Analysis of the Relationship between Policy, Organization, BIM, WBS, Laser Scanner, and Information Systems with Dam Maintenance Performance

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ABSTRACT: *Indonesia has a list of 201 National Strategic Projects and 48 of which are in the dam construction sector. The construction of these dams aims to support economic growth, enhance community competitiveness, promote equitable development outcomes, and ensure adequate water suppy for agriculture. In reality, many reservoirs and dams suffer from damage and functional decline, posing potential disaster risks in the event of dam failure or collapse. Due to the numerous issues of affecting dams, there has been a paradigm shift in priorities, where dam projects are not only focused on construction but also require optimization of management through operations and maintenance efforts. This research analyzes the relationship model between policies, organizations, BIM, WBS, laser scanning, and information systems with dam maintenance performance. By modeling these relationships, this research is expected to serve as a decision-making tool for prioritizing dam maintenance practices in Indonesia.*

KEYWORDS – *dam, information systems, maintenance performance, modeling relationships, policies*

I. INTRODUCTION

There are 201 National Strategic Projects and 48 of those are dedicated to dam construction which aim to support economic growth, enhance community competitiveness, ensure equitable development outcomes, and secure water supply of agriculture. By 2024, Indonesia is projected to have 230 dams with a total capacity of 3.812,85 m^3 (Ministry of Public Works and Public Housing, 2024).

Dam management can have catastrophic consequences from operational errors. One striking incident in Indonesia was the collapse of Gintung Dam in Banten Province on March 27th, 2009, which destroyed 300 houses and 99 lives. Additionally, the failure of Oseo Dam in East Nusa Tenggara Province resulted in flooding that affected residential areas and farms.

Valeria (2020) emphasized that dam failure is heavely influenced by sediment dynamics. Similarly, Liu (2020) highlighted that improper maintenance can lead to significant structural damage and an increased risk of disasters, suchs as floods and droughts. This perspective aligns with Suyono (1977), who noted that leakage or seepage within the dam structure can compromise dam stability.

Dam maintenance is a critical aspect of ensuring the safety and integrity of dam structures. Several challenges hinder the effectiveness of dam maintenance, infuding the following of these factors:

1. Policy factors
   Inefficient strategies for dam operation and maintenance (Nasrat Adamo et al., 2021) and the lack of standardized maintenance activities (Ahmed Badr et al., 2023).
2. Organizational factors
   The absence of proper planning and budgeting for dam operation and maintenance activities (Ary Aprianto, 2024); insufficient monitoring during the construction process, which impacts the quality of dam structures (Pradika et al., 2020); and inadequate human resources

with the necessary competencies for dam operation and maintenance activities (Victoria et al., 2024).

3. Information system factors
   Incomplete Work Breakdown Structure (WBS) development from the construction phase to dam maintenance (Pradika et al., 2020), and the lack of adoption of Building Information Modeling (BIM) technology (Wahyuningrum et al., 2019).

To support maintenance and ensure construction quality, the government has begun adopting BIM technology. This initiative aligns with the government's implementation of BIM in the Karangnongko Dam Project (Mursyid, 2023). Moreover, laser scanner as part of information systems, also play a crucial role in collecting, processing, and presenting accurate and detailed spatial or geometric data. For example, in GIS, data obtained from laser scanners are used for digital mapping, topographic analysis, and 3D environmental reconstruction (Vosselman& Maas, 2010). In addition, applying the WBS in project management can facilitate a more systematic approach. WBS breaks down the project infto smaller and more manageable components known as work packages (Marchewka, 2015). The integration between BIM and WBS is expected tocreate a more structured and efficient maintenance system.

This study aims to analyze the relationship model between policies, organizations, BIM, WBS, laser scanners, and information systems with dam maintenance performance.

II. RESEARCH OBJECTIVES

The research objectives represent the answers to the research questions of the outcomes intended from this study, as follows:

1. To identify the current dam maintenance system implemented by the government.
2. To identify the variables that are required for dam maintenance activities.
3. To analyze the relationship model bbetween policies, organizations, BIM, WBS, laser scanners, and information systems with dam maintenance performance.
4. To provide recommendations for policy development related to dam maintenance and repair work using WBS and supported by BIM.

III. LITERATURE REVIEW

3.1. Dam maintenance performance

According to the International Commission on Large Dams (1998), a dam is a structure built to retain water or sediment, primarily on rivers, and water management such as irrigation, flood control, and electricity generation. Dam failure refers to the partial or complete collapse of the dam or its auxiliary structures or damage resulting in the dam's malfunction.

Dam operation and maintenance must emphasize that these activities should be well-planned, covering repair systems, cost requirements, personnel avilibility, recorded, and documented sequentially (chronologically).

