateng et al., 2022; Khodabakhshian & Re Cecconi, 2022; Shojaeimehr & Rahmani, 2022). Construction projects are often faced with high complexity and unpredictable risk dynamics. Various factors, such as changing weather conditions, fluctuating building material prices, and logistical issues, can significantly impact the course of the project. These complexities are not only related to the technicalities of the project but also involve aspects such as regulations, government policies, and design changes. Therefore, risk management in construction projects must be able to anticipate and respond to fast-changing dynamics to mitigate potential negative impacts(Divya Sankar & Selvam, 2020; Fabbri, 2019; Hatta et al., 2022; Wahyuningrum et al., 2021).

Construction risk management is becoming a significant challenge, requiring a holistic and adaptive approach. Proper risk identification, accurate risk assessment, and effective risk management are crucial in meeting this challenge. A key challenge lies in coordinating project teams to respond quickly to changing risks, ensuring that appropriate mitigation measures are taken according to the complexity of the ongoing construction project. The construction environment is often filled with uncertainty. External factors, such as regulatory changes or unstable economic conditions, can significantly impact construction projects. This uncertainty requires proactive risk management and responding quickly to unexpected changes. Focusing on a deep understanding of the construction environment is critical in dealing with this uncertainty.

Changes in project conditions, both technical and non-technical, can have a significant impact on the sustainability of a construction project. Delays, design changes, or other issues can affect the project schedule and budget, potentially harming the relevant stakeholders. Therefore, risk management should focus on early detection and mitigation of changes in project conditions so that project sustainability can be maintained without compromising project quality and deliverables. Currently available risk management applications may need help addressing construction project risk dynamics. Therefore, the relevance of developing mobile-based risk management applications is becoming increasingly important(Akhtar et al., n.d.; Al-Saqqa et al., 2020; Batliner et al., 2022; Dingsoeyr et al., 2019; Mishra & Alzoubi, 2023; Sarhadi et al., 2022; Senabre Hidalgo, n.d.; Serrador & Pinto, 2015; Wiechmann et al., 2022). These applications offer mobility, enabling real-time information access in the field and accelerating response to changing risks. Integrating the application with mobile devices as a standard work tool is increasingly becoming necessary, enabling project teams to collaborate more efficiently and effectively in managing construction project risks. Using an Extreme Programming approach in the application development is expected to improve the resulting software's responsiveness, flexibility, and quality, explicitly addressing the complex challenges in construction project risk management.

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METHODS

The research was structured in three main complementary phases, starting with the Data Collection phase. This phase includes essential steps such as a literature review to understand the theories and research related to construction risk management, an initial survey to identify needs, and expert interviews to gain practical perspectives. The initial data from this phase became the foundation for the mobile-based application development plan, the second phase of the research. This plan included applying Extreme Programming (XP) methods to enable iterative prototype development and continuous functionality testing. Integration with mobile devices was also a focus, ensuring affordability and optimal performance in the mobile environment. Finally, the research involved User Acceptance Analysis as the final stage. This involved drafting questionnaires, surveying potential users, and analyzing the data to evaluate the extent to which the application met the expectations and needs of users. This entire set of activities is designed to deliver comprehensive research results, detailing requirements through user acceptance evaluation in a systematic and targeted method.

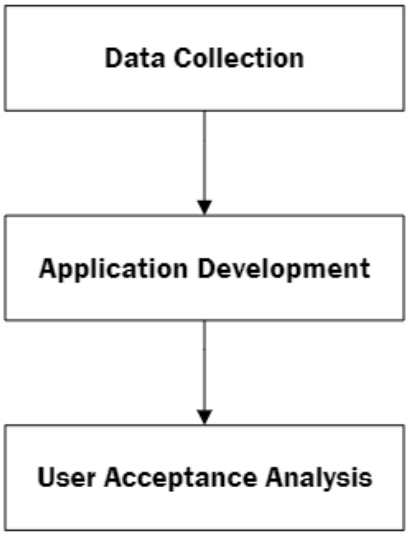

Figure 1. Research Methods

Data Collection

Data Collection, starting with an in-depth literature study to understand the theories and research related to construction risk management, was followed by drafting an initial survey and expert interviews. This step aimed to identify critical needs and challenges in construction risk management, forming an essential basis for the research journey.

