Leveraging on building information modelling (BIM) for infrastructure project: Pan Borneo Highway Sarawak Phase 1

Zohari Akob¹, Mohd Zaidee Abang Hipni², and Mohd Rizal Rosly³

¹Kementerian Kerja Raya Malaysia, Kuala Lumpur, Malaysia
²Lebuh Raya Borneo Utara Sdn. Bhd., Kuching, Sarawak, Malaysia.
³BIMASIA Sdn. Bhd., Petaling Jaya, Selangor, Malaysia

E-mail: zohari@kkr.gov.my

Abstract. The construction industry in Malaysia has always been confronted with various challenges to enhance productivity, efficiency, infrastructure value, quality and sustainability. The Pan Borneo Highway Sarawak (PBHS) is currently under construction, a large-scale project had to overcome technical and land issues at its outset, as well as manage communication and project management challenges due to its dispersed construction locations and the involvement of multiple regulatory agencies. To address these issues, Building Information Modelling (BIM) offers a better way to address multi-disciplinary inefficiencies and miscommunication throughout the lifecycle of the project. The Project Delivery Partner has adopted BIM to monitor and manage the project to ensure more effective collaboration and communication between all parties, towards delivering on time and within the budgeted cost, as well as to enable a meaningful strategic and tactical asset management once the Highway is completed. Whilst BIM has numerous benefits, implementation has its challenges with regard to people, process, policy and technology (PPPT). PBHS demonstrates how these PPPT challenges were overcome, benefits attained, and what can be improved for future implementation. PBHS is also setting the benchmark for future infrastructure BIM implementation to be used in Malaysia and elsewhere, including for research.

1. Introduction
1.1. Background
The Malaysian construction industry is a key contributing sector towards the Malaysian economy. It contributes approximately 3 to 5 percent of the Gross Domestic Product (GDP) annually [1]. Although it plays a big role in contributing to the growth of Malaysia’s economy, the construction industry needs to be improved, especially its productivity. The Malaysian construction industry should upgrade its current construction execution and strategies, whether in terms of practice, management or technology in order to be globally competitive [2].

Research advocates that BIM (Building Information Modelling) is a vital asset for building construction from preconstruction through operation to its end of life [2]. The advantages of BIM for infrastructure construction has started to be recognized and realized. Additionally, advantages of using BIM for infrastructure include the opportunity to record details of every construction action. Such documentation could offer a record for each element based on the history of the construction [3].
Engineers, construction managers, owners, and facility managers are acquiring the benefits of implementation of BIM for infrastructure as being dynamic, decisive, and an organized approach of maintaining their assets [4].

Research has demonstrated the extent of benefits of using BIM in vertical construction (i.e. buildings) and horizontal construction (i.e., infrastructure) [4]. Although there have been many efforts by the Malaysian Government to increase BIM implementation in construction projects, implementation is still slow and less favourable. People, process, policy and technology (PPPT) are the key challenges in the implementation of BIM today in Malaysia [5, 6].

This paper will elaborate how BIM is being used in the Pan Borneo Highway Sarawak Project and how those challenges are solved.

1.2. Building Information Modelling (BIM)
BIM can be viewed as a combination of advanced processes and technology that offers a platform for collaboration between different parties in a construction project by exploiting the use of Information Technology (IT). In the Malaysian construction industry, many construction players regard BIM as a new technology. It is not widely used as yet [11].

Traditionally, 2D design approved for construction are checked manually for discrepancies. This method is time consuming, especially for complex designs. With BIM, the process of creating and using 3D parametric computer-aided-design (CAD) technologies for design allows the exchange of information within a construction project team in a digital format. More importantly, clash detection is possible with the available pool of information [7, 8, 9, 10].

This approach is faster and reduces incidences of human error to a minimum. The models can be passed onto the contractor for estimation and planning of the construction projects.

