MOBILE BIM PROJECT EXECUTION PLAN MANAGEMENT SYSTEM (MoB-MaS) FOR PUBLIC WORKS DEPARTMENT MALAYSIA

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Dedicated to my Heavenly Father,
Loving parents, academic supervisors,
Kai Len, Zhi Peng, Chue Eng,
and my Hope companions.

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ABSTRACT

BIM Project Execution Plan (BPEP) defines Building Information Modelling (BIM) information, standards, and a set of processes to execute a BIM project. Preliminary study with Public Works Department (JKR) reveals that manually managing BPEP information using text processing software and email had lengthened the updating and sharing process, leading to miscommunication and information loss throughout the project. Therefore, real-time communication and collaboration of stakeholders in managing BPEP is required to reduce conflicts in BIM project execution raised by data inconsistency. JKR, which spearheads BIM adoption in Malaysia public projects is selected as a case study with the aim of digitalising BPEP with real-time information through Mobile BPEP Management System (MoB-MaS). The study's first objective, which is to determine the user requirements of MoB-MaS, is achieved by conducting a semi-structured interview with JKR BIM unit. The data collected was analysed with content analysis approach using a matrix table. Consequently, the second objective was executed by using agile scrum approach to develop MoB-MaS. Lastly, the acceptance and usability of MoB-MaS were evaluated by JKR BIM unit with the aid of questionnaire survey. The findings of user requirements led to the development of MoB-MaS with elements such as a real-time information, push notification, publish, and sharing features. JKR substantiated good reception to 18 functionalities of MoB-MaS, entailing to the high average mean score (4.40 out of 5.0) for its effectiveness. MoB-MaS ensures the continuity flow of timely data for BPEP information management, overcoming the information delay and miscommunication caused by non-collaborative tools.

ABSTRAK

Pelan Pelaksanaan Projek BIM (BPEP) mentakrifkan maklumat Building Information Modelling (BIM), piawaian dan set proses untuk melaksanakan projek BIM. Mengikut kajian awal dengan JKR, kekangan mengurus maklumat BPEP secara manual menggunakan perisian pemprosesan teks dan e-mel telah memanjangkan proses pengemaskinian dan perkongsian yang kemudiannya membawa kepada salah komunikasi dan kehilangan maklumat sepanjang projek. Justeru, komunikasi masa nyata dan kerjasama pihak berkepentingan dalam menguruskan BPEP diperlukan untuk mengurangkan konflik dalam pelaksanaan projek BIM yang dibangkitkan oleh ketidakkonsistenan data. JKR, yang menerajui penggunaan BIM dalam projek awam Malaysia dipilih sebagai kajian kes dengan tujuan mendigitalkan BPEP dengan maklumat masa nyata melalui Sistem Pengurusan BPEP Mudah Alih (MoB-MaS). Objektif pertama kajian iaitu menentukan keperluan pengguna MoB-MaS telah dicapai dengan melakukan temu bual separa berstruktur dengan unit BIM JKR. Oleh itu, objektif kedua dilaksanakan dengan menggunakan pendekatan *agile scrum* untuk membangunkan MoB-MaS. Akhir sekali, penerimaan dan kebolehgunaan MoB-MaS telah dinilai oleh unit BIM JKR dengan mengguna kajian soal selidik. Hasil kajian keperluan pengguna membawa kepada pembangunan MoB-MaS dengan unsur-unsur seperti maklumat masa nyata, pemberitahuan tolak, dan ciri aliran kerja pernebitan dan berkongsi. JKR membuktikan penerimaan yang baik kepada 18 fungsi MoB-MaS, dengan membawa kepada purata skor min yang tinggi (4.40 daripada 5.0) bagi keberkesanannya (*Effectiveness*). MoB-MaS yang memastikan aliran kesinambungan data tepat pada masanya untuk pengurusan maklumat BPEP, telah mengatasi kelewatan maklumat dan salah komunikasi yang disebabkan oleh alat yang tidak kolaboratif.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
API	Application Programming Interfaces
APK	Android Application Package
BaaS	Backend-as-a-Service
BEP	BIM Execution Plan
BIM	Building Information Modelling
BPEP	BIM Project Execution Plan
CDE	Common Data Environment
CIDB	Construction Industry Development Board
CITP	Construction Industry Transformation Program
COVID-19	Coronavirus Disease of 2019
eCOMs	Engineering Content Management System
EIR	Employer Information Requirement
GCM	Google Cloud Messaging
HODT	Head of Design Team
HOPT	Head of Project Team
IDE	Integrated Design Environment
IEEE	Institute of Electrical and Electronics Engineers
IPD	Integrated Project Delivery
JKR	Public Works Department
JPBIM	BIM Steering Committee (*Jawatankuasa Pemandu BIM*)
JTBIM	BIM Technical Committee (*Jawatankuasa Teknikal BIM*)
Lod	Level of detail
LOD	Level of Development
LOdc	Level of documentation
LOi	Level of information
MBaaS	Mobile Backend-As-A-Service

