

PAPER

Development of a Mobile Application Integrated with Building Information Modeling for Real-Time Construction Project Monitoring

Kasmaruddin Che Hussin¹,
Anas A. Salameh²(✉),
Mohd Nasrun Mohd
Nawi^{1,3}, Mohamad Amin
Khadimalah²

¹Universiti Malaysia Kelantan,
Kelantan, Malaysia

²Prince Sattam Bin Abdulaziz
University, Al-Kharj,
Saudi Arabia

³Universiti Utara Malaysia,
Kedah, Malaysia

a.salameh@psau.edu.sa

ABSTRACT

The construction sector contributes significantly to the economic growth and development of all other economic sectors and industries in any country. To achieve the economic sustainability of construction projects, it is important to assess their current and future costs. Monitoring construction projects enables the timely completion of projects, quality assurance, cost-effectiveness, and effective communication with stakeholders involved in the project. The conventional ways of monitoring projects are usually based on data collection done manually and reporting done on paper. This may lead to delays and mistakes, as well as the impossibility of obtaining up-to-date information. In this study project, it is proposed to create an application that would be based on building information modeling (BIM) that would solve the problem of monitoring construction projects. With this application, engineers, site managers, and supervisors would have the opportunity to access and edit the necessary information in a real-time way. With the combination of mobile technology and BIM, users are able to view building models, keep track of construction progress, communicate about site problems, monitor what has been done, and manage data instantly. The app provides smooth information exchange between operating staff at the construction site and the project management back office. Research is focused on developing, testing and assessing the application. The evaluation of the effectiveness of the system is based on usability, accuracy, accessibility, and the impact it has on the efficiency of project monitoring. The results will show how BIM-based mobile applications enhance the construction monitoring process by delivering data in real-time, facilitating cooperation, reducing mistakes, and helping to conduct effective project management during the whole process of construction.

KEYWORDS

building information modeling (BIM), mobile application, construction monitoring, real-time project management, digital construction, site progress tracking

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1 INTRODUCTION

A construction project encompasses many players, including the client, architect, general contractor, sub-contractors, suppliers of materials [1], machinery producers, and others. To implement each construction project, an organization is formed, but its existence is temporary, creating a high degree of uncertainty in the environment in which the construction works are carried out. If the site manager does not keep track of the changes going on around him/her [2], the project is bound to miss both the deadlines and the budget. As a result, effective progress monitoring is a vital aspect in the governance of construction projects, providing the ground for proper management and decision-making.

Nevertheless, the techniques employed in typical construction sites for progress monitoring are usually ineffective and require significant time for data collection and analysis. Due to the necessity of carrying out voluminous manual operations [3], the method is difficult in terms of labor. The disadvantage of the above approach has been named one of the key issues of project delay and exceeding costs. Typically, management methods are affected by the following problems: low monitoring frequency [4], poor efficiency of reporting methods, poor quality of data collected manually. Yet for years' management has relied on conventional methods and tools until the advent of building information modeling (BIM) technology which created a paradigm shift in how projects are planned, conceived, implemented, and maintained [5].

Building information modeling is a modeling system innovative in architecture, consisting of various relevant data connected to construction projects. BIM simulates and integrates real information about buildings with the use of digital technologies and provides information throughout the whole life cycle of project planning, design, construction, operation and maintenance, thus helping to boost productivity [6], cut expenses, and reduce time needed for construction. Smart construction, which is based on BIM technology and collaborative platforms, employs a holistic informatization approach that utilizes BIM technology to enhance the management and control capabilities of man, machinery [7], materials, methods, and environment during construction. This technology provides an opportunity for reliable data collection, allowing for an effective accumulation of knowledge and information. Ultimately, the integration of virtual construction and physical construction processes is accomplished through platform-based tools, making it possible to conduct data analysis and provide choices for decision-making in construction. Based on the features of smart construction [8], the automation system that is based on the BIM technology and collaborative platform provides for the sharing of model data. Data management takes place centrally, which ensures its consistency and relevance.

With this application [9], engineers, site managers, and supervisors would have the opportunity to access and edit the necessary information in a real-time way. With the combination of mobile technology and BIM, users are able to view building models, keep track of construction progress, communicate about site problems, monitor what has been done, and manage data instantly. The app provides smooth information exchange between operating staff at the construction site and the project management back office [10]. Research is focused on developing, testing and assessing the application. The evaluation of the effectiveness of the system is based on usability, accuracy, accessibility, and the impact it has on the efficiency of project monitoring.

