Optimizing maintenance of electrical components with BIM and web-based inputs to improve safety performance in government green building

S Dewi*, Y Latief and R A Machfudiyanto

Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI Depok, Jawa Barat 16424, Indonesia

*sridewi.semesta@gmail.com

Abstract. A green building with proper maintenance will have higher energy efficiency and longer lifetime, as damages to building utilities can be minimised. One of the vital utilities are electrical components. Damages to electrical components may have fatal consequences such as short circuit or fire. This research aims to improve the maintenance of electrical components of green building. A case study is taken from a government green building for electrical components, in order to meet the building reliability requirements which consist of safety, health, comfort, and convenience. Maintenance system which is Work Breakdown Structure (WBS) level 4 of building maintenance integrated with information systems and Building Information Modeling (BIM) are influential factors for building maintenance performance. The research methods used are archival analysis, case study, survey, expert judgement, and statical analysis. This research generates product of web based information system integrated with BIM, and also mathematical model that enhance the maintenance performance of government green building for electrical components would become more effective and efficient especially for safety performance.

1. Introduction

Active maintenance accounts for more than 90% of building’s longevity [1]. Without maintenance, damages to structural, architectural, electrical, and mechanical components accumulates over time, causing building failure, meaning shorter building lifespan [2]. This research will only focus on maintenance of electrical components. A proper electrical system must be able to protect the building from danger of fire breaking out caused by short circuit [3]. As a building ages, the electrical components also ages leading to efficiency loss. [4]. Efficient use of electricity is one of the key aspects in the management of green buildings [5]. Fortunately, if active action is taken as a precautionary measure, the efficiency can be maintained even as the building ages. Green building concept is popular in developed country, but recently it has also become a mandatory for new and existing buildings in Jakarta based on Provincial Government of DKI Jakarta Regulation Number 38/2012. Assessment of green building includes location, energy, water, indoor environmental quality, materials, waste and pollution, and management. In reality green building concept is of economic interest due to its premium cost, one of the solution to reduce the cost by using technological advancement [6].

Work breakdown structure (WBS) is a decomposition method for developing maintenance guidelines that aims to make work package more structured to the smallest components [3]. Building information
modeling (BIM) can be both a tool and a process, it can represent the 3D models of an object while BIM also defines the methodology for the design and construction phase [7]. 3D BIM modeling is made from as built drawing of the building which contain identity data of the components. Web of the building based information system enhanced performance of management operational that aims as information, automation, and transformation tool [8]. Furthermore, website can be used as data recording for building maintenance.

This research’s case study is located in Ministry of Public Works building, which achieved platinum Greenship certification from GBCI (Green Building Council Indonesia). The building still uses manual reporting system through the call center, and also paper based system for data recording of maintenance history. This can cause inefficiency and risk of data loss. By applying appropriate and relevant information technology, such as web-based data log, a more effective and efficient building maintenance can be achieved. Usually building information modeling (BIM) is used to conduct virtual construction before actual physical construction, to reduce uncertainty, improve safety, solve problems, and analyze potential impacts [9]. However, BIM can also be used to improve maintenance efficiency of existing building by integrating web based information system with BIM. This capability will be demonstrated in this paper.

2. Method

Archival analysis, survey, expert judgement, and statitical analysis are used for research method. First step of this research generates alternative design of electrical components based on WBS of green building maintenance. Developing website integrated with 3D BIM modeling for the case study building is the second step. The developed website is then validated by experts and users. The last step in this research is to establish a relationship model between building maintenance system and the performance of the building maintenance through expert validation and interview with green building experts. Those data will be tested using statical analysis. The relationship model will be in the form of mathematical model. This research involved 5 experts in green building maintenance for at least more than 10 years and 45 respondents, of whom have Greenship Professional certification from GBCI and more than 5 years’ experience in maintaining green building. Respondents came from various government agencies such as the Ministry of Public Works and the provincial government of DKI Jakarta who were involved in the making of Governor's Regulations on green buildings, as well as various companies related to green building maintenance.

3. Results and discussion

3.1. Validated alternative design of electrical components

WBS level 1 describes as the project name, which is government green building maintenance. WBS level 2 is work section and WBS level 3 is sub-work section. Electrical component is in WBS level 2 and consist of four WBS level 3. Decomposition from WBS level 1 to 3 for building maintenance as shown in Figure 2.

![Figure 1. Research method and process.](image-url)
Figure 2. WBS of Government Green Building Maintenance which focus on electrical work section (WBS lv.2) and decomposed to 4 sub-work section (WBS lv.3).