MoB-MaS	Mobile BPEP Management System
NAS	Network Attach System
NCI	National Cancer Institute
OS	Operating System
SDG	Sustainable Development Goals
SDK	Software Development Kit
UAT	User Acceptance Test
UI	User Interface
UX	User Experience
VR	Virtual Reality
VS Code	Visio Studio Code
WeB-MaS	Web-Based BPEP Management System
WPD	Representative of Project Director (*Wakil* Project Director)

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CHAPTER 1

INTRODUCTION

1.1   Background of research

A Building Information Modelling (BIM) implemented project increase productivity and reduce waste through the collaboration of structured data throughout the life cycle of a building (BSI, 2016). According to Eastman (2008), there are several crucial features of BIM, namely parametric design where information is linked to a digital model by algorithm. In addition, it has a close approximation of actual building construction, 3D graphics for better visualisation, information at every level, coordination among different disciplines, and monitoring the entire life cycle of the building from conception to maintenance or demolition. These features enabled sharing of object-based models and data between two or more disciplines to create a federated model (BIM Guide, 2016). Hence, BIM collaboration based on the model is highly required for successful BIM adoption (World Economic Forum, 2018).

In order to achieve BIM collaboration for information to flow freely throughout the project lifecycle, each BIM project should have a designated BIM Execution Plan (BEP) (AIA, 2012). BEP is a document that provides a clear workflow for BIM data coordination and management, specifies BIM uses, deliverables aligned with BIM standards, and outlines a project team's roles and responsibilities to attain the project goal (CIDB, 2016). There is a correlated relationship between BEP and the success of BIM collaboration, as BEP clarifies the responsibilities of a team member at different project stages (Lu *et al*., 2013).

In Malaysia, Construction Industry Development Board (CIDB) has collaboratively published a BEP guideline with Public Works Department (JKR),

which spearheads BIM implementation in public projects (CIDB, 2017a). In JKR, the BEP, also known as BIM Project Execution Plan (BPEP), facilitates BIM projects internally and is a guideline for awarded contractors. Since BPEP is a rule book for all contracting parties (BIMForum, 2018) and needs to be updated frequently upon changes, it is shared and published in a digital data management platform, which is also called a Common Data Environment (CDE). In JKR, BPEP is shared via Engineering Content Management System (eCOMs), and the document is managed manually by distributing hardcopy and softcopy via email to all stakeholders (JKR, 2014).

In JKR, BPEP is generated and revised manually using pre-designed templates and text-processing software like Microsoft Word or Excel by BIM manager prior to a BPEP preparation workshop. (Sulaiman, 2020). The BPEP preparation requires real-time collaboration of stakeholders and project stakeholders must be instantly informed on any changes on BPEP for effective BIM project execution (Ikerd, 2019). The BPEP workshop gathered project stakeholders, including the Head of Design Team (HODT) of each department, the consultant and the client, to complete the BPEP in a collaborative environment (UBIM, 2021a).