Application Development

Application Development involves planning the development of mobile-based applications. This plan includes implementing Extreme Programming (XP) methods to ensure iterative and responsive development, continuous functionality testing, and

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seamless integration with mobile devices. These activities form the foundation for effective app development that meets the needs identified in the previous stage.

User Acceptance Analysis

User Acceptance Analysis evaluates user response and acceptance of the developed application. It begins by drafting a questionnaire to measure user perceptions, followed by data collection through surveys. The results are then analyzed in depth to evaluate the success rate of the application in meeting users' expectations and needs. This stage provides essential insights into the effectiveness of mobile-based applications and potential improvements in construction risk management. As such, this entire series of stages formed a structured approach to this research, incorporating a comprehensive methodology and analysis.

RESULTS AND DISCUSSION

Data Collection

An in-depth literature study was the first step in data collection for this research. This phase involved exploring scientific sources, journal articles, books, and research related to construction risk management. In previous construction projects, the researcher explored vital concepts such as risk identification, risk assessment, and mitigation strategies. By detailing the frameworks and approaches related to risk management, this research aims to understand the theoretical foundation that can guide the development of the application.

After the literature study, the next step was preparing an initial survey. The survey was designed to understand the concrete needs and challenges construction companies face in managing their project risks. The survey questions covered various aspects, such as the types of risks most commonly encountered, the effectiveness of the current risk management tools, and expectations for better solutions.

Expert interviews were a crucial step in gaining first-hand perspectives from practitioners and experts in the construction industry. In these interviews, researchers interacted with project managers, construction engineers, or risk experts to gain in-depth insights into their experiences, barriers, and views toward developing risk management applications. The interview results provide a human and practical dimension that can further guide this research.

Table 1. Data Collection Results

Stages	Result
Literature Study	The literature review identified critical concepts in construction risk management, including risk identification, risk assessment, and mitigation strategies. This theoretical foundation will guide the development of the application.
Initial survey	The initial survey included responses from 50 respondents from various construction companies. The data showed that risks related to project delays and fluctuations in the cost of building materials were

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Stages	Result
	identified as critical challenges. In addition, most respondents expressed the need for more effective risk management tools.
Interview	Interviews with project managers and construction engineers yielded an in-depth understanding of their experiences in managing project risks. They highlighted the complexity of risk dynamics and the desire for more responsive and easy-to-use solutions.

The overall outcome of the data collection, Table 1, provides an in-depth understanding of the field conditions, emerging needs, and challenges to be overcome in developing a risk management application for construction companies. This data forms a critical basis that will guide the next steps in this research journey, ensuring that the solution developed genuinely responds to the needs and context of the construction industry.

Application Development

An in-depth plan is conducted in the Application Development stage to direct the mobile-based application development process. This plan involved identifying the key features and functionality required based on the needs identified in the previous stage. In addition, the Extreme Programming (XP) method was chosen as the primary development framework to ensure an iterative, responsive, and collaborative approach.

Figure 2 illustrates the workflow for developing a risk management application for a construction company using the Extreme Programming (XP) approach. The process starts with risk identification and assessment, followed by mitigation strategy planning if the risk is deemed acceptable. Risk management is integrated with project management and continued with XP implementation for application development. Real-time monitoring and reporting are used to ensure application responsiveness to project changes. Team collaboration was implemented, and if necessary, application modifications were made with the development team's involvement. Notification, alerting, security, and access control features were implemented to ensure effective communication and information security. Finally, an audit trail is implemented for transparency and a track record of activities. This diagram reflects a structured and responsive development approach, combining risk management and XP practices for an adaptive application in a construction environment.