2 LITERATURE REVIEW

Liang and Liu [11] use of BIM technology together with Internet of things technology has made it possible to conduct analysis of safety risk warning system in underground engineering construction. Initially, both the concept and application of BIM technology and safety risk warning system in underground engineering construction are described. Further, the chapter elaborated on safety issues in underground construction, and provides detailed information on the operation mechanisms of underground construction safety indicator system, the process of establishment of the system and safety risk indicator system, and formation of safety risk warning and control system for underground construction based on BIM technology together with Internet of things technology. Lastly, the functioning mode and real-time monitoring of underground engineering early warning using BIM technology coupled with the Internet of things are explained. The findings indicate that the underground engineering forecast system based on BIM technology along with the Internet of things follows a working mode that integrates circular safety risk alert wheel mode with three-dimensional safety risk alert mode. Furthermore, real-time dynamic monitoring of security risk alert system can be accomplished with the help of the periodic recording and monitoring of process indicators by the BIM management platform. It is expected that this study would assist in creating an efficient management tool for safety during underground construction and minimizing safety accidents in underground construction.

Rane et al. [12] introduces a new framework that unites BIM with models such as ChatGPT and Bard. The integrated technique presented in this piece has significant and huge consequences. Firstly, it considers the improvement of the process of design, when generative AI is responsible for getting additional creative input from designers and engineers generated through BIM data. The collaboration spirit of BIM is furthered through natural language systems offered by ChatGPT, contributing to smooth communication and sharing of ideas among the parties involved in the project. In the construction phase, this integration provides real-time decision-making for workers, supplying them with AI-based insight gained from BIM data. The combination of BIM and generative AI is also applied in simulation and analysis, allowing forecasts of a building's performance characteristics, energy efficiency, and environmental consequences. The study proposes a novel architecture that successfully integrates BIM and generative AI technologies with an emphasis on interoperability, consistency of data and user-oriented interfaces. The architecture is meant to respond to the character of real conditions typical to AEC projects thus providing a basis for collaboration and communication between stakeholders at any stage of a project. However, the process of integration also includes certain drawbacks, such as the need for measures for securing data, ethical issues, as well as high calculation capabilities and resources needed for this. The study gives a base for the future researches.

Kanangkaew et al. [13] have developed an application prototype that merges BIM in conjunction with augmented reality (AR) technology with the aim of enhancing an evacuation procedure in case of fire and providing the ability to have up-to-date information regarding the evacuation process. A marker-based localization system was created, meaning that physical information is linked to spatial coordinates via the marker. The system was evaluated for its exactitude, together with the conceived system and MATAALL Laser Distance Meter on the fourth floor of the Department of Civil Engineering at Chulalongkorn University. The findings revealed that the mean percentage difference of the present place in comparison to the exit determined by

this system was less than the value indicated by MATAALL Laser Distance Meter as the mean percentage difference was under 2.2%. Therefore, it was concluded that the proposed system works properly, which makes it possible to gain access to current information in real-time as far as the current position, exit and length of the shortest path from the starting location to the destination together with virtual green path and audio-visual direction that facilitate the evacuation process are concerned.

Choi et al. [14] The study investigates how drones can be included in the digital construction site management process with the goal of creating BIM models that can recognize objects more easily. Initially, the research was looking to achieve photorealistic model generation of point cloud models (PCM) by applying blur/sharpen filters and GAN (generative adversarial network) models. However, the results did not satisfy expectations in terms of photorealistic model generation. Subsequently, the study began exploring other options, such as fine-tuning object recognition algorithms using real-world datasets, in order to enhance the effectiveness of object recognition process. The outcome of the research provides a delicate knowledge of the difficulties and opportunities for accomplishing photorealistic rendering in the PCM process, emphasizing the difficulty of the process and preparing the ground for relevant advances in this area in the future. While the results of the research faced difficulties in achieving the initial aim of photorealistic rendering for identification of an object, they provide useful information for subsequent researchers and technology creators in digital construction site management.