Along with the growth of BIM adoption, the development of a mobile application for BIM has increased to allow real-time data exchange in the BIM environment (Sattineni & Schmidt, 2015). It has been utilised for the purpose of collaborative communication as the continuous flow of data is required among project stakeholders for the successful execution of BIM projects (Juan & Zheng, 2014). The common mobile BIM applications are BIM 360, BIMx, BIM Server, and TrimbleProject Sight (Abanda et al., 2015), which allow the documents to be shared through cloud service for better communication.

Furthermore, BPEP not only acts as the preparation and communication platform but also offers clarity and transparency for the project stakeholder (AIA, 2012). There are existing platforms for BPEP management, such as Plannerly and PlanBIM. These applications are commercially developed to provide users with the freedom to create their BPEP in accordance with project and organisational requirements. However, there are limited editing features in the current mobile version where the user cannot respond to the changes instantly (PlanBIM, 2020; Plannerly, 2020). Therefore, the study of mobile application development for BPEP in JKR is required to improve the efficiency of the BPEP management process.

1.2   Problem statement

Currently, BPEP document management in JKR uses platforms such as Microsoft Word, JKR intranet server, and email. The constraint and hassle of documenting BPEP in Microsoft Words consumes a perceptible amount of time (Abbas & Ajayi, 2022). In addition, the use of email as platform to distribute BPEP in JKR results in miscommunication amongst project stakeholders when email on the latest BPEP version is being overlooked (Sulaiman, 2020). Hence, the latest information collected from stakeholders could not be synchronised, updated and shared instantly, resulting in a delay in BPEP information delivery. Additionally, the use of intranet results in the inconvenience of retrieving data, especially when dealing with massive information in the file-based storage system (Ahmadzadegan *et al*., 2020).

Applying conventional communication and document editing tools has led to the inefficiency of BPEP document management in JKR, where it is less effective for quick access, real-time sharing and updating data in a collaborative manner (Abbas & Ajayi, 2022). Thus, a mobile application is the choice of a real-time collaborative platform to share and notify the updated version of BPEP as it offers prompt cooperation with no space constraint (Bello *et al*., 2021; Ding & Xu, 2014).

At present, there is a lack of studies on mobile application usage in BPEP document management at pre-planning stage. Previous studies mainly focused on mobile app in BIM field construction management and BIM project information management (Araszkiewicz & Szerner, 2017; Park *et al*., 2016; Phong *et al*., 2018). Moreover, the existing mobile BPEP has limited features where only allow users to view files and edit overview of project. Hence, it is imperative to develop a BPEP mobile application for JKR as a real-time platform will enable instant collaboration and communication among project stakeholders

1.3   Research questions

The following research questions were defined for this study:
  i.   What is the current practice for BPEP monitoring and updating process?
  ii.   What are the user requirements of Mobile BPEP Management System (MoB-MaS)?

iii.   What is the method used to develop MoB-MaS?

iv.   How is the MoB-MaS usability of MoB-MaS in improving the efficiency of BPEP monitoring and updating process?

1.4   Research objectives

The aim of the research is to improve the efficiency of the BPEP monitoring and updating process by developing Mobile BPEP Management System (MoB-MaS) for JKR Malaysia. The objectives of this study are:

i.   To determine the user requirements of the Mobile BPEP Management System (MoB-MaS).

ii.   To develop a Mobile BPEP Management System (MoB-MaS) for JKR.

iii.   To evaluate a Mobile BPEP Management System (MoB-MaS) for JKR in terms of user acceptance level and usability of the application.

1.5   Scope of research

The study outcome is aimed to develop a customized BPEP mobile application for JKR to enhance the process of monitoring and updating BPEP. The target respondent in this research is restricted to BIM unit staff of JKR only as pioneering user due to their expertise and experience in the BPEP's preparation and coordination. The selection of JKR BIM unit as case study is due to its responsibility as government agency that spearheads BIM adoption in public projects and there is existing BPEP management practice. In relation, the success of BPEP mobile application development helps JKR project awarded contractors to utilise BPEP easily.