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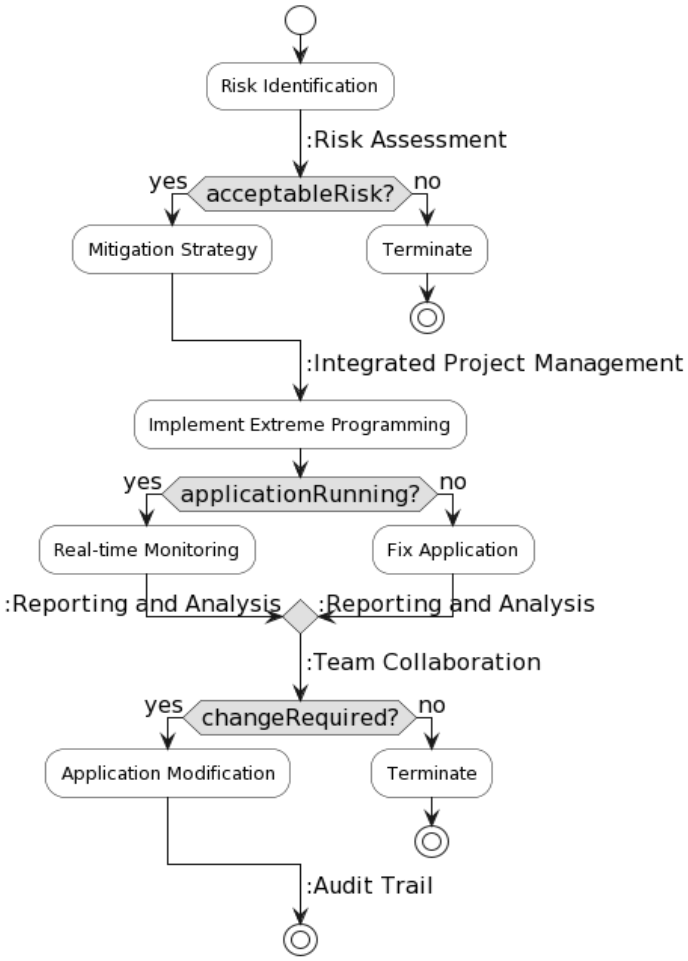

Figure 2. Activity Diagram

The entity-relationship model in Figure 3 reflects the data structure for developing the construction risk management application. The entity "Project" represents a construction project with linkages to the entity "Risk," indicating that a single project can have multiple risks. The entity "Risk" represents risks, which can have many mitigation strategies reflected through the entity "Mitigation." In addition, the model involves a "TeamMember" with a relationship with the project, showing how team members play a role in a construction project. These relationships provide a coherent structure and support risk management from identification and mitigation to implementation in construction projects. Attributes and relationships can be customized according to the specific needs of the risk management application.

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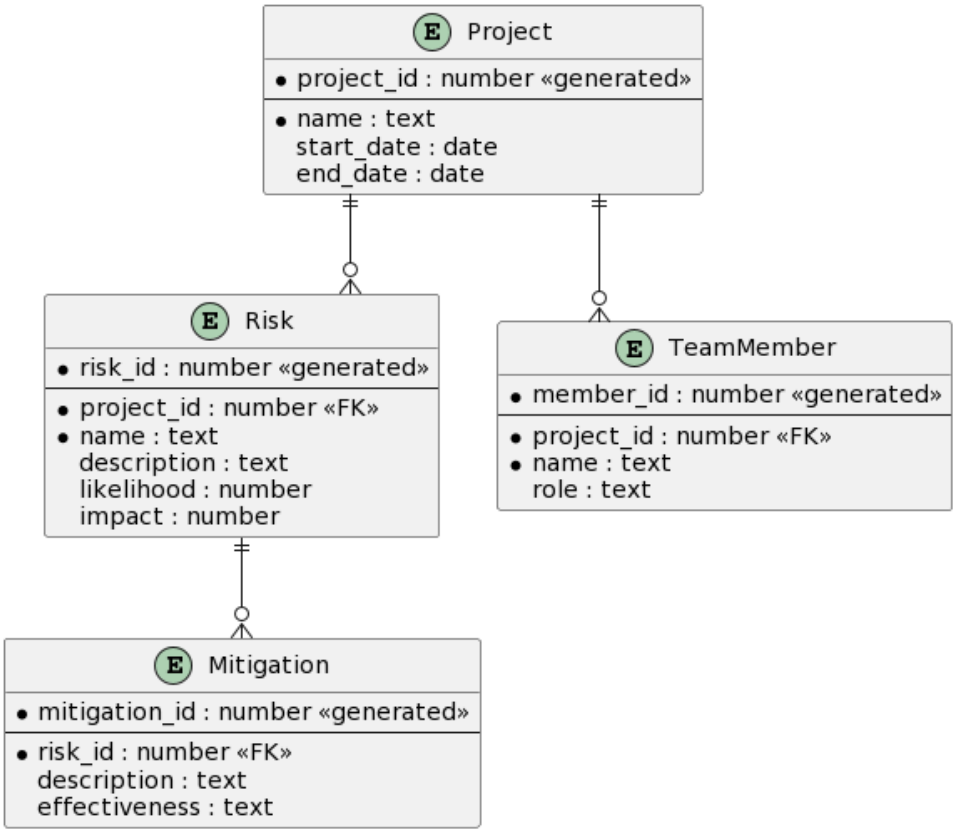