3 PROPOSED METHODOLOGY

The methodology adopted in this investigation involved the use of research and development (R&D) in order to create a mobile app with a BIM system for the purpose of monitoring a construction project in real-time. In general, the study aimed to design an app that would allow engineers, supervisors, and managers to track construction progress and work with BIM data directly from the construction site. In this study, a systematic process was implemented in the development stage beginning with the establishment of procedures for project monitoring through reviewing construction processes and BIM-assisted practices. The system was conceived, created, and configured based on requirements identified in the review to provide visualization of building models as well as tracking progress, reporting issues, and making communication between the employees at the sites and the headquarters possible as shown in Figure 1.

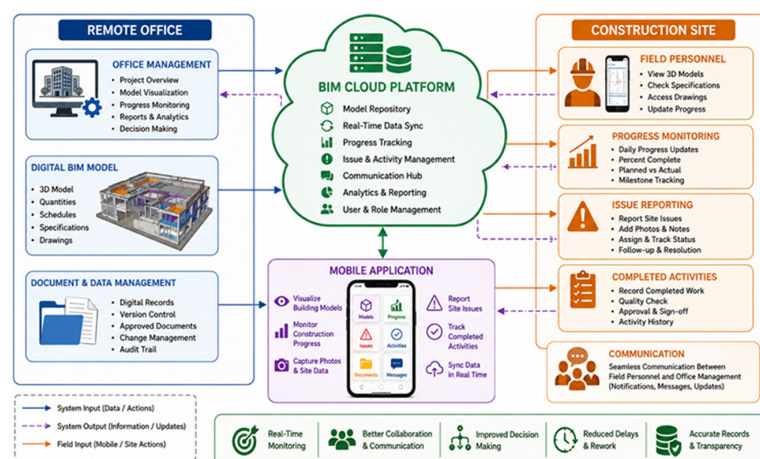


Fig. 1. Workflow of the proposed model

3.1 Planning phase

The goals, extent, functions and requirements of the mobile application have been determined. It was established what functions the mobile application should perform, such as visualization of the BIM model, monitoring of the project development, reports on issues arising during the project implementation, tracking of activities performed, and user management.

3.2 Requirements analysis

Functional and non-functional requirements had been gathered in order to find out the capabilities and performance expected from the system. These requirements became the basis for designing the application architecture and user interface.

3.3 System design

The design of system architecture, the structure of database, the application workflow as well as user interface took place. UML diagrams and database models were created in order to present system processes and interactions between users and the BIM platform.

3.4 Development phase

The mobile app, back-end services, and database were created utilizing chosen programming languages and development frameworks. The BIM integration was designed to allow visualization of three-dimensional building models and to facilitate the exchange of project information between the mobile application and the server.

3.5 Integration phase

Individual system components—including the mobile application, BIM services, backend server, and database—were integrated to ensure seamless communication and real-time data exchange.

3.6 Deployment

The completed application was deployed within the intended environment, allowing authorized users to access project information through mobile devices connected to the central database.

3.7 Information exchange and authority management of BIM technology

By understanding the internal and external environment, having connections all over the world and engaging in information processing, learning and

taking rational decisions one can achieve a better system of technology regarding construction:

$$p_{1i} = \sum_{i=1}^n \frac{q_{1i}}{r_{1i}} = \sum_{i=1}^n \frac{s_{1i} - k_{1i}}{a_{1i} - e_{1i}} \quad (1)$$

In p_{1i} , there is efficient and comprehensive use of space; in q_{1i} , there is the safety management module; in r_{1i} , there is the cost management module; in s_{1i} , the application layer corresponding to safety management, which includes drawing data and preparation of special plans.

By using BIM visualization features, the automation system ensures that construction organization, hazard identification, safety protection, safety hazard tracking [15], special planning, technical disclosure, etc., are carried out, thus achieving clear and effective information transmission by management to operations layer:

$$t_{1i} = u_{1i} - \frac{v_{1i}}{w_{1i}} - (d_{1i} - q_{1i})^2 \quad (2)$$

In the equation, t_{1i} stands for emergency escape drill management; u_{1i} means building site safety supervision; v_{1i} is safety technology-report; w_{1i} is safety space management with respect to changing management

The necessity of data use security involves the implementation of a reliable data security management system and a data security regulatory system; data security management organization creation also involves an approach of thorough data security control process and decision from upper level to be made according to the following:

$$y_{1i} = \frac{x_{1i} - z_{1i}}{a_{2i}} - \frac{q_{1i} - u_{1i}}{t_{1i}} \quad (3)$$

In this equation, x_{1i} refers to key factors influencing the protection of smart industry data; y_{1i} denotes the process of storing, processing and transferring data; z_{1i} represents transfer of monitoring data; and a_{2i} describes the operational nature of data dynamics.

