Development information system for building maintenance for structural components of government green building using Building Information Modelling (BIM)

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Abstract. Structural components are the most important components in building from the stages of design-construction-maintenance. The failure of structural components will result in the reliability and function of the building not being achieved. Therefore, maintenance of structural components is one important factor to maintain and achieve the reliability and the function of building. This research discusses about maintenance system in government green building that are not implemented properly due to poor maintenance schedule, undocumented data and no history of maintenance checks stored. Maintenance of structural components that aren’t implemented properly can lead to increased operating and maintenance costs, and potentially increases the risk of building failure. The purpose of this research is to increase the maintenance performance of structural components of government green building. The case study in this research is Ministry of Public Works and Public Housing’s Building which is one of the government green building in Indonesia. The methods that used in this research are literature review, case studies and surveys done by questionnaires from structure’s experts and Greenship Professional. Result of this research in the form of integrated information system development using BIM is expected to facilitate users to improve performance in maintaining structural components of green building.

1. Introduction
Usually the building is planned to function during a certain service / operational period. The potential for damage to a building, whether an old building or a relatively new building is very large, is usually seen damage that occurs after the building starts operating [1]. Based on the appearance that occurs it needs to be identified as early as possible about the existence of other damage that can cause adverse effects on the building, identification of damage that occurs in the building elements needs to be done by looking at so much damage to the building with various causes. To avoid those damage in future, good maintenance is required, both of preventive and corrective maintenance [2]. The implementation of building maintenance work is influenced by various aspects. One of them is the aspect of data and information about the building itself.

Good maintenance requires sufficient data and information about the building. Lack of data and information can result in improper maintenance. With good care, it is expected that the life of an equipment will be longer and can be operated at any time [3]. Historical data during the construction phase contained in as-built drawings are very important in achieving success during the building...
maintenance phase [4]. Gaps in information and knowledge transfer and sharing between various phases of construction and maintenance phase could lead facility management issues [5]. In several cases, government buildings that appear damaged are not maintained well, the use of personal stability and the way it is formed [6].

In addition, the system used by facility management must be easily accessible to make it easier for building users to report damage. The current system used in the Jakarta government building that relies on the call-centre system cannot cover and record all reports at the same time. Paper-based information records also worsen the maintenance system, especially for long-term maintenance. This research improves initial information systems to maintain structural components by developing new systems to improve building maintenance performance, especially in structural components.

2. Literature study

2.1. Structural component maintenance WBS

Work Breakdown Structure (WBS) is the breakdown of work and project results into smaller components that can be better managed in terms of building maintenance. Smaller component defines resources which is consist of materials, tools, and manpower [7]. Variable X1 in this study is maintenance of structural components divided into several sub-variables to facilitate research results. WBS level 5 will be used to define maintenance work and relate it to building performance. There are 42 alternative designs in total that will be tested with the normality test to eliminate variables that are not related to green building performance.

2.2. Creating 3D BIM model based on the guideline

The role of BIM is potentially used for visualization and coordination as a 3D modelling tool [8]. As a picture of government buildings taken as a basis for making models in 3D software followed by information about the material of mechanical components. Expert validation to develop the BIM model is used to produce the right model that improves building performance.

2.3. Integrating BIM model with Web-based information system

A computerized maintenance management system (CMMS) is a tool that brings many benefits to improve maintenance performance and reduce costs [9]. Information systems are used for information, automation, and transformation to reduce and replace human resources [10]. Web-based information systems are used to improve system maintenance and replace the initial call center system. To bridge communication between the BIM model and the web-based information system, BIM will be uploaded to the website to provide real-time data to facilitate facility management. Expert validation of the developed system is also used to produce the right model.

2.4. Relationship test to calculate green building performance

The research hypothesis will be tested using a regression test to find answers to past research questions and to develop a mathematical model between the proposed maintenance information system and the performance of maintaining green buildings. Data sufficiency, normality, reliability, and validity tests will also be tested before entering regression. This study surveyed 50 respondents specializing in green buildings, mechanical components, or building maintenance systems backgrounds.
3. Research method

Figure 1. Operational model of research (top) and research methodology (below).

From the operational model used and the research methodology above, there are two X variables (X.1 is Maintenance System of Structural Components and X.2 is Information System integrated to BIM) that will be linked to achieve the Y variable which is the building maintenance performance. Building performance is divided into 4 categories: safety, comfort, convenience, and health based on Minister of Public Works Regulation No. 24, 2008.

4. Result and discussion

4.1. Mechanical components that enhance the maintenance performance

The result of RQ 1 is expert approval of alternative design variables related to the Y variable. Using the normality test, it shows that only 37 variables out of 42 variables are related to the Y variable, therefore the rest will be eliminated. This test used $\alpha = 0.1$ Shapiro-Wilk method. Hypotheses testing: if $\text{Ho: } P \geq 0.1$ Data is normally distributed and if $\text{Ha: } P < 0.1$ Data may not normally distributed. Validity test is performed as correlation analysis where it's used to measure strength of the association (linear relationship) between two variables. Usually, variables that has $r$ above than ±0.5 has high coefficient of determination (R) to perform regression. So, from the table above we seek variables which has $r$ above than ±0.5. To perform correlation analysis, Hypotheses testing must be done as: if $\text{H}_0: \rho = 0$ (no correlation) and if $\text{H}_A: \rho \neq 0$ (correlation exists). From the tests given, only 8 variables are correlated with the Y variable, therefore only these variables will proceed to the regression test as shown below:
4.2. Development of 3D BIM model integrated with web-based information system
The BIM model was drawn using Autodesk Revit 3D based on building image data from a case study followed by relevant information about mechanical components. All are combined as a baseline and framework to be used in the maintenance phase.

Table 1. Variables that shows strong correlation with green building maintenance performance.

| WBS Level 3 (Sub-work Section) | WBS Level 4 (Work Package) | WBS Level 5 (Alternative Design) |
|---------------------------------|-----------------------------|----------------------------------|
| Foundations                     | Deep Foundations            | X1.2 Well Foundations             |
|                                 | Shallow Foundations         | X1.5 Continuous Foundations       |
| Column                          | Structural Column           | X1.13 Reinforced Concrete Column  |
| Beam                            | Structural Beam             | X1.20 Composite Beam              |
| Stairs                          | Concrete Stairs             | X1.28 Conventional Concrete Stairs|
|                                 | Retaining Wall/             | X1.32 Concrete Retaining Wall/ Diaphragm Wall |
| Wall                            | Diaphragm Wall              | X1.34 Steel Core wall / Shear wall|
| Roof                            | Frame Roof                  | X1.38 Wooden Roof                 |
|                                 | Core wall / Shear wall      |                                  |

Findings from experts show that BIM is best for visualization and coordination. Especially during the post-construction phase, BIM has high potential to be used as a basis for information systems for building maintenance. After the BIM model was developed, this research continues to integrate the BIM model into the web-based information system shown above.
Figure 3. Web-based building maintenance information system.

From the picture above, there are 2 pages that differentiate between the building management page and the building user page. The building management page will function as; notified by damage reported from building users, notified by daily maintenance work, documenting any actions taken in maintenance, reporting work to building owners, accessing BIM for maintenance-related information and updating the energy efficiency of related components. In addition, building user pages will have different functions as: notifying damage to building components and receiving feedback from each report provided. After the two proposed solutions have been tested with a validity test with expert validation, the results show that the web-based information system that is integrated with the BIM model is associated with improving the performance of green building maintenance.

5. Conclusion
- There are 8 variables that are strongly related to structural components in the performance of maintaining green buildings, especially for foundation systems, columns, beams, walls, stairs and roofs.
- Safety, convenience and comfort of maintenance performance is the most dominant performance of the 8 variables.
- The use of BIM in web-based information systems in the maintenance of mechanical components has been proven that it is related to improving the performance of green building maintenance with its function to develop integrated information, automation and communication systems not only for facility management but also building users.

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