Figure 3. ER-Diagram

The implementation of the XP method is the main focus in this phase. The development team works collaboratively with users and stakeholders to produce prototype applications that can be tested and evaluated quickly. Continuous iteration allows for ongoing adjustments based on feedback so that the application can better meet evolving needs. The Risk Management application developed using the Extreme Programming (XP) approach offers a comprehensive set of features, Table 2, to support construction companies in managing project risks. The risk identification and risk assessment features allow users to systematically identify, assess, and plan risk mitigation. Integrated mitigation strategies and unified project management provide users with complete visibility of the relationship between risks and the course of the project. Real-time monitoring provides up-to-date information for quick decision-making, while robust reporting and analytics facilitate an in-depth understanding of risk status. Team collaboration, notifications and alerts, and security and access control add crucial collaborative and security dimensions. With these features, the app provides a solid framework for risk management and improves the efficiency, transparency, and responsiveness of project teams per XP principles.

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Table 2. Application Features

Stages	Results
Risk Identification	It enables users to identify and document different risks that may arise during a construction project.
Risk Assessment	Provides a tool to assess the level of impact and probability of each identified risk, assisting in prioritizing and focusing on mitigation.
Mitigation Strategy	Enables users to plan and implement effective mitigation strategies to reduce the impact and probability of risks.
Integrated Project Management	Integration with project management features that allow users to manage risks alongside project schedules and resource allocation.
Real-Team Monitoring	Integration with project management features allows users to manage risks, project schedules, and resource allocation.
Reporting and Analysis	Provide personalized reporting features and risk data analysis to support informational decision-making.
Notifications and Alerts	Automatically sends notifications and alerts to project teams when there are changes in risk status or mitigation actions required.
Audit Trail	Automatically notify and alert project teams when there is a change in risk status, or mitigation actions are required.

Functionality tests are conducted on an ongoing basis throughout the development process. It aims to ensure that every feature and function works as expected and identify and fix potential problems immediately. These tests involve developers and end-users to ensure the user perspective is directly accommodated.

Integration with mobile devices is another focus. The application is designed to run seamlessly on various mobile devices, ensuring users can access it easily in the field. Compatibility with various operating systems and devices was a significant concern in this endeavor.

As such, the Application Development stage focuses on technical aspects and prioritizes intensive interaction with users and stakeholders. Overall, the outcome of this stage is a solid foundation for a practical and responsive application, in line with the needs identified at earlier stages in this research journey.

User Acceptance Analysis

The User Acceptance Analysis stage is a critical step in evaluating user response and acceptance of the developed Risk Management application. To understand user perception, a questionnaire was carefully designed to measure various aspects, including user interface, usability, and user satisfaction. A survey involving a number of respondents from

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potential users was then conducted to collect significant data regarding their experiences and views on the application.