The BIM technology and collaborative platform elaborates on the technical avenues of intelligent construction in surveying and design, engineering construction, and construction management. It clarifies such technologies as the combination of BIM with IoT (Internet of Things), and integrated designing. Security of data storage includes physical security, security of the system, and security of stored data. Data storage security is mainly provided by purchasing appropriate hardware; whereas data transmission security entails both data encryption and network control.

A model of the data of construction enterprises represents models of the financial sector and the telecommunications sector, as well as the applicability of the sphere of construction and construction enterprises; moreover, it makes use of an industry-oriented method of designing. The model consists of actors, contracts, engineering, project management processes, project resources, planning and budgeting, and accounting and financing, along with benchmark and reference classifiers. The collaboration platform is an addition and upgraded version of the business data model and a solution for the implementation of the business data integration and business collaboration process.

4 EXPERIMENTAL RESULTS

An experimental investigation has been performed to discover how well the mobile application integrates with BIM technology and works in the conditions of simulated construction project monitoring scenarios. For this purpose, basic performance indicators (i.e., response times, efficiency of BIM loading process, data availability, service reliability, resource usage efficiency, time to accomplish tasks, degree of end-users satisfaction, and monitoring process effectiveness) were assessed. Graphs were utilized to present the data so that the performance of the system can be easily compared and understood. The results provide quantitative proof of the effectiveness of the application in monitoring construction projects in real-time. Overall, the experimental findings indicate that the system in this study can improve project management efficiency via mobile phone integration and BIM.

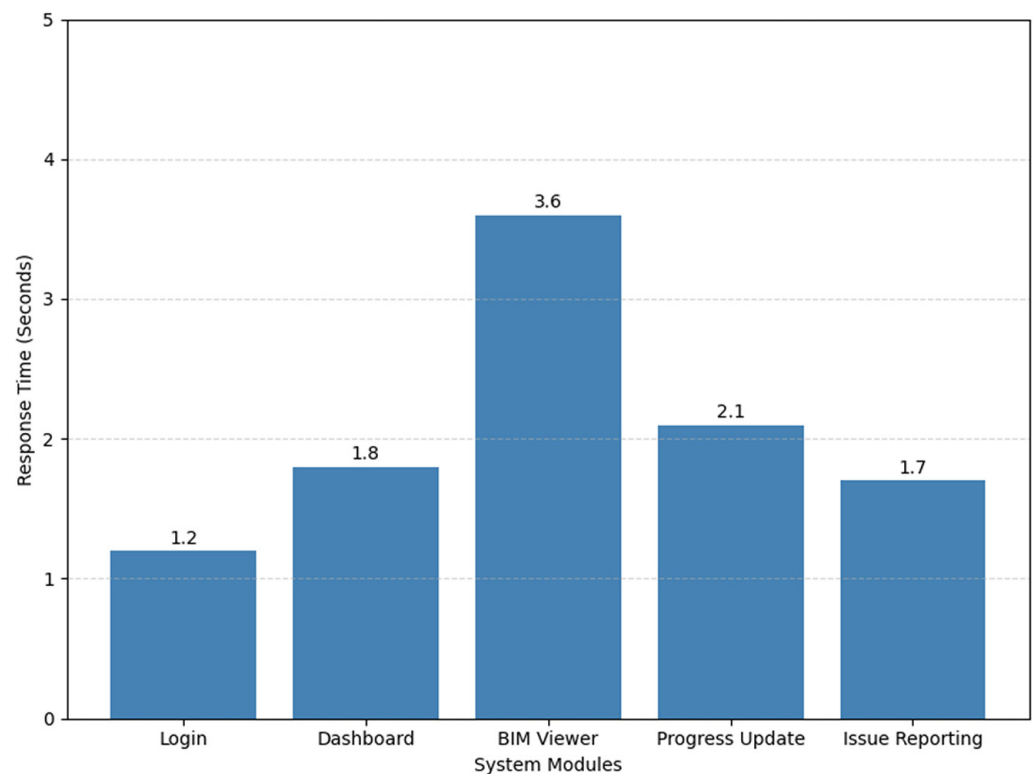


Fig. 2. Average response time of system modules

The average response times of the main modules of the BIM mobile application are shown in Figure 2. The login module showed the quickest response time of 1.2 seconds, while the BIM viewer encountered delays with a response time of 3.6 seconds as a result of 3D model processing. The dashboard, updates, and issue reporting modules had response rates lower than 2.5 seconds. In general, the application can successfully deliver responses needed for regular monitoring of the construction site.