In general, BIM can be viewed as a single repository system that supplies and receives relevant information in a digital form relevant to the construction project [11].

1.3. BIM for Infrastructure
BIM for infrastructure processes can benefit multiple stakeholders by incorporating project information into a single or multiple 3D models with multiple data sets. For example, owners can use the model for operation and maintenance, while engineers and contractors can use the information for design and building considerations. Various alternatives can be compared to achieve an optimum lifecycle cost [3].

A key benefit is the accurate geometrical representation of parts of the building infrastructure in an integrated data environment. Here, project stakeholders can acquire a greater level of detail at early stages of the project for better decision-making before they are implemented at site [12].

In addition, operation and maintenance histories can be well documented. Transportation infrastructure typically has a lifecycle of decades and generally maintenance is driven by financial considerations. BIM enables this to be done more cost effectively by providing the potential for up-to-date, accurate, and geometric representations of the asset and their sub assets [12].

Overall, the initial cost of constructing and maintaining a BIM model can be minimal in comparison with the benefits gained over the lifecycle of the infrastructure asset [12].

1.4. Value of BIM
BIM potentially allows for such considerations to be assessed and addressed through collaboration using a 3D model. Stakeholders can provide design alternatives in a digital format to address problem areas and apply degradation models to determine the most effective and appropriate means of addressing design and construction issues [12].

The use of BIM can help stakeholders transfer important decisions from the site to the computer where changes are easier to be made and more effective. Additionally, stakeholders can develop a shared understanding of the project through cross-disciplinary collaboration that helps reduce design errors and miscommunication, which in turn reduces risk and liability [13].
Finally, additional value may result through the use of BIM by avoiding data dispersions, and duplication of effort, thereby increasing efficiency and safety, reducing time for routine data collection and recording. All of these translate into cost savings for the owner and increased structural safety of the assets [14].

BIM can also help decision-makers to schedule regular maintenance for infrastructure assets. Research has suggested that BIM implementation can lead to noticeable cost savings. Overall cost diminishes as unplanned maintenance is replaced by planned maintenance, helping infrastructure owners and engineering firms to seek integrated and cost-effective solutions that span the entire project lifecycle [15,16].

2. Case study: PBHS Phase 1 project

This research implemented uses a case study methodology whereby the key tasks were to:
1) Compare and analyse BIM implementation on the PBHS Project with PPPT Challenges with regard to Aryani Ahmad Latifi’s [2] research about PPPT;
2) Validate findings through interviews of project representatives.

2.1. Project Overview

The long-awaited Pan Borneo Highway in the Malaysian state of Sarawak on the island of Borneo will span an estimated 1,060 km. Works are on-going to develop and upgrade the current 2-lane single carriageway which connects the entire state into a 4-lane dual carriageway. The project is being undertaken by the Government of Malaysia and State Government of Sarawak through a Project Delivery Partner (PDP). For this, a special purpose vehicle private entity, Lebuhraya Borneo Utara (LBU), has been appointed as the PDP.

Costing RM16.5 billion, Pan Borneo Highway Sarawak is deemed to be the single largest infrastructure project ever awarded by the Government in Sarawak. Implementation of the project involves construction of 786km of a new 4-lane highway in 11 works packages. Works began in January 2016, with the Highway targeted for completion in 2021. Operations and maintenance of the Highway will follow upon completion of construction.

As PDP, LBU is in charge of the entire project lifecycle, from planning to design and construction, to operations and maintenance of the completed highway. As PDP to the Government, LBU is committed to deliver the project on time and within budget. An associated company will then undertake operations and maintenance of the highway.

Phase 1 development of Sarawak’s single largest infrastructure project is divided into 11 works package stretches averaging between 60-90 km each. BIM has been implemented for Phase 1 of the PBHS project up to Level 2 of BIM maturity and provided up to LOD 500. Powered by five BIM Modellers and one Coordinator for each package, the total number of dedicated personnel for BIM Implementation on the PBHS project is 55 BIM Modellers, 11 BIM Coordinators, 8 BIM Specialists, 4 BIM Lead Family, 1 BIM Lead Coordinator and 1 BIM Director.