WBS level 4 is decomposition from WBS level 3, and the last is alternative design which is decomposition from WBS level 4. Based on literature study and expert validation, there are 44 variables were obtained as alternative designs of electrical components, as seen on Figure 3. Those alternative designs for electrical component become variable X1 in this research.

Figure 3. Alternative design of electrical component for government green building maintenance.

3.2. Website integrated with 3D BIM modeling

The 3D BIM modeling is made with Autodesk Revit as shown in Figure 4, this model shows layout on fifth floor of the main building of Ministry of Public Works. From the 3D BIM modeling, the role of BIM is very prominent in terms of visualization and coordination, and also in the context of energy
efficiency, particularly at some stage after construction, BIM is used as premise data for building maintenance [10].

Afterward, web-based information system is developed for logging electrical component maintenance. The interface of website as seen on Figure 5. This log in the website includes building maintenance, repair history, and also reporting of damaged components.

There are two user levels can be used to log in into website, first as the building user and second as the building management. Every building user will have their own identity to log in and make complaint report of damage components to this website, and the building management will directly get the notification for every reports. The reports will be recorded and responded by building management who is responsible for repairs. It will facilitate the existing reporting system in the Ministry of Public Work building, such as call center system. The development of this website becomes a dynamic warning system according to the latest conditions, so that delayed complaints reports can be seen, especially for important components. The building management can quickly repair the damage before it gets worse and requires greater repair costs.

To showcase the capability of the 3D BIM integrated with web based logging a sample case of building’s user logging broken lighting sensor is elaborated. Due to the faulty sensor, the lamps continue to light up despite sufficient sunlight, leading to energy waste. Any occupant of the building can make report to building maintenance management through the website. Once the report reaches the management team, they can use the 3D BIM model to detect the location of faulty sensor. In addition, sensor’s brand, installation date, specification, etc. of the component can be seen from the BIM model. Then the repair team can be dispatched with the necessary replacement sensor. Without 3D BIM model, the repair team can take longer to locate the faulty sensor and may not bring the correct replacement sensor on their first
trip. The repair team then reports their work on website, which can then be evaluated. This evaluation helps to predict and prevent future damages, improving the overall efficiency.

3.3. Relationship maintenance model

The conceptual framework of this research is shown in Figure 6. Variable X1 is alternative designs from decomposition of WBS level 4. Information system as variable X2, which consists of website and BIM are shown in Figure 7.

![Figure 6. Research conceptual framework.](image1)

![Figure 7. Decomposition of variable X2.](image2)

The coordination of information system is an important variable that influence the energy efficiency of the building. Sub-variables of website and BIM are its own function. Website functions are information, automation, and transformation tool [8]. BIM functions are documentation, data integration, visualization, and coordination tool [10]. Referring to Minister of Public Works Regulation Number: 29/PRT/M/2006 about Building Maintenance Guidelines, there are 4 performance indicators for building maintenance, i.e. safety, health, comfort, and convenience, which become variable Y.

Based on respondent questionnaires and statical test, following is the calculation result for variable Y1 (safety performance), using 90% confidence level:

| Variable X1 Building Maintenance System | Variable X2 Information System | Variable Y Green Building Maintenance Performance |
|-----------------------------------------|-------------------------------|-----------------------------------------------|
| X1 Alternative Design (decomposition of WBS lv.4) | X2.1 Website | Y1 Safety |
|                                        | X2.2 BIM | Y2 Health |
|                                        |          | Y3 Comfort |
|                                        |          | Y4 Convenience |

![Table 1. Regression output.](image3)

| Regression Statistics |   |
|-----------------------|---|
| Multiple R            | 0.709528 |
| R Square              | 0.503430 |
| Adjusted R Square     | 0.467095 |
| Standard Error        | 0.423379 |
| Observations          | 45 |

| Table 2. Anova.         |   |
|-------------------------|---|
| df                      | SS  | MS  | F      | Significance F |
| Regression              | 3.00 | 7.45 | 2.48   | 3.85     | 0.02 |
| Residual                | 41.00 | 7.35 | 0.18   |         |      |
| Total                   | 44.00 | 14.80 |        |         |      |

| Variable X1 | Coefficients | Std Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 90.0% | Upper 90.0% |
|--------------|--------------|-----------|--------|---------|-----------|-----------|-------------|-------------|
| Intercept    | 2.048        | 0.411     | 4.989  | 0.000   | 2.129     | 2.157     | 2.739       |
| X1.7         | 0.295        | 0.217     | 1.360  | 0.181   | -0.143    | 0.733     | 0.660       |
| X1.24        | 0.142        | 0.285     | 0.497  | 0.622   | -0.434    | 0.718     | -0.338      | 0.622       |
| X1.2.2       | 0.153        | 0.202     | 0.758  | 0.453   | -0.255    | 0.561     | -0.187      | 0.493       |

From the correlation and regression test, only Y1 has significant relation with variable X. And only three variable X have significant impact to variable Y. Those are solar panel, high voltage cable and data integration for BIM. This coefficient can be written as mathematical equation:
This result is conformed with the literature that explained maintenance of electrical component can increase building safety performance. Solar panel is one of the renewable energy, it directly converts the sun’s energy into electrical energy through the photovoltaic effect. Maintenance of solar panel is quite easy, just clean the cell from dust or dirt for optimum output. The energy output from solar panel helps to reduce energy consumption [11]. High voltage cable as a part of electricity load based on WBS. Replacement of a damaged cable before its age requires a much more expensive cost than its maintenance [12]. Besides replacement costs, the fatality risk from unmaintained cables must be taken into account. Therefore well maintained of high voltage cable as a part of electrical component could increase building safety performance. BIM purpose is to transfer data into facility management operations, so BIM provides a model which is integrated with databases to store all information. BIM can be defined as the role of real-time documentation tools in the repository to manage information about buildings during the life cycle, so that the owner can use it to manage facilities [13].

4. Conclusion
The development of this alternative designs for electrical components becomes a supporting tool for the related green building maintenance process. From 44 variables $X_1$ and 7 variables $X_2$, only 2 variables $X_1$ and 1 variables $X_2$ have significant relation with green building maintenance. Those independent variables have significant impact only to safety performance. This means maintenance for electrical components in green building have a more significant correlation or relationship to increase safety performance based on research results, compared to health performance, comfort and convenience. This applicable to government green buildings in Jakarta. As a result, this paper assist responsible parties for building maintenance to overcome the problems that often occur in the maintenance of electrical components in the government green building. The existence of an integrated website and BIM increases green building maintenance performance in terms of information, documentation and data integration.

Acknowledgement
The authors wish to thank and acknowledge Project Management Study Program, Faculty of Engineering, Universitas Indonesia, Indonesia, for generous support and encouragement of this research especially for the networking to green building colleague. We also thank to all the organizations and individuals who kindly participated in the research. Their time and input in the interview and survey are much appreciated.

References
[1] Olanrewaju L A, Idrus A and Khamidi M F 2011 Investigating building maintenance practices in Malaysia: A case study Structural Survey 29(5):397-410
[2] Machfudiyanto R A , Latief Y, Soeandji B S and Putri P A 2018 Improving business processes to develop standard operation procedures on government building maintenance work in Indonesia MATEC Web of Conferences p 195
[3] Ilham R M, Latief Y, Riantini L S and Susilo B 2018 Development of maintenance-repairation guidance and material specifications for green building’s electrical component in government building based on work breakdown structure (WBS) IOP Conference Series: Materials Science and Engineering p 446 012005
[4] Cheng C, Zhang Y, Niu Y and Ren L 2018 Research on energy saving technology and design for green building electrical International Conference on Engineering Simulation and Intelligent Control (ESAIC) p 283-285
[5] Illankoon I M C S, Tam V W Y, Le K N and Shen L 2017 Key credit criteria among international green building rating tools Journal of Cleaner Production 164 pp 209-220

$$Y_1 = 2.048 + 0.295X_{1.7} + 0.142X_{1.24} + 0.153 X_{2.2}$$ (1)
[6] Basten V, Latief Y, Berawi M A, Rsiwanto and Muliarto H 2018 Green building premium cost analysis in Indonesia using work breakdown structure method *IOP Conf. Series: Earth and Environmental Science* **124** 012004

[7] Farooq J, Sharma P, Kumar S 2017 Applications of building information modeling in electrical system design *Journal of Engineering Science and Technology Review* **10**(6) pp 119-128

[8] Alaraifi A 2012 The application and impact of sensor based information systems in data centers: a literature review *Procedia Engineering* **41** pp 819-826

[9] Smith P 2014 BIM & the 5D project cost manager *Procedia – Social and Behavioral Sciences* **119** 475-484

[10] Motawa I and Almarshad A 2013 A knowledge-based BIM system for building maintenance *Automation in Construction* **29** 173-182

[11] Maghami M R, Hizam H, Gomes C, Radzi M A and Hajighorbani S 2016 Power loss due to soiling on solar panel: a review *Renewable and Sustainable Energy Reviews* **59** 1307-1316

[12] Zhou C, Yi H and Dong x 2017 Review of recent research towards power cable life cycle management *IET Journals* **2**(3) 179-187

[13] Wills N and Diaz J 2017 Integration of real-time data in BIM enables FM processes *Building Information Modelling (BIM) in Design, Construction and Operations II* pp 127-133