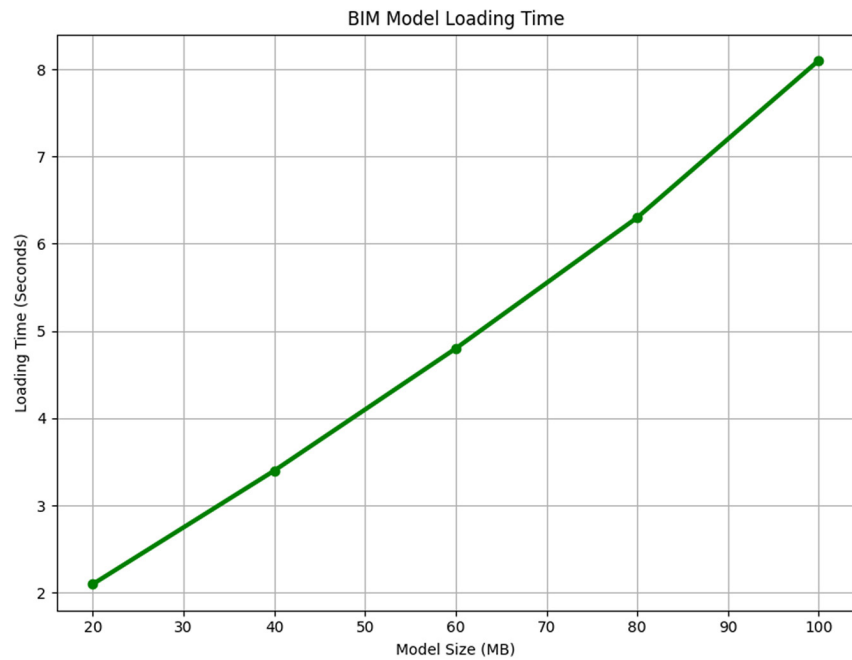


Fig. 3. BIM model loading time vs. model size

In Figure 3, the connection between BIM model size and loading times can be seen. Specifically, as the size of the BIM model grows from 20 MB to 100 MB, the time to load these models also grows, from 2.1 seconds to 8.1 seconds. This trend is logical due to the fact that higher sizes necessitate processing larger amounts of geometrical and metadata information before it can be visualized. However, despite growing loading times, these times have preserved their acceptability for use in the field.

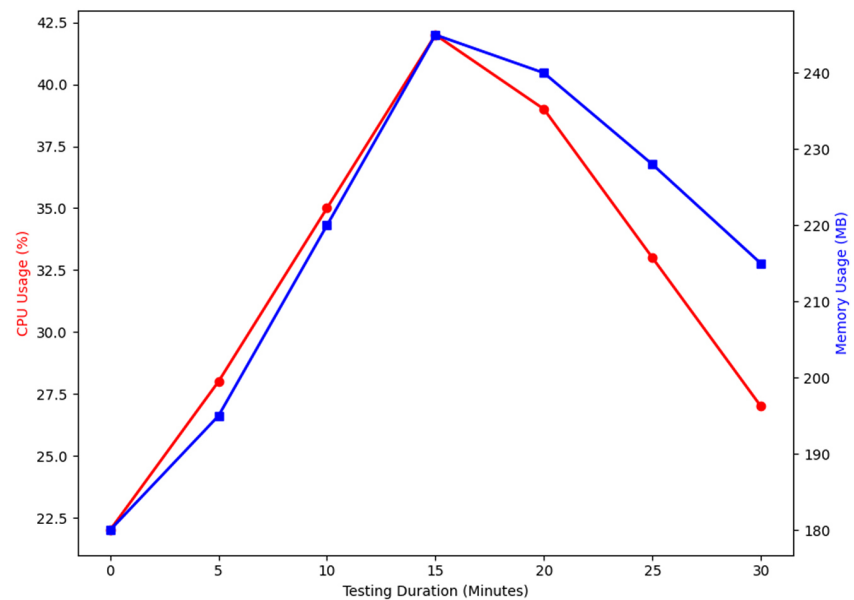


Fig. 4. Mobile resource utilization

The CPU and memory utilization of the mobile app for continuous operation is presented in Figure 4. The CPU utilization was between 22% and 42%, whereas the memory usage was in the range of 180 MB and 245 MB. There was an increase in resource utilization during BIM visualization and data synchronization, but it

reduced when the job was done. This shows that the application is able to control the resources properly and function efficiently on standard Android mobile devices without causing any strain on hardware devices.

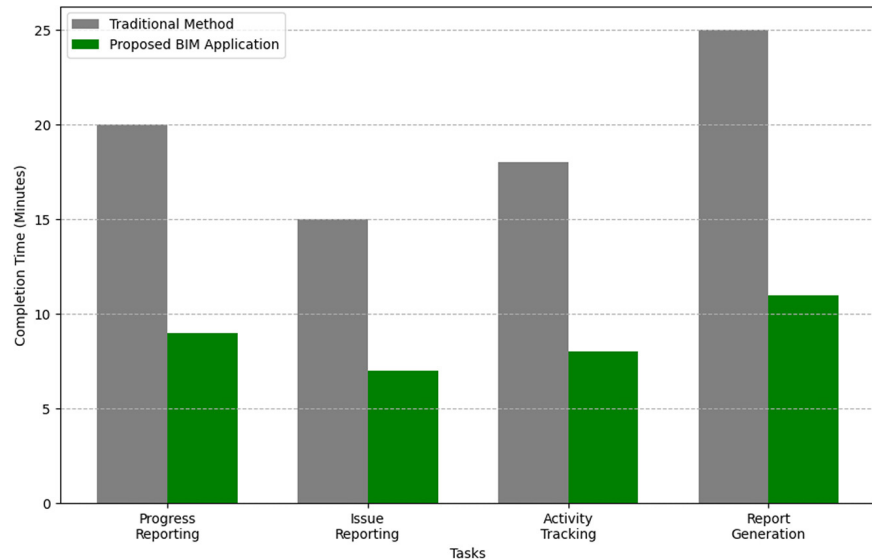


Fig. 5. Mobile resource utilization

The mobile application's utilization of both processing power and memory in constant utilization is displayed in Figure 5. The results show that the CPU load ranged from 22% to 42%, whereas the memory utilization was between 180 MB and 245 MB. The resource utilization increased considerably during visualization of BIM and synchronization of information but later reduced after completion of these tasks. The findings show that the mobile application has effective resource utilization and can run without major hardware requirements.

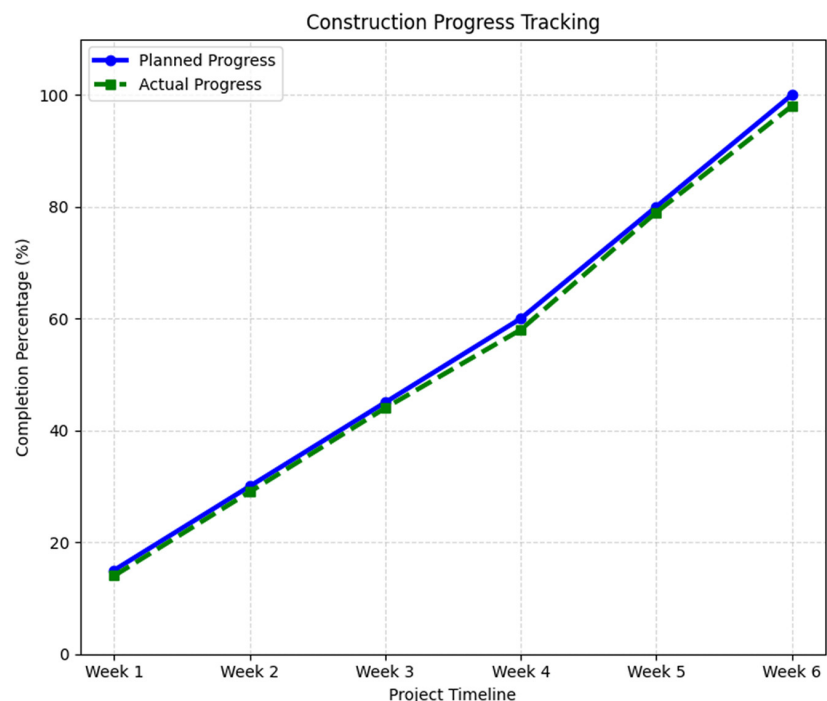


Fig. 6. Planned vs. actual construction progress

Figure 6 illustrates the contrast between the anticipated construction progress and the actual progress registered by the BIM-integrated mobile application over a duration of six weeks. The actual progress of the project has matched the planned schedule with negligible discrepancies of 1% to 2% every week. This correlation between actual progress and planned schedule affirms that the efficiency of the system under discussion is guaranteed in monitoring the project's progress and delivering accurate information in real-time. The availability of timely and accurate project progress information ensures effective project management and makes it possible to take timely corrective measures.