2.2. People, process, policy & technology (PPPT) challenges

With reference to Aryani Ahmad Latifi’s [2] research on PPPT, there are several factors and causes which contribute to barriers and challenges of BIM implementation in construction projects. These can be categorised as people, process, policy and technology [17].

2.2.1 People. Many construction players refused to adopt BIM because they are more comfortable with conventional processes in managing construction projects. Lack of knowledge and understanding in BIM, lack of awareness and encouragement to adopt BIM among top management and availability of good BIM resources are the key factors contributing to the slow adoption of BIM [2].
Lack of knowledge and skill in BIM is another factor contributing to the slow implementation of BIM among construction players. A lack of awareness on BIM and little encouragement to implement BIM among clients and top management in construction organizations contribute to the lack of knowledge and skill on BIM among players [17, 18].

2.2.2 Process and Policy. Clear guidelines on BIM are important to assist construction players to implement BIM in construction projects. Without proper guidelines, BIM implementation can be inaccurate, causing construction players more problems and failure to reap the optimum benefits of using such technology [6].

It has been seen that many construction players have developed their own version of BIM implementation guidelines. These guidelines can and in many cases have resulted in confusion among construction players, causing users to be doubtful as to the use of BIM implementation [6, 19].

This has contributed to the slow acceptance and adoption of BIM in the local construction industry due to the reluctance of implementing BIM in future projects [6, 19].

2.2.3 Technology. Respondents felt that the adoption of new technology such as BIM requires high cost, especially for new hardware (computer), software (BIM tools) and BIM training. Costs to implement BIM range from RM15,000 to RM90,000.00. Many felt such costs could only be afforded by large organisations [2, 8, 19, 20].

The combination of all these factors has resulted in the slow implementation of BIM among Malaysian construction projects in general. Table 1 shows the summary of barriers and challenges of BIM Implementation in construction projects.

Table 1. Barriers and challenges of BIM implementation

| No | Factors               | Challenges & Problems                                                                 |
|----|-----------------------|--------------------------------------------------------------------------------------|
| 1  | People                | • Comfort with conventional processes used add to refusal of construction players to change. |
|    |                       | • Lack of knowledge of BIM.                                                          |
|    |                       | • Lack of skill on BIM.                                                             |
| 2  | Process & Policy      | • No BIM guideline and specific model could assist construction players to implement BIM.   |
| 3  | Technology            | • BIM tools are expensive.                                                          |
|    |                       | • New hardware is expensive.                                                        |
|    |                       | • BIM training is expensive.                                                        |

3. BIM implementation: PBHS Phase 1 project
While People, Process, Policy and Technology are seen to be challenges in BIM Implementation not only in Malaysia but across borders, BIM implementation in the Pan Borneo Highway Sarawak (PBHS) Phase 1 project has proven that these challenges can be mitigated by execution of strategies. Based on the performance and actual site coordination, leveraging on BIM has become part of the daily work of project stakeholders who now understand and reap the benefits of its implementation.

3.1. People
The initial lack of knowledge and skill in BIM was addressed by providing intensive training to employees of the Project Delivery Partner of the PBHS project. BIM Modellers and BIM Coordinators attended a one-month intensive training course for both roles. They were trained on implementing
BIM in real work conditions, understanding the functions of BIM Tools, and familiarising themselves with the workings of a BIM Environment.

For PBHS Phase 1, the BIM Modellers and Coordinators were given basic, intermediate and advance level of BIM Tools usage, such as Autodesk Civil 3D®, Autodesk Revit® and Autodesk Infraworks® for highway modelling, followed by Autodesk Navisworks®, Bentley ProjectWise® and Oracle Primavera P6® for coordination and management.