Maintenance activities are categorized into preventive maintenance and extraordinary maintenance. Preventive maintenance aims to prevent damage and deterioration of the dam and its auxiliary structures, thereby extending the dam's service life. This maintenance is performed routinely and on a schedule basis. In the other side, extraordinary maintenance focuses on repairing damage caused by deterioration, floods, earthquakes, equipment malfunctions, failures (structural, hydraulic, seepage, operational), vandalism, and other factors. This maintenance occurs outside of the established maintenance schedule and includes repair work, reinforcement, and rehabilitation activities.

3.2. Policy

Policy is a set of principles, rules, and procedures designed to regulate the actions of and organization, institution, or government in achieving specific objectives (Nugroho, 2008). Dye (2005) states several factors influence public policy, including politics, economic, social, and cultural aspects as well as technology.

Ministry of Public Works and Public Housing during the 2015-2019 period aimed at achieving goals to support food sovereignty, water security, and energy sovereignty. Water resources management was carried out through water conservation efforts to maintain the function and storage capacity. These conservation efforts were implemented through the construction and rehabilitation of water storage facilities such as ponds and dams/reservoirs, as well as river restoration, lake revitalization, and swamp

conservation.

However, dam optimization faces governance challenges due to sedimentation threats and declining security levels. For example, the water supply for irrigation from dam covers only 12,3% of the total irrigated area. This is due to poor operational and maintenance performance, which are not yet fully integrated for online and real time access for documentation system about infrastructure damage and water usage.

3.3. Organization

Galuppo (2020) states that organizations should not only focus on productivity, but also on fulfilling individual needs and ensuring alignment between individual values and organizational values in order to achieve organizational success.

The development of dams faces complex challenges, rnaging from the planning phase, construction, to operation and maintenance, involving project owners/governments, planners, consultants, and contractors (Catur, 2019). Human resources competency is a key factor in the successful implementation of BIM (Naufal, 2023).

The plan for establishment of a dam management unit must include at least the organizational structure, job descriptions, human resource requirements, and sources of funding. The dam manager is required to develop an emergency action plan. The structure and qualifications of personnel in the organization of dam operation and maintenance activites, which aim for effectiveness and efficiency.

3.4. WBS

The Work Breakdown Structure (WBS) approach, based on the PMBOK 6th Edition, is a highly structured and detailed tool that helps project managers manage various aspects of a project. WBS divides a project into smaller, more manageable elements, which are referred to as work packages. Each work package can be estimated, planned, and monitored effectively. WBS serves as the foundation for other aspects of project management, such as schedule planning, cost estimation, resource allocation, and risk management. The focus of WBS is on specific deliverables and the processes required to achieve them.

3.5. BIM

Building Information Modelling (BIM) has become a transformative force in the construction industry, an advanced tool for information technology, and an integrated digital platform for the design, management, and harmonization of responsibilities among all stakeholders in a project (Jigme Wangchuk et al., 2023). BIM represents innovation in infrastructure projects by advancing conventional methods used throughout the design, construction, and operational processes. According to ISO 19650, BIM involves the use of digital representations of built assets to facilitate the design, construction, and operational processes, forming the foundation for reliable decision-making.

3.6. Laser scanner

Laser scanner is a device to measure the distance, dimensions, or shape of an object using laser technology. Its basic principle involves Its basic principle involves emitting a laser beam onto an object, then the sensor detects the reflection of the laser to determine the distance or characteristics of the scanned object. The data collected by the laser scanner is then processed into a 3D digital model. The accuracy of a laser scanner is highly influenced by various factors, such as the scanning distance, environmental conditions, and device specifications (Gielsdorf et al., 2004). Although highly accurate, laser scanners have limitations, such as low reflectivity of the object's surface, which can lead to measurement errors, and they can be affected by optical interference or dense atmospheric conditions (Bohler et al., 2003).

3.7. Information system

Dam managers are required to established a dam and reservoir information system that is accessible to public by collecting, processing, and provisioning data and information of dams and reservoirs. Furthermore, dam managers should updating the dams and reservoirs information regularly.

IV. METHODOLOGY

Based on the research questions in this study, the research strategy employed includes grounded theory, survey, and case study.The object of this study is the model of relationships between policy, organization, WBS, BIM, and information

systems in relation to dam maintenance performance. The population includes stakeholders involved in the process, such as professionals from relevant agencies, staff directly engaged in emergency response tasks and roles, and the community that directly benefits from the existence of the emergency response team. In accordance with Kumar's theory (2011), the sampling technique used is non-probability sampling in the form of purposive sampling.

