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Development of E-Maintenance in Green Building Maintenance and Repair Work of Government Buildings Based on Work Breakdown Structure Using Building Information Modeling

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Abstract

Government building is one of the country's assets that has a very strategic and urgent function for the interests of public services. In order to realize sustainable development, it is necessary to carry out government buildings that implement the integration of technical, economic, social and environmental aspects effectively through green buildings. Green buildings have measurable performance in saving energy, water and other resources. Green buildings of government buildings require effective and efficient maintenance and repair management to maintain the reliability of buildings and their facilities and infrastructure so that they are always worthy of functions both in terms of safety, health, comfort and convenience. The development of technology and information systems has led to the concept of e-maintenance which combines the principles of maintenance, web services and the principles of modern electronic collaboration. E-maintenance combined with Work Breakdown Structure (WBS) and integrated with Building Information Modeling (BIM) will improve the building maintenance and repair process that is precise, accurate, fast and easy. This study uses primary and secondary data from the literature and is validated by experts through questionnaires and through Focus Group Discussion (FGD)

Keywords: Building Information Modeling (BIM), Building Maintenance, E-maintenance, Government Building, Green Building, Work Breakdown Structure (WBS)

I. INTRODUCTION

State buildings hereinafter referred to as government buildings in the Minister of Public Works and Housing Regulation No. 22 of 2018 are defined as buildings for official purposes that become state or regional property and will be held with funding sources originating from the State Budget (APBN) and / or the Regional Budget (APBD), or other legal acquisition (Ministry of Public Works and Housing, 2018). In order to realize sustainable development, it is necessary to implement buildings that implement technical, economic, social and environmental integration effectively. The Indonesian Government's efforts to realize sustainable development in the implementation of buildings including government buildings is through the issuance of Minister of Public Works and Housing Regulation No. 2 of 2015 concerning Green Buildings.

Green buildings are an alternative choice for building operations in an era of global warming that is increasingly recognized as a way to reduce carbon dioxide (CO2) emissions and energy consumption, because buildings are one of the contributing sectors of greenhouse gas emissions in the world (Wu & Low, 2010; Alsanad, 2015) . An interesting concept of green buildings is the fact that technological advancements have combined the categories of high performance and green, green building performance will result in real cost savings exceeding the amount of costs incurred at an early stage (Wu & Low, 2010). Green buildings provide financial benefits that are not provided by conventional buildings, such as energy and water savings, waste reduction, improving environmental quality in the room, increasing employee comfort / productivity, reducing employee health costs, and reducing operating and maintenance costs (Kats, 2003) .

The importance of maintenance and repair functions has increased because of its role in maintaining and increasing system availability and security, as well as quality (Muller et.al., 2008). Buildings that have stood for decades will experience a decrease in quality, both structural and non-structural. If the building can be used functionally, then the building needs maintenance and care to minimize the risk of building users (Dermawan & Wijaya, 2018). But in actual practice, most buildings are always maintained with 'ad-hoc' maintenance, where damage to the building will wait until complaints are made before repairs are made (Zulkarnain & Rahman, 2011). In fact, poor and improper maintenance and repair of buildings will cause more damage and more expensive repair costs if left unattended (Suffian, 2013).

The development of technology and information has led to the concept of e-maintenance which provides opportunities for a new generation of maintenance. The concept of e-maintenance integrates the principles of existing remote maintenance, with web services and the principles of modern electronic collaboration. Such collaboration makes it possible to share and exchange not only relevant data and information but also all knowledge and intelligence that is available and can be used in the right place and time to facilitate reaching good maintenance and repair decisions (Lee et.al., 2006; Muller et al., 2008). E-maintenance is a maintenance governance concept where assets are monitored and managed through the internet (Levrat et al., 2008). E-maintenance aims to support changes in maintenance activities after "failing and fixing" towards "predictions / estimates and proactive prevention strategies" (Iung, 2003; Lee et al., 2006).

Maintenance and care and / or e-maintenance included in the management of facilities is a difficult and complicated job. Facility staff usually use paper or information systems to record facility maintenance work. However, it is not easy for facility staff to refer to 2D CAD-based traditional information illustrations in facility maintenance (Su et.al., 2017). To overcome these problems is to implement and develop Building Information Modeling (BIM) modeling as a 3D information model for managing and maintaining facilities (Su et al., 2017). BIM is a 3D model-based process that provides architecture, engineering and construction professionals with insights and equipment to plan, build and manage buildings and infrastructure more efficiently (Autodesk, 2019).

The maintenance and repair activities of buildings especially green buildings of government buildings using both conventional systems and e-maintenance require a detailed Standard Operational Procedure (SOP) through the use of Work Breakdown Structures (WBS). WBS is one of the tools available to project managers to determine and organize projects (Ibrahim et.al., 2007). WBS is a hierarchical decomposition of the total scope of work to be carried out by the project team to achieve project objectives and produce the required results (Project Management Institute, 2017). Each decreased WBS level represents an increasingly detailed definition of project work. WBS defines all work and not just project work, thus clarifying the scope of the project; provide a baseline for controlling subsequent changes; key inputs to other project management processes, such as resource planning, cost estimation, scheduling development and risk management; and provides a framework for project control, performance monitoring and communication platforms with stakeholders.

I.I Use of Government Green Buildings in Indonesia

In Indonesia, the implementation of buildings that implement mandatory green building requirements has only been carried out by the DKI Jakarta Government in 2012 through Governor Regulation No. 38 of 2012 concerning Green Buildings and Bandung City Government in 2016 through the Mayor of Bandung Regulation No. 1023 2016 About Green Buildings. Whereas in Minister of Public Works Regulation No. 2 of 2015, mandatory buildings to apply green building requirements only apply to buildings with no simple or special complexity, buildings up to 2 (two) floors with a total floor area of more than 5,000 m2, and buildings that consume very large amounts of energy, water and other resources and have significant savings potential (Ministry of Public Works and Housing, 2015).

In 2008, a non-profit organization called the Green Building Council Indonesia (GBCI) emerged, which pioneered the introduction of the concept of green bulding in Indonesia (Wimala et.al., 2016). GBCI appointed an independent business entity named PT Sertifikasi Bangunan Hijaus to certify buildings in accordance with the green building assessment standards in Indonesia with a standard product called GREENSHIP (PT Sertifikasi Bangunan Hijau, 2019). GREENSHIP is divided into 3 (three) categories, namely Certified (Final Assessment), Registered, and Design Recognition (DR) which includes assessments for new buildings, existing buildings, interior spaces, homes, and neighborhoods. Data on buildings in Indonesia whether certified, registered or obtained design recognition as green buildings are presented as in Table 1.

Based on Table 1, it can be seen that the impact of the absence of government regulations that mandate (mandatory) green building requirements for all buildings, until 2019 there is a significant difference between government buildings and non-government buildings both certified, registered and obtained design recognition in the program. GREENSHIP.

I.II Implementation BIM in Indonesia

Indonesia is a country that has not required the use of BIM for infrastructure, but only classifies BIM as a technological innovation as regulated in Law Number 2 of 2017 concerning Construction Services Article 5 paragraph (5), which states that the Central Government has the authority to develop material standards , and construction equipment, and technological innovation (Republic of Indonesia, 2017). Whereas in the Appendix to the Minister of Public Works and Housing Regulation No. 22 of 2018 it is stated that the use of BIM must be applied to non-modest state buildings with criteria above 2,000 m2 and more than 2 (two) floors (Ministry of Public Works and Housing, 2018). The number of government buildings with an area of more than 2,000 m2 and more than 2 (two) floors from 2008 to 2018 is 436 buildings and all of them have not used BIM modeling (Directorate General of Human Settlements, 2019).

Table 1. Green Building in Indonesia

GREENSHIP	Certified (Final Assesment)		Registered		Design Recognition	
	Government	Non Government	Pemerintah	Non Government	Pemerintah	Non Government
New Bulding	3	22	11	59	2	31
Existing Bulding	1	11	0	5	0	0
Interior Space	0	2	0	2	0	0
Homes	0	0	0	0	0	0
Neighbourhood	0	0	2	2	0	0

Source: PT Sertifikasi Bangunan Hijau (2019)

Currently Indonesia is based on the BIM roadmap sequence namely adoption, digitalization, collaboration and integration, until 2019 is still in the adoption phase (Ministry of Public Works and Housing, 2017). In this adoption phase, the BIM standard is prepared as a means of communication of construction stakeholders, providing training and various BIM simulations for all regulatory stakeholders related to construction and making BIM and making BIM a curriculum and competency standard for universities and professional associations. In the discussion that has been outlined, it can be concluded that in Indonesia there is a need for guidance on building maintenance, especially for government buildings that apply the concept of green building. In connection with the development of technology and information on the use of e-maintenance and BIM is the right solution. Based on the literature that has been studied, there have been many studies on e-maintenance for government buildings, BIM and Work Breakdown Strucure (WBS), but there is no research that combines the three objects into a single unit as a whole.

This study aims to develop e-maintenance for the maintenance and repair work of green buildings of WBS-based government buildings by using BIM to improve building maintenance and repair performance. The research began by analyzing policies on the maintenance and repair work of government green buildings, developing guidelines for the maintenance and repair of WBS-based government green building buildings, developing e-maintenance for the maintenance and repair work of WBS-based government green building buildings and developing e-maintenance for maintenance works and maintenance of green buildings in WBS-based government buildings by using BIM to improve building maintenance and repair performance

II. THEORITICAL STUDY

II.I Government Building

Pursuant to the Minister of Public Works Regulation No. 22 / PRT / M / 2018 concerning Technical Guidelines for the Construction of State Buildings, Government Buildings or State Buildings are buildings for official purposes that become state or regional property and will be held with funding sources derived from the Revenue Budget and State Expenditure (APBN) and / or Regional Revenue and Expenditure Budget (APBD), or other legal acquisition (Ministry of Public Works and Housing, 2018).

Referring to PMK 248 / PMK.06 / 2011 concerning the standard of goods and the standard requirement for state property in the form of land and / or buildings, the classification of state buildings can be distinguished by complexity, namely simple buildings, non-simple buildings and special buildings. Other classifications are based on building users, which can be divided into several types, namely office building buildings, state house buildings and other buildings of a special nature (Ministry of Finance, 2011).

II.II Green Building

Green building is one part of sustainable development (sustainable development) which is a process that makes people aware of improving their quality of life in protecting and enhancing the earth's carrying capacity. In the framework of sustainable development, green building is beneficial for human health, community, environment, and life cycle costs (Wu & Low, 2010). The application of the concept of green buildings encountered obstacles, namely the addition of costs specifically at the beginning of development due to the use of green techniques such as high-performance isolation protection, water and energy saving equipment that have an impact on increasing capital costs (Shi et.al., 2013).

II.III Maintenance and Repair Building

According to the Minister of Public Works Regulation Number: 24 / PRT / M / 2008 concerning Guidelines for Building Maintenance and repair of Buildings is divided into:

1. Preventive maintenance is an activity to maintain the reliability of buildings and their infrastructure and facilities so that buildings are always worthy of function (Ministry of Public Works, 2008) which are carried out regularly (Aboelmaged, 2015). Preventive maintenance is established to overcome the losses from corrective maintenance, by reducing the possibility of damage and avoiding unexpected failure (Mydin, 2016).

2. Corrective maintenance is the activity of repairing and / or replacing parts of a building, components, building materials, and / or infrastructure and facilities so that the building can remain functional (Ministry of Public Works, 2008). Corrective maintenance is a form of routine maintenance that is carried out after a problem requires action (Aboelmaged, 2015).

II.IV E-maintenance

The concept of E-maintenance is a new way of thinking or as a new maintenance technology. E-maintenance is a maintenance governance concept where assets are monitored and managed through the internet (Levrat et al., 2008). E-maintenance increases the possibility of (1) utilizing data from various sources; (2) to process large volumes of data and make more advanced reasoning and decision making; and (3) to implement collaborative activities (Iung et.al., 2009).

Problems related to the type of maintenance, equipment, and activities. With regard to the type of maintenance, there are four things related to e-maintenance namely: security, risk management, and human resource issues, collaborative maintenance (eg network and integration issues), distributed maintenance (eg optimization and synchronization problems), and predictive maintenance (eg diagnostic and prognostic methods) (Marquez & Iung, 2008; Muller et al., 2008).

II.V Work Breakdown Structure (WBS)

WBS can be defined as a group of results-oriented deliverables to project elements, which govern and determine the overall structure of the project (Jung & Woo, 2004). Work Breakdown Structure (WBS) is the breakdown of work and project results into smaller components that can be better managed. The making of WBS is the process of describing the results of work and projects in the form of individual components in the form of top-down lists and hierarchically describing the work components (Farizi & Latief, 2018). time, cost management, quality management, resource management, communication management, risk management and procurement management (Project Management Institute, 2017).

II.VI Building Information Modeling (BIM)

BIM is a 3D model based process that provides Architecture, Engineering and Construction (AEC) professionals with insights and tools to plan, build, manage buildings and infrastructure more efficiently (Autodesk, 2019). BIM is able to transform how a building is designed and built, able to facilitate multi-disciplinary coordination, integration of 3D design, analysis, cost estimation, and construction scheduling (McArthur, 2015). The use of BIM in various process phases consists of various types, namely 3D, 4D (+ cost), 5D (+ scheduling), 6D (+ sustainability), and 7D (+ facility management) (Kacprzyk & Kępa, 2014).

In general the purpose of BIM is to transfer data into FM operations. So BIM provides a model that is integrated with databases to store all information. Therefore, BIM in FM can be defined as a real-time documentation tool in a repository / storage area to manage information about buildings during the life cycle, so that the owner can use it to manage facilities (Azhar et.al., 2012).

III. METHODOLOGY

This research was developed based on several previous studies on the relationship between 5 (five) research variables. The linkage of the summary of various previous studies with the research model can be seen in Fig. 1

This research consists of 4 (four) Research Questions (RQ). RQ 1 related to policy analysis for government green building, RQ 2 is related to WBS-based government green building maintenance and repair guidelines, RQ 3 relates to WBS-based e-maintenance for government green buildings while RQ 4 relates to WBS-based e-maintenance that integrated with BIM for government buildings green buildings.For each stage the RQ consists of 3 (three) general stages, namely input, process and output. Each stage is described in a more detailed research method for each RQ as in Fig. 2

Data validation used in this study is to use the Delphi Method.

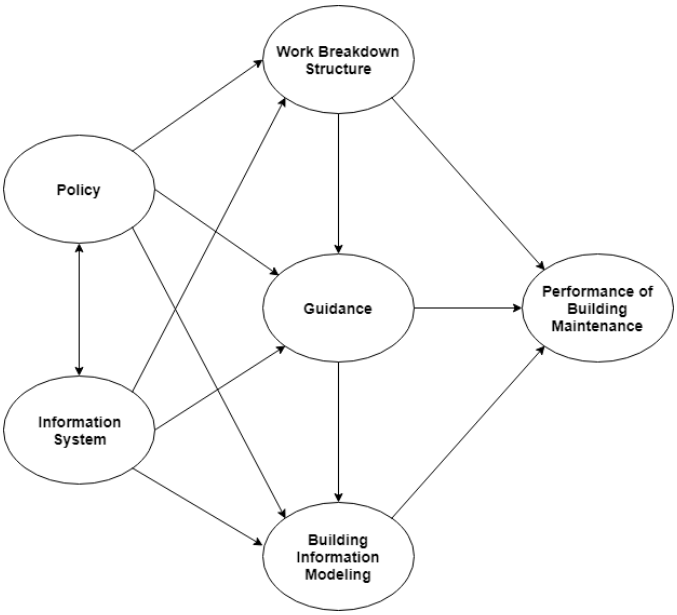

Fig. 1 Conceptual Model Development Framework WBS-based e-maintenance and integrated with BIM

IV. RESULT AND DISCUSSION

This study produced 4 (four) findings based on the existing Research Question (RQ), namely policy analysis for green buildings of government buildings, guidelines for maintenance and repair of green buildings of WBS-based government buildings, WBS-based e-maintenance for green buildings of government buildings and e- WBS based maintenance integrated with BIM for green buildings of government buildings.

IV.I Policy for Green Building of Government Building

Based on Republic of Indonesia Government Regulation No. 38/2007, national policies in Indonesia consist of Norms, Standards, Procedures and Criteria. In preparing the Policy for Green Building of Government Building, policy factors are grouped into 2 (two), which are related to the maintenance and repair of buildings and the appropriateness of building functions.

From the results of the identification of maintenance and repair policy factors that affect the performance of the green building functions of government buildings, obtained 3 (three) dominant factors, namely planning and development (X1), implementation (X2) as well as information and systems (X3). The function worthy factors that have an important role are safety (Y1), health (Y2), security (Y3) and comfort (Y4) (Adam & Latief, 2018).

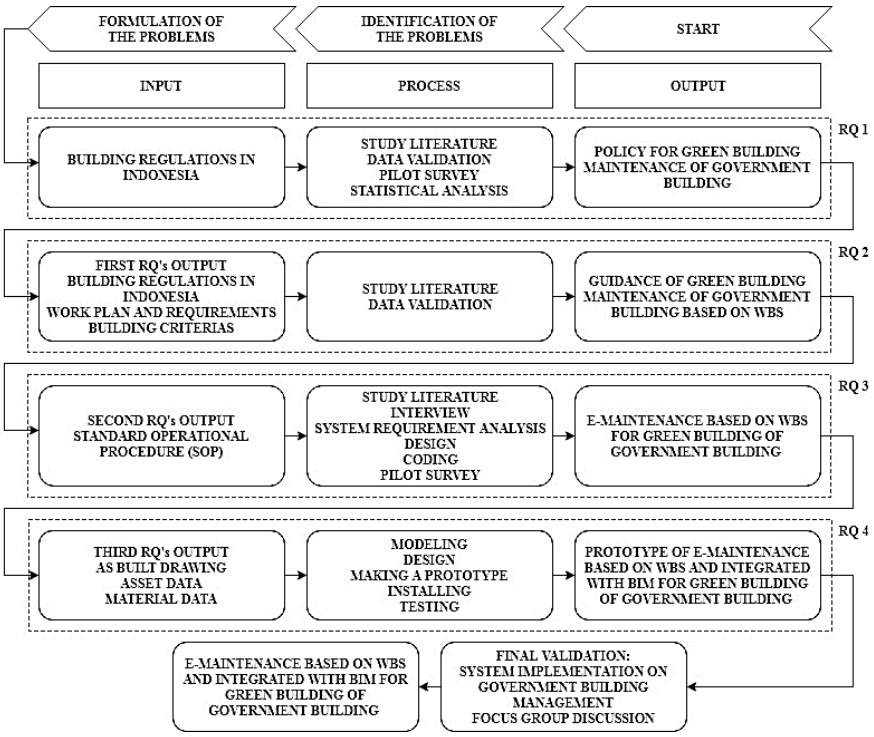

Fig. 2 Research Method

In addition to the identification of factors, further research is carried out to obtain a modeling scheme from the results of an analysis of effective operational models to improve the performance of the feasibility of the function in terms of maintenance and repair policies with the results as in Fig. 3.

Based on Fig. 3, the relationship between variables and the relationship between integral variables can be explained through Table 2.

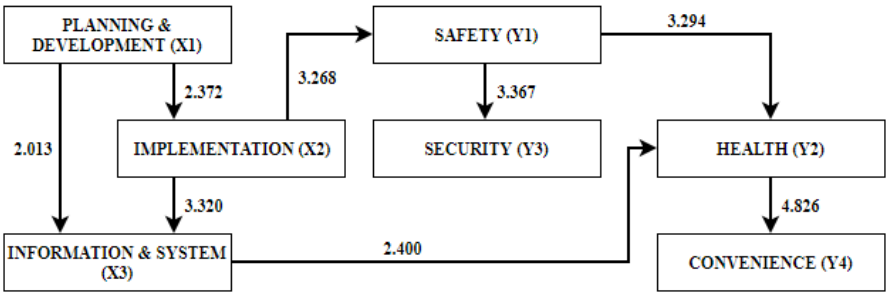

Fig. 3 PLS Algoritm – Full Process Model

Table 2. Identification Relationship Reasearch Variables

No	Relationship
1	Planning and Development > Implementation
2	Planning and Development > Information and System
3	Implementation > Information and System
4	Implementation > Safety
5	Information and System > Health
6	Safety > Security
7	Safety > Health
8	Health > Convenience
9	Planning and Development > Implementation > Information and System
10	Planning and Development > Information and System > Health > Convenience
11	Planning and Development > Implementation > Safety > Security
12	Planning and Development > Implementation > Safety > Health > Convenience

IV.II Guidance of Green Building of Government Building Maintenance Based on WBS

Guidelines for the maintenance and repair of green buildings of government buildings compiled on the basis of WBS. Maintenance and repair work of green buildings of government buildings are divided into 5 (five) clusters namely structures (Setiawan et.al., 2018), architecture (Pratiwi et.al., 2018), mechanical (Aryaningrum et.al., 2018), electrical (Ilham et.al., 2018) and housekeeping and landscape (Rahmah et.al., 2018).

Based on the results of literature studies and surveys through questionnaires to several experts, the maintenance and repair work of green buildings of government buildings are broken down into 5 (five) WBS levels, namely the name of the project (level 1), group of jobs (level 2), type of work (level 3), work packages (level 4) and finally the alternative design / method (level 5). The detailed examples of WBS for the maintenance and repair work of green buildings in government buildings can be seen in Fig. 4 and Table 3.

In addition, WBS can identify all the resources needed, including materials, tools and human resources (manpower). Examples of identified identification models can be seen in Table 4.

Based on WBS, Standard Operational Procedure Maintenance and repair of green buildings of government buildings can be developed and improved. SOP can be divided into 2 (two) stages, namely preventive maintenance and corrective maintenance (Machfudiyanto et.al., 2018). Examples of Standard Operational Procedures can be seen in Table 5.

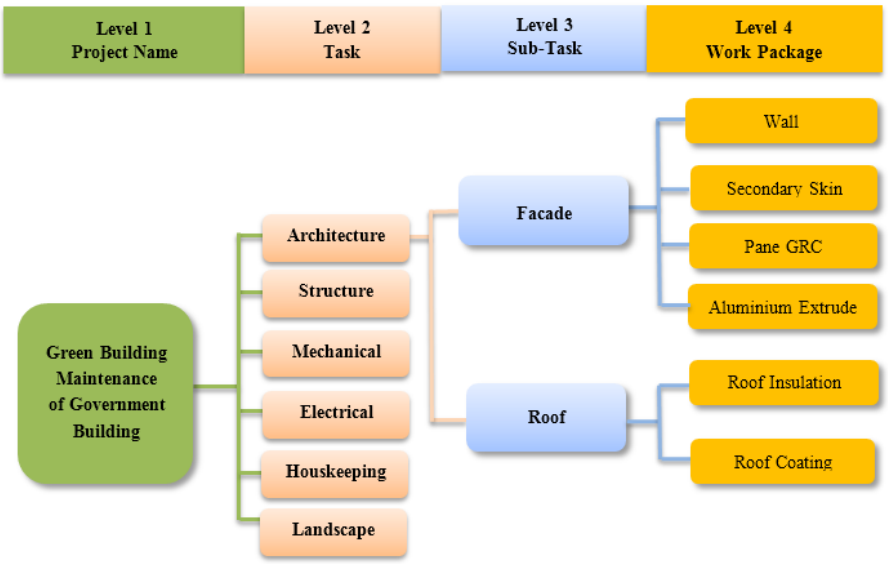

Fig. 4 WBS Details on Building Maintenance and repair of Green Buildings in Government Buildings

Table 3. Alternative Design / WBS Method for Maintaining Green Buildings in Government Buildings

WBS Level 1	WBS Level 2	WBS Level 3	WBS Level 4	Alternative Design/Method
Project Name	**Task**	**Sub-Task**	**Work Package**	
Green Building Maintenance of Government Building	Architecture	Facade	Wall	Expose Brick Wall
				Sticky Brick Wall
				Precast Concrete Wall
				Tempered Glass
			Secondary Skin	Surtain Wall (Cladding Alumunium Composite)
				Sunscreen Lattice
			Pane GRC	
			Alumunium Extrude	

Table 4. Model of WBS Identification Results in Maintenance and Repair Work Green Buildings Government Buildings

Code	**Description**			
WBS Level 2	Task		Architecture	
WBS Level 3	Sub Task		Façade	
WBS Level 4	Work Package		Wall	
	Desain Alternatif/Method		Expose Brick Wall	
Work Package	**Alternative Design/Method**	**Activity**	**Resources**	
Wall	Expose Brick Wall	Inspection	Wage	Labourer
			Tool	Checkllist, stationary
		Preventive Maintenance	Wage	Builder
			Tool	Purifier
			Material	Liquid
		Corrective Maintenance	Wage	
			Tool	Shovel, waterpass, trowel, light toothed brick 6x6 mm, electrical mixer, rubber hammer, saw
			Material	Cement, local brick

Table 5 Standard Operational Procedure for Maintenance and Repair of Green Buildings in Government Buildings

STANDARD OPERATIONAL PROCEDURE – Expose Brick Wall
Inspection
TERMS OF IMPLEMENTATION 1. Routine inspection using checklist forms 2. Analyzing the results of the inspection whether there is a need for improvement
Preventive Maintenance
TERMS OF IMPLEMENTATION 1. Prepare equipment for complete cleaning. 2. Clean the surface from sticking stains, using equipment adapted to the wall surface base material, if needed.
Corrective Maintenance
TERMS OF IMPLEMENTATION 1. Check the damage. 2. Analyzing the need for equipment and materials needed for repairs. 3. Prepare equipment to check and repair damage completely. 4. Replace the damaged surface layer with a new layer. 5. Replacing damaged material with new materials that are suitable and similar. 6. Checking the improvement results.
Material Specification
MATERIAL REQUIREMENTS 1. Requirements for the material used are as follows: a. Super Quality Bricks must fulfill SNI.SO4 - 89 – F b. Portland cement must fulfill SNI.SO4 - 89 – F c. Sand must fulfill SNI. SO4 - 89 – F d. Water must fulfill PUBI - 1982 article 9 2. Quality standards comply with relevant SNI standards regulations
BRAND RECOMMENDATIONS a. Cement - Indocement - Semen Gresik

IV.III E-maintenance Based on WBS and Integrated with BIM for Green Building of Government Building

The development of WBS-based e-maintenance for green buildings in government buildings requires inputs including (1) Standard Operational Procedures for the maintenance and repair of green buildings in government buildings; (2) guidