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An Analysis of Existing Literature and Prospects for Building Information Modeling (BIM) in Dam Construction

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Research Article
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ABSTRACT A dam is a man-made construction with many useful purposes, such as reducing flooding, providing electricity and water, protecting habitats, and attracting tourists. But it comes with a long list of responsibilities throughout development, including planning/design, building, operation, and upkeep. Consequently, all parties involved must pay close attention, be precise, and work together effectively at all times. The integration of all disciplines, beginning with the AEC aspects, is essential. Building Information Modeling (BIM) is a technology invention that is helping to answer the huge problem of how to ensure an efficient and effective building process for owner/government, designers, consultants, and contractors.
The goals of this research were to (1) ascertain the current state of BIM research in the field of dam management and (2) suggest potential future research directions in this area. In addition, the study outlined the benefits of technical advancements on dams, discussed their possible added value, and evaluated the obstacles that may reduce their efficacy in Indonesia. Researchers found that building information modeling (BIM) may be used for dam projects with the right government rules and enough competent human resources, but that this approach would lead to higher investment costs. The study's results should boost efficiency and effectiveness across the board and promote BIM's use in dam building and management in Indonesia.

KEYWORDS Building Information Modeling; Construction; Dam; AEC

1 INTRODUCTION

To manage or store water, dams are man-made barriers constructed on top of naturally occurring topography (Schurer, et al. 2002). The United States Department of Homeland Security (2007) defines these complex facilities as following: reservoirs; powerhouses; spillways; reservoirs; control structures; and canals or drains. Recreation, flood control, water storage, irrigation, mining tailings, electricity production, debris management, and navigation are among the many high-priority advantages associated with dams (U.S. Department of Homeland Security 2007). Not only that, but they are also beneficial for conservation efforts, fisheries, and raw water supplies (Mulyono, 2017). Nevertheless, there are intricate issues linked
Owners/government, planners, consultants, and executors are all involved in the many phases of dam development, from design and planning to building and maintenance, in order to deliver these advantages. More recently, a technical breakthrough known as Building Information Modeling (BIM) is resolving these issues.
Paul (2018) states that this approach is now being used for infrastructure projects in industrialized nations. But Indonesia is also on the cusp of embracing technology in building infrastructure. For instance, when it comes to state buildings, BIM is required for non-modest structures with an area exceeding 2,000 m2 and more than 2 floors, according to the Appendix to the Minister of Public Works and Housing Regulation No. 22 of 2018 (Ministry of Public Works and Housing, 2018). However, there are no such regulations that compel the use of BIM for other types of infrastructure, like roads, bridges, dams, etc.
A number of projects controlled by the Directorate General of Human Settlements have already used this technology, demonstrating its rapid deployment (BIM Ministry of Public Works and Housing, 2019b). In addition, the Directorate General of Highways has used BIM in multiple toll projects (Directorate General of Human Settlements, 2018). They intend to make BIM mandatory by 2020, so

they've formed three groups to examine the current legal framework, create BIM training materials, and draft technical guidelines, manuals, and modules.

Despite BIM's widespread usage in construction projects, it has seen surprisingly little adoption in civil engineering, particularly when it comes to dams (Wang et.al. 2018). In South Korea, for instance, the technology has mostly been used for process management, advertising, stimulation, and the planning phase of dam building (Ju & Seo, 2012). On the request of the Directorate General of Water Resources, contractors in Indonesia are starting to use building information modeling (BIM) in a number of dam projects. However, there are currently no rules requiring its use during either the consultant's planning phase or the contractor's construction implementation phase. According to these accounts, research on building information modeling (BIM) for dams is necessary. So, to find out what the latest scientific breakthroughs are and to define what kind of study has to be done on dam projects in Indonesia, this article reviews a number of papers that have dealt with this subject.

2 METHODOLOGY

The paper was conducted by analyzing the use of BIM in infrastructure projects including dam projects both inside and outside Indonesia through the use of academic papers from several construction science journals, book chapters, dissertations, and conference proceedings with a focus on dams and BIM. Papers and articles used were classified based on their use of keywords such as BIM, dams, and the use of BIM on dams. Meanwhile, qualitative analysis was used to identify the interaction of papers from different backgrounds. Moreover, the research process flow is shown in Figure 1.

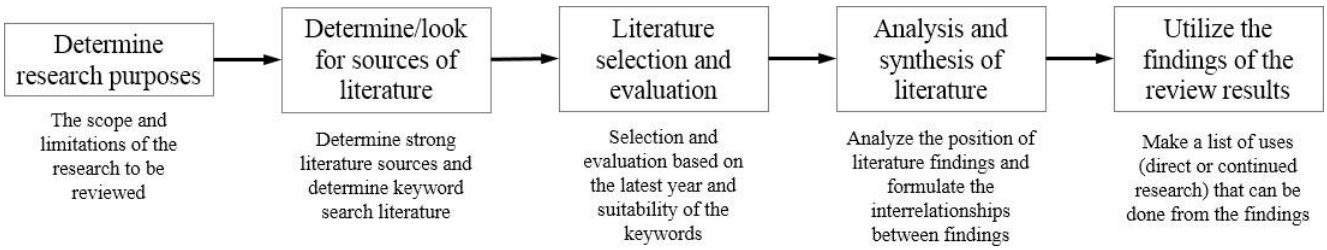


Figure 1. Research Methodology Review

3 RESULT AND DISCUSSION

3.1 Current Application of BIM in AEC

Better building information modeling (BIM) allows AEC professionals to better design, construct, and manage infrastructure and buildings via the use of 3D models (Autodesk, 2019). Throughout a building's lifespan, it may be helpful for creating and organizing data related to geometry, spatial connections, quantities, component qualities, and more (Ratajczak et al., 2019). Multi-disciplinary collaboration, analysis, cost estimate, and construction scheduling are just a few of the ways in which building information modeling (BIM) may revolutionize the design and construction processes (McArthur, 2015).

Azhar (2011) states that this technology has several applications in the construction industry, including visualisation, shop drawings, code reviews, cost estimates, construction sorting, forensic investigation, and facility management, among others. Figure 2 also shows that there are several kinds of BIM applications used in various stages of project development. The basic forms, 2D and 3D, are used for documentation and visualization. 4D, on the other hand, takes more time and is mainly used to optimize planning through schedule. 5D, on the other hand, comes with additional costs and is used to produce a more efficient, cost-effective, and sustainable construction through cost/estimation. 6D, on the other hand, offers additional energy analysis and is used to regulate overall energy consumption for as-built

operation or sustainability. 7D is used for optimizing asset and facility management from the design to the operations and maintenance phase (Kacprzyk & Kępa, 2014; Ministry of Public Works and Housing, 2017).

According to a study by Eadie et al. (2013), building information modeling (BIM) was used at 55% of the design stage, 52% during detailed design and auction, 35% during construction, 27% during feasibility, and 9% during operation and maintenance. It was also found that the BIM application was useful throughout the project because it improved design quality, was easy to implement, allowed for information sharing, cut down on construction costs, design mistakes, and time, increased energy efficiency, and helped with project management and construction.

In addition, research by McGraw Hill Construction (2014) found that while 52% of BIM implementations in the UK were in response to owner demands, 90% of planning teams and 70% of general contractors used it anyhow. In 2016, 55% of owners of infrastructure projects consistently used BIM consultants, according to various indications.

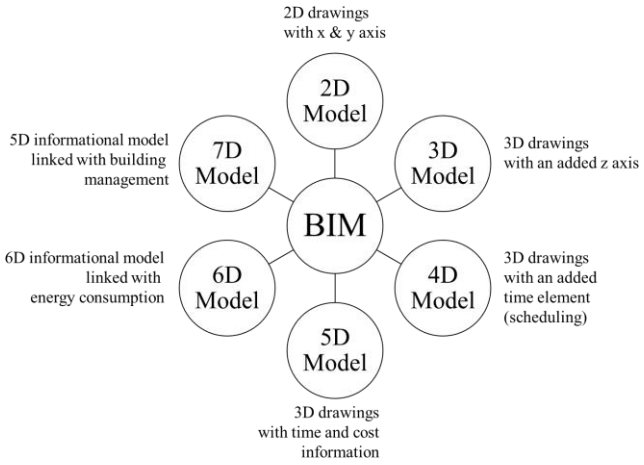


Figure 2. The dimension of BIM and AEC Capability (Azhar, 2011)

3.2 The Benefits and Constraints of Using BIM

The infrastructure life-cycle is mainly divided into 3 phases and these include Design (D), Construction (C), and Operations (O) (Succar, 2009). In Indonesia, the project delivery method, especially for each Design-Bid-Build is the standard acronym for the government project life cycle. Efficiency, effectiveness, transparency, accountability, and synergy are some of the obstacles that each stage of the 4.0 infrastructure life cycle must overcome.

Xu et al. (2014) found that building information modeling (BIM) may help with information management and hence overcome these obstacles. Succar (2009) asserts that life-cycle management's connections, activities, and duties may be transformed by incorporating this technology breakthrough. Xu et al. (2014) and Becerik-Gerber et al. (2012) both agree that this digital tool is perfect for storing and managing all data connected to a building's life-cycle. It also makes sure that all parties involved are constantly exchanging and updating information, from the design phase all the way through operation and maintenance. Knowing how Building Information Modeling (BIM) works in terms of data flow and sharing is crucial (Xu et al., 2014).