The results of these surveys formed the main basis for the in-depth analyses conducted to evaluate the success rate of the app in meeting user expectations and needs. The data collected was analysed holistically, taking into account general trends, positive responses, as well as areas that required improvement. The evaluation covered aspects such as the app's usability, clarity of features, and ease of navigation, thus providing a deep insight into the factors that influence user acceptance.

Table 2. Application Feature Testing Results

Stages	Scenario	Results
Risk Identification	Ensure that users can effectively identify and document project risks.	Successful
Risk Assessment	Verify the accuracy of risk impact and probability level assessments based on inputted data.	Success
Mitigation Strategy	Ensure that users can effectively plan and implement mitigation strategies.	Success
Integrated Project Management	Verify the application's integration with integrated project management, including schedule and resource allocation.	Success
Real-Team Monitoring	Assess the speed and accuracy of real-time monitoring of risk status and mitigation strategies.	Success
Reporting and Analysis	Test personalized reporting functionality and risk data analysis capabilities.	Success
Notifications and Alerts	Verify that notifications and alerts are provided accurately and timely to users.	Success
Audit Trail	I tested the application's ability to record and store user activity logs as an audit trail.	Success

From the table's analysis of user satisfaction scores, the Risk Management for Construction Companies app received an overall positive response. The risk identification feature, with an average score of 84.0, demonstrated the effectiveness of the app interface in making it easy for users to identify project risks. The risk assessment, with an average score of 80.0, indicates that users are satisfied with the accuracy of the risk assessment provided by the app. With an average score of 86.0, mitigation strategies received high ratings, signaling that this feature helps users plan and implement mitigation strategies effectively. While receiving a positive response with an average score of 82.0, integration with project management has the potential for further development according to some users' expectations. Real-time monitoring, reporting, and analysis also received high ratings, with scores of 88.0, 84.0, and 84.0, respectively, signaling that these features add

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value in providing accurate information and analysis. With an average score of 80.0, team collaboration features received positive ratings, although some users wanted additional features to improve team interaction. Users rated Notifications, alerts, and security and access control, with an average score of 86.0 and 88.0, respectively, highly, providing a sense of security and timely alerts.

While the audit trail scored an average of 82.0 and was considered quite transparent, some users wanted more details in the activity log. Overall, scores above 80 on each feature signaled the app's success in meeting or exceeding user expectations. A 0-100 scale provides a more quantitative picture, provides a basis for continuous improvement and development, and confirms that the app adds significant value to construction risk management. The User Acceptance Analysis stage insights become important guidelines for further development. This analysis provides an overview of the extent to which the app has successfully met user expectations and identifies opportunities for improvement and further development. As such, this stage is not only the conclusion of a study but also the starting point for further iteration and development to ensure that the application is genuinely relevant and well-received by users in construction risk management.

CONCLUSION

Developing a mobile-based risk management application using the Extreme Programming (XP) approach can effectively address the complexity and dynamics of risks in construction projects. As the central pillar of economic growth, the construction industry requires proactive and responsive risk management to overcome challenges such as changing weather conditions, material delivery delays, and safety issues. The research stages, from Data Collection with literature studies, surveys, and expert interviews to Application Development with the application of XP, demonstrate a holistic and adaptive approach. The User Acceptance Analysis results painted an overall positive picture, with high scores on critical features such as risk identification, risk assessment, mitigation strategies, real-time monitoring, reporting, analytics, notifications, and security. Integration with mobile devices, focus on user needs, and continuous iteration through XP were critical to the app's success. While some areas have the potential for further development, scores above 80 on each feature signaled that the app could add significant value in the context of construction risk management. This research provides a strong foundation for implementing similar apps in the construction industry, improving project risk management's responsiveness, flexibility, and quality. In addition, this research highlights the importance of integrating mobile technology and XP approaches in addressing the challenges of complexity and risk dynamics in construction projects. It provides a basis for future development and continuous improvement.

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