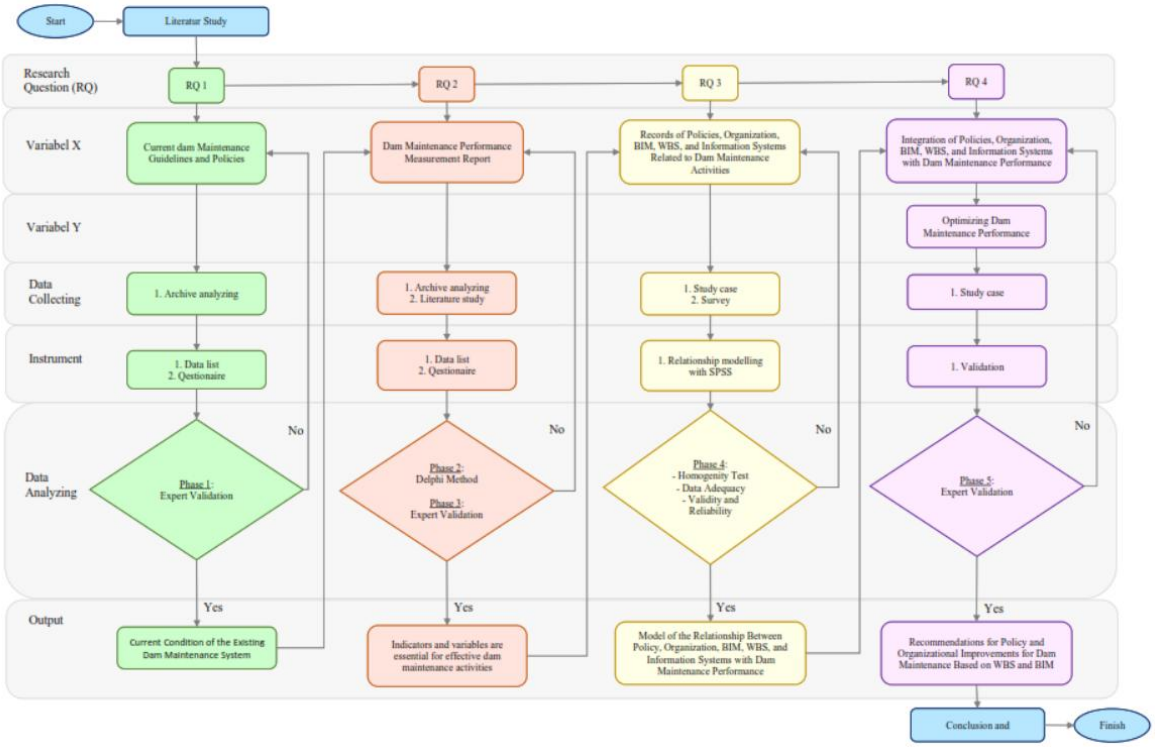

Figure 1. Methodology

V. RESULT AND DISCUSSION

Based on the literature review and previous studies, data collection that conducted through expert validation via interviews and discussions with specialists in the field. The expert validation was carried out to identify the elements and indicators of each variable, namely Policy (X1), Organization (X2), WBS (X3), BIM (X4), Laser Scanner (X5), and Information Systems (X6), which influence Dam Maintenance Performance (Y). The results of the verification, clarification, and validation were provided by experts with a minimum of 5 years of experience in dam operation and maintenance, as well as a minimum of a Bachelor's degree (S1). Data collection in phases 1 and 2 involved 5 (five) experts from the owner/government side. Subsequently, data collection in phase 3 used a questionnaire survey with 71 respondents.

Based on the results of the expert validation on phase 1, the majority of the identified factors have met the criteria or contribute to influencing dam maintenance performance. The experts identified that BIM and Laser Scanner have not yet been fully utilized or integrated into current dam maintenance activities. In contrast, other factors such as policy, organization, WBS, and information systems are already being implemented, although some adjustments are still required to meet the specific needs of each dam.

Results on phase 2 showed all experts agreed that the factors of policy, organization, WBS, BIM, laser scanner, and information systems influence the success of dam maintenance activities.Data collection in phase 3 was conducted using input from the validated data collected in phase 2 by the experts. Subsequently, a questionnaire was distributed using Google Forms. The data obtained from the target respondents were then processed using IBM SPSS.

Policy is the most significant factor in improving dam maintenance performance. The strategies developed by the Ministry of Public Works and Public Housing (Kementerian PUPR) for enhancing dam performance and reducing dam risks are as follows:

a. Improving the safety level of high-risk dams;
b. Conserving dam catchment areas;
c. Enhancing human resource capacity in dam management; and
d. Improving dam operation performance in accordance with standards and supported by competent dam management units.

In this study, the Work Breakdown Structure (WBS) is one of the main aspects that serves as the basis for developing guidelines. This is because WBS can effectively meet the needs of maintenance and repair tasks (Wardhani, 2019). Furthermore, WBS is considered capable of defining the scope of work into simpler components and detailing each deliverable in the project stages (Roswidiyastuti, 2009).

The third dominant factor identified in this study is BIM. According to Yuhang Zhou et al. (2023), BIM modeling can serve as a tool to effectively evaluate operational activities and dam monitoring. The application of BIM is outlined in the Circular Letter No. 04/SE/Da/2023 regarding the Guidelines for Implementing Building Information Modeling (BIM) in the Technical Planning and Construction Implementation of Water Resources Infrastructure. Monitoring and evaluation of BIM implementation are carried out by the Head of the River Basin Authority, from the preparation phase to the construction project monitoring stage.

Code	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Work Experienc	10 years	12 years	15 years	10 years	13 years
Study	Magister	Magister	Magister	Magister	Magister
Position	Operation and Maintenance	Operation and Maintenance	Head of Operation and	Head of Dam Maintenance Unit	Head of Water Management
Duty Location	Sukamahi Dam and Ciawi Dam	Sukamahi Dam and Ciawi Dam	Pamali Juana Dam	Ciawi Dam	Nusa Tenggara River Basin

Figure 2. Expert Validation Data

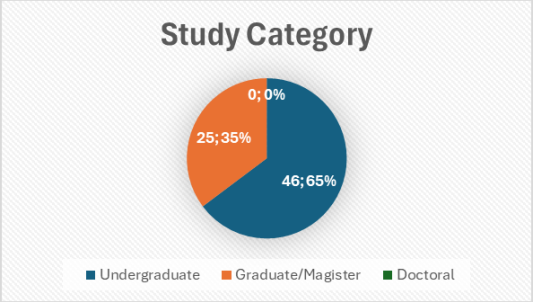

Figure 3. Demographics of the Respondents' Study Background

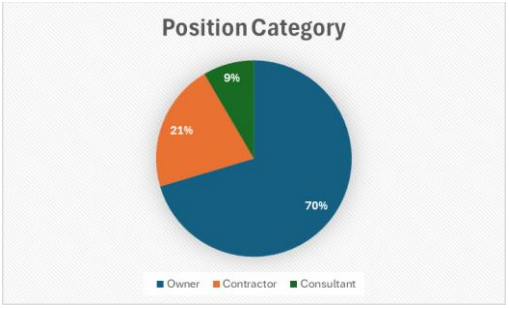

Figure 4. Demographics of the Respondents' Position Background

Figure 5. Demographics of the Respondents' Work Experience Background

VI. Conclusions

This study concludes that the primary factors influencing the performance of dam maintenance are policy, Work Breakdown Structure (WBS), and Building Information Modeling (BIM). A well-defined and structured policy is crucial in setting the direction and goals for dam management and maintenance. For instance, policies supporting the enhancement of dam safety and addressing critical issues such as sedimentation and structural integrity can significantly reduce the risk of failure, thereby improving dam performance. The Ministry of Public Works and Housing has developed strategies to enhance dam performance, including

focusing on high-risk dams, improving water catchment area conservation, and increasing the capacity of human resources in dam management.

Furthermore, WBS has proven to be an effective tool for breaking down dam maintenance tasks into smaller, more manageable components. This structured approach enables stakeholders to monitor project progress systematically, allocate resources efficiently, and provide more accurate cost estimations. By providing a clear structure to maintenance projects, WBS enhances the operational efficiency and effectiveness of the maintenance process, leading to better project outcomes.

Lastly, the application of BIM has been shown to be an invaluable tool in improving dam maintenance performance. BIM facilitates a deeper understanding of dam and infrastructure conditions, enabling more effective monitoring and maintenance. By allowing for better visualization and collaboration, BIM ensures that all stakeholders, such as planners, contractors, and dam operators, can manage the maintenance process more seamlessly. As a result, BIM implementation can significantly improve the quality of dam maintenance and reduce operational risks.

However, while these factors contribute positively to the maintenance of dams, there are some limitations. Policies can be slow to adapt, and local regulations may pose challenges in the implementation of advanced technologies like BIM and WBS. Additionally, the complexity of BIM and WBS may require significant upfront investment and specialized knowledge, which can be a barrier for some organizations. Furthermore, while BIM offers substantial benefits, it is still not widely implemented in some regions, limiting its impact.

In conclusion, clear policy frameworks, a structured WBS, and the integration of BIM technology are critical for improving dam maintenance performance. To maximize the effectiveness of maintenance activities and minimize the risk of failure, dam management should be supported by strong policies, systematic management approaches, and the application of cutting-edge technological tools. The main limitations include the need for continuous policy updates, training for staff on advanced tools, and investment in the necessary infrastructure to adopt BIM and WBS comprehensively.

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