The inapplicability of data from one stage of the infrastructure life-cycle to another is another issue that has been identified (Jiao, et al. 2013). One example of this is the failure to use design data during construction and, as a result, operation. The most crucial part of life-cycle management is good

communication and information utilization, and BIM is a great tool for integrating information from many phases to make this happen (Xu, et al. 2014). Three types of management are carried out by technological innovation: collaborative, which involves negotiating between different parties using different software; risk management, which involves reducing the likelihood and impact of negative events on the project; and sustainability analysis, which involves analyzing the performance of complex buildings to ensure optimal and sustainable design (Xu et al., 2014). Stakeholders such as owners, designers, contractors, and facility managers are involved in every step of the infrastructure life-cycle. Azhar et al. (2012) lists the advantages of building information modeling (BIM) for each of these groups in Table 1.
Several sources in the field of project management have acknowledged BIM's benefits, such as its capacity to guarantee higher-quality project performance, higher productivity, faster delivery, more revenue and business opportunities, and lower construction costs (Diaz, 2016). Research on 35 projects by Bryde et al. (2014) found that using BIM successfully reduced costs, improved communication and collaboration, increased quality, decreased negative risks, and improved organizational performance. Additionally, the application was able to cut building expenses by 5-9%, according to another research by Fanning et al. (2014).

Table 1 BIM Application for Project Stakeholders

BIM Application	Owners	Designers	Contractors	Facility Managers
Visualization	√	√	√	√
Options Analysis	√	√	√	
Sustainability analysis	√	√		
Quantity survey		√	√	
Cost estimation	√	√	√	
Site logistics	√		√	
Phasing and 4D scheduling		√	√	
Constructability analysis		√	√	
Building performance analysis	√	√	√	√
Building management	√			√

The advantages of BIM were also summarized in CRC Construction Innovation (2007:
However, despite these advantages, there are several obstacles to the application of BIM in different countries. According to McGraw Hill Construction data (2014), these constraints include (1) cost/funding/initial investment, (2) training investment/lack of skilled users, (3) adoption on a broad scale and (4) lack of BIM standards throughout the industry. This was also supported by Eadie, et al. (2013) that the software is mostly not used in construction projects due to the lack of expertise among the project team members and several organizations, lack of demand for the use of BIM, investment costs, and the lack of additional project costs to support its application.

3.3 Future Utilization of BIM in Dam Construction

A mechanism to integrate and manage each stage of construction and all parties involved is necessary for a dam, due to its complex and intricate facilities. For instance, cut-and-fill earthworks execution is notoriously difficult owing to the large degree of uncertainty it entails; as a result, there is no assurance that the dam will be built in its entirety according to design (Rozy, 2015). Dewatering, earthworks, support and protection, drilling and grouting, top of the dam, drainage of foot dam, instrumentation, and electrical equipment are all components of the main dam work Work Breakdown Structure (WBS), according to Hidayah et al. (2018). Because the project is so reliant on the site's topography and geology, there is a great deal of room for error in all of these tasks. Dams are complex man-made

structures that can be exceedingly costly; in fact, the World Commission on Dams (WCD) (2001) estimated that USD 6 billion would be needed to construct just three dams. This is just one of the many reasons why the construction of a dam can take anywhere from four to six years. To get over these issues, BIM can combine all phases of the implementation, which allows for cost estimation and real-time monitoring of modifications or deviations via 3D model visualization. According to Matt (2013), BIM can improve design efficiency and quality while reducing costs and misunderstandings between parties. Russell and Jackson (2014) found that it ensures effective quarry management. Additionally, BIM was used to design and manufacture pre-cast concrete reservoirs. Also, it's part of the monitoring process now (Coetzee, 2018). One reason BIM hasn't been used more frequently in Indonesian dam projects is because there aren't enough qualified human resources (HR) with software knowledge. This is especially true for planners and government/owners. Another reason is that there aren't enough government regulations mandating that dam construction projects in Indonesia use BIM. Lastly, there are high initial investment costs associated with providing software that integrates 3D design, finance, and schedule.
Government legislation mandating the use of building information modeling (BIM) from the planning stage is therefore anticipated to initiate BIM deployment for dam projects. In the bidding phase, the owner would utilize the DED findings, while the contractor would use the shop drawing that includes estimated costs and construction schedules. Before being presented to the government or owner, the shop drawings would be organized as-built drawings according to the field circumstances. The project timeline and budget may be estimated by evaluating the 4D through 7D capabilities of BIM. Another potential issue is to use building information modeling (BIM) during asset management for the dam's operation and maintenance. There are many public advantages and risks associated with dams, making them an important asset that requires careful management. But repairs and upkeep may be pricey, and they tend to add up over time. Thus, sufficient, prompt, and high-quality procedures are required to lessen the financial load of maintenance and re-engineering. According to Kivits and Furneaux (2013), BIM incorporates a new level of technical cooperation to help with sustainability and asset management.
Some crucial data connected to the building and administration of dams may reportedly be better accounted for with the use of BIM by the government or owner. Asset locations, shop and as-built drawings, a record of damage to assets (including the time and money spent on repairs or maintenance), and government cost allocation are all part of this.

4 CONCLUSION

Through the review of several pieces of literature, it is possible to apply BIM in dam projects in Indonesia starting from the planning stage, bidding process, construction phase up to the operations and maintenance activities of the dam. It also has the ability to build good coordination among planners, executors/contractors, and consultants to the government/owner as well as in integrating the fields of Architecture, Structure, and Construction (AEC).

Considering the urgency in the application of BIM in future dam projects, planners, contractors, consultants, and government are expected to prepare by ensuring there is:

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