5 CONCLUSION

In this study, we introduced application based on BIM that would solve the problem of monitoring construction projects. With this application, engineers, site managers, and supervisors would have the opportunity to access and edit the necessary information in a real-time way. With the combination of mobile technology and BIM, users are able to view building models, keep track of construction progress, communicate about site problems, monitor what has been done, and manage data instantly. The app provides smooth information exchange between operating staff at the construction site and the project management back office. Research is focused on developing, testing and assessing the application. The evaluation of the effectiveness of the system is based on usability, accuracy, accessibility, and the impact it has on the efficiency of project monitoring. The results will show how BIM-based mobile applications enhance the construction monitoring process by delivering data in real-time, facilitating cooperation, reducing mistakes, and helping to conduct effective project management during the whole process of construction.

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8 AUTHORS

Dr. Kasmaruddin Che Hussin is the Head of the Department of Logistics and Operations Management and a Senior Lecturer at the Faculty of Entrepreneurship and Business, Universiti Malaysia Kelantan. He holds a Bachelor of Business Administration (Operations Management), a Master of Business Administration, and a PhD in Operations Management from Lancaster University, one of the UK's top universities. He is a member of the European Operations Management Association (EurOMA). During his doctoral studies, he collaborated with major industry players in the UK and Germany. His research has been published in various national and international journals and proceedings (E-mail: kasmaruddin@umk.edu.my).

Dr. Anas A. Salameh is an Associate Professor in the Department of Management Information Systems, College of Business Administration at Prince Sattam Bin Abdulaziz University, where he has been a distinguished faculty member in the College of Business Administration since 2016. His research expertise spans e-commerce, with a focus on mobile commerce (m-commerce), e-business, e-marketing, technology acceptance and adoption, e-learning, and e-CRM (E-mail: a.salameh@psau.edu.sa).

Mohd Nasrun Mohd Nawi specializes in the area of integrated design and construction management. He is working at the Disaster Management Institute (DMI), School of Technology Management and Logistics, Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia. He is also affiliated with the Global Entrepreneurship Research & Innovation Centre, Universiti Malaysia Kelantan, Malaysia. He holds a PhD in the field of Construction Project Management from the University of Salford, UK. As an academic and a fully qualified Building Surveyor, he has been actively involved in research and consulting work related to the areas of Industrialized (offsite) and Modern Methods of Construction, as well as Integrated Design Delivery Solutions. Integrated Project Delivery, Lean Construction, Building Information Modelling, Sustainable (Green) Construction, Life Cycle Costing, Value Management, Building Performance (e.g., Energy Management and Audit), and Management of Technology. Besides actively participating in various academic activities, he is also a prolific author with numerous publications, particularly in the field of Construction and Technology Management (E-mail: nasrun@uum.edu.my).

Dr. Mohamad Amin Khadimalah is a Professor in the Department of Civil Engineering, College of Engineering in Al-Kharj at Prince Sattam Bin Abdulaziz University, where he has been serving in the College of Engineering. His research interests focus on structural engineering, particularly the dynamic analysis of structures, fluid–structure interaction (FSI), vibration and vibroacoustic analysis, functionally graded materials (FGMs), composite and thin-walled structures, and the development of advanced computational techniques, including the Dynamic Stiffness Method (DSM) and Continuous Element Method (CEM). His work aims to develop efficient and accurate numerical frameworks for analyzing complex engineering systems with applications in pipelines, cylindrical shells, aerospace, offshore, and energy infrastructure. In addition to his research activities, Dr. Khadimalah is actively involved in engineering education, curriculum development, and quality assurance. He contributes to accreditation and assessment initiatives and serves as an ABET Program Evaluator (PEV). His academic interests also include sustainable infrastructure, advanced structural mechanics, and computational modelling for resilient engineering systems (E-mail: m.khadimalah@psau.edu.sa).