In addition to training the BIM Modellers and Coordinators, the local construction industry involved on the PBHS project were also introduced to BIM Awareness through seminars, project showcases, and conferences. Socialization and promotion are important activities to introduce BIM to all construction players and carry them along the BIM Process and build acceptance of the technology’s usefulness.

Questionnaire is used to determine BIM implementation value based on real approach. Within the duration between March until April 2018 there are 31 respondents are involved in this questionnaire and giving their opinion about benefit of HIM implementation (A.1). In question Have you / your team gained any value / benefit from HIM implementation? the result shown that 80.6% respondents said yes and the rest said no. Most of them answered that BIM help to gain detail information on pre-construct about clashes, better 3d modelling view, give better mitigation and more efficient solution.

3.2. Process and Policy

References for BIM Process and Policy are available extensively to be adopted by projects. For PBHS Phase 1, it established its own process and policy for implementation by adhering to BIM guidelines implemented successfully for other countries such as Singapore and the United Kingdom.

BIM Essentials Guidelines from Building and Construction Authority (BCA) Singapore became the first reference to create a series of BIM Execution Plan templates. For the process of BIM Implementation PBHS Phase 1, the British Standards Institution (BSI) Public Available Specification (PAS) series became a key reference point.

BCA and BSI were able to accommodate the workflow of BIM implementation in PBHS Phase 1 Project. Additional policies and processes may be added if required. Additional workflows need to be documented and researched further if it is to be used as a reference for Malaysian Standards for BIM Infrastructure. The Government of Malaysia is currently preparing this standard to be used as a national guideline.

3.3. Technology

The main software used in PBHS Phase 1 project is Autodesk Infrastructure Design Suite Ultimate® 2016, a subscription base system. This package includes all BIM tools to be used for infrastructure and building projects. Whilst the software may be costly, with proper BIM implementation, the Returns of Investment (ROI) of using such technology has multiple benefits.

Freeware was also being considered for this project, such as Autodesk Navisworks Freedom® for site coordination purposes. Today, users enjoy the benefits of the system. They are able to gain access, view models, and study comparisons between the model and actual site conditions to identify and visualise the clash objects. Based on coordinators clashes report it prove that this tool help to collect all potential clash data (A.2). This report will help to gain all potential clash and inform the site team to justify all the clashes before it constructed. It proves that along the construction stage, site team able to check the clash report and compare with site condition. It helps to reduce time for checking the clash by using visibility check only based on the clash reports.

Usage of Network Attached Storage (NAS) Servers are other cost-saving measures to create your own Common Data Environment (CDE) instead of using the Cloud based systems which are paid monthly and with limited number of users. The NAS Server is also a good inventory investment as it can be used multiple times.
4. Conclusion
BIM Implementation in the PBHS Phase 1 project can be used as a national reference to leverage BIM in infrastructure projects. Among the benefits as seen through the successful use of BIM in implementation of this large-scale Highway project are:

- It has been proven that the challenges of PPPT can be mitigated by using the right strategies.
- BIM has resulted in the more effective use of resources and better coordination.
- Stakeholders benefit with better management and coordination.
- Collaboration between BIM practitioners and the Government plays an important role to drive the implementation of BIM in the local construction industry.
- Cooperation between both parties is also important to develop a standardized BIM guideline to be used by construction players in the country.

The experience of BIM Implementation in the PBHS Phase 1 project can be used as a benchmark for infrastructure projects both in Malaysia and elsewhere.

It is hoped that the information contained in this paper can be useful to construction players in other countries intending to implement BIM. The information can help to expose construction players to the realities of implementing BIM. Lessons learned can be used as guidelines to avoid unexpected circumstances in the journey to implementing BIM. It is anticipated that research will be made richer with the experiences of other types of construction projects. All such resources will be useful to increase BIM implementation in the architecture, engineering and construction (AEC) industry both here in Malaysia and elsewhere.

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