The maturity level, level of detail, and development of BIM are defined according to BIM Guide published by CIDB in 2017. Note that the BPEP of completed JKR BIM projects and 'JKR BIM Guidelines 2014' are the main references for the database and the mobile application layout. There is new edition of BIM Guideline published which is 'JKR BIM Guideline 2021". Hence, there is a diffence between the sample BPEP template published where the latest version has removed "Section K: Finance Allocation". Moreover, there are new term defined such as LOi (Level of information) and LOdc (Level of documentation) has lead to limitation of default

template in MoB-MaS. However, MoB-MaS is designed to allow new information added to database.

In addition, the mobile application is designed for Pre-Contract BPEP only as JKR has the responsibilities for BPEP preparation to provide a method and procedure to present BIM deliverables during the design stage for conventional project. In contrast, the Post-Contract of BPEP will be prepared or updated by the contractor to manage and coordinate the BIM information during the construction and operation. The responsibility of JKR on post-contract BPEP for a conventional project is to facilitate contractor to prepare post-contract BPEP. On account on the fact that JKR is chosen as a single research and has fully responsible for Pre-Contract BPEP from preparation to publish, the development of post-contract BPEP in MoB-MaS is excluded in this study. Since the MoB-MaS prototype is designed and deployed in the Android version, the devices used for evaluation is limited to Android-based device.

1.6 Significance of research

This study focuses on BPEP, which acts as a moderator for BIM implementation to drive the Malaysian construction industry towards successful BIM adoption. The development of the BPEP mobile application serves as an initiative to upgrade the current data sharing platform to a real-time sharing platform for JKR. This is aligned with the Construction 4.0 Strategic Plan (2021-2025), which is targeted to enhance the BIM process with digital construction. The case study also demonstrates the need for the BPEP mobile application to improve the BPEP information management workflow. Other than that, the current issues addressed are anticipated to raise awareness of the significance of accurate information flow in the BIM process. The outcomes will undoubtedly boost the confidence of stakeholders in the construction industry to adopt mobile cloud technologies in the BIM process.

From the academic aspect, this research provides insight into the current practice of BPEP updating and sharing process in JKR. The study helps the academic researcher to recognize the need to embrace digital transformation. Therefore, this research study filled the gap for BIM mobile applications by developing the BIM mobile application for document management.

Along with the successful development of mobile BPEP, the role of BPEP would be fully utilised for a smooth BIM project delivery process where the breakdown of communication and information flow is overcome. It creates a straight path for better BIM adoption, as well as empowering and strengthening the construction industry to stay competitive in the revolution of digital construction.

1.7 Research methodology

The case study was undertaken in this study to develop a mobile application of BPEP for JKR. The research methodology applied in this research is briefly explained below:

Stage 1: Preliminary study

At this stage, an unstructured interview was conducted to explore the need for this research. The current practice and issues encountered in JKR for BPEP management were explored, which were highlighted in the problem statement.

Stage 2: User Requirements Analysis

At Stage 2, a semi-structured interview was held as pre-planning for the MoB-MaS development process to achieve Objective 1, which is to determine the user requirements of MoB-MaS. This interview aims to understand the main purpose of developing the mobile application. Furthermore, the user requirements were identified from the content analysis of interview data. The user requirements were written in user stories while both functional and non-functional requirements were identified.

Stage 3: Mobile Application Development

The application development model adopted in this research is the Agile Approach in order to fulfilled Objective 2. Hence, the user requirements were analysed for product backlog (user stories) before designing the user interface (UI) and user experience (UX). A prototype was developed using Figma to get feedback from JKR to verify the user interface design. The technological stack for both front-end and back-end was determined at this stage.

Stage 4: Mobile Application Testing and Evaluation

The Mobile BPEP Management System (MoB-MaS) for JKR was evaluated in terms of user acceptance level and usability of the application to attain Objective 3. At the last stage of the research, MoB-MaS was evaluated by a 5-point Likert scale questionnaire survey. The respondents who participated in the evaluation were JKR's BIM unit staff. Subsequently, the respondent explored the mobile application by performing the test scenario distributed. Then, the mobile application was evaluated from the aspect of user acceptance and usability.

1.8 Summary

The background of the study has introduced BIM and BPEP. The preliminary study results stated the current issues encountered by JKR in preparing, updating, and monitoring BPEP. Hence, the development of a mobile application was proposed to improve the efficiency of the BPEP management process by digitalization. The scope of the study was clarified to set the boundaries of the application development. Lastly, the methodology to accomplish this study was briefly discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed the overview of Building Information Modelling (BIM), including BIM practices in the Malaysian construction industry, followed by the BIM implementation in the Public Works Department (JKR). The BIM Project Execution Plan (BPEP) elements, current practice, and issues of BPEP in JKR and the existing platform for BPEP management are reviewed. Consequently, the gap analysis for past research findings related to the BIM mobile application in construction project management is discussed. Lastly, the need for the mobile BPEP application in real time is justified.

2.2 Building Information Modelling (BIM)

BIM technology is a new approach to the construction industry. It shifted the project delivery process from traditional 2D drawing to information-rich architectural 3D modelling. However, it is not just about 3D modelling but focuses on gathering and managing all data assets to a BIM respiratory throughout the project lifecycle. The enriched information BIM model has eased the project execution by analysis, such as automated quantity taking-off, simulation, and clash analysis reports (Memon *et al.*, 2014). As a result, BIM has successfully brought forth the benefits in terms of time-saving and cost efficiency from various analyses at the early stage. Moreover, the BIM technology enables collaboration among stakeholders in a network-based environment to get real-time info and reduce information loss (Ratajczak *et al.*, 2015).

2.2.1   Definition of BIM

BIM is defined as "a modelling technology and associated set of processes to produce, communicate and analyse digital information for construction life cycle" (CIDB, 2015; (Sacks et al., 2018). The definition corresponds to Succar (2009), who introduced a BIM framework to define BIM as integration of product and process modelling. The author defined BIM as "a set of interacting policies, processes, and technologies" to generate a management method for building the life cycle from design to demolishing data in digital format. Apart from that, the BIM field's interactions among policies, processes, and technologies are the transaction of push-pull knowledge for BIM implementation. For instance, the overlapping process and technology yields communities in the BIM practice. As a result, the framework outlined the BIM steps in relation to the BIM fields across each BIM maturity level towards the evolving target, Integrated Project Delivery (IPD). The integration in project flow and delivery is facilitated by collaborating with the backbone of BIM, the semantically rich shared 3D digital building models (Isikdag & Underwood, 2009). Furthermore, Sacks *et al.* (2018) added the project team could use the shared model to perform coordination, planning, scheduling, quantity take-off, and cost estimation. In other words, the data prepared by different parties is exchanged within Common Data Environment (CDE) (BSI, 2016).

2.2.2   BIM in the Malaysia construction industry

In Malaysia, the current status of BIM implementation is still in its infancy stage (Mohd *et al.*, 2016; Othman *et al.*, 2021; Roslan *et al.*, 2019). The BIM usages commonly implemented in projects are project visualisation in the pre-construction phase, developing 3D models with project information to avoid discrepancies, clash detection for Mechanical &Electrical (M&E) design, and quantity take-off (Latiffi, Brahim, and Fathi, 2016). Other than that, research conducted by Wong (2015) has identified that the BIM maturity level in Malaysia lies between Levels 0 and 2. Level 0 indicates zero collaboration among discipline. The utilization of unmanaged computer aided design (CAD) is mainly for production information only as each party share no common standard and process. Level 1 involves 3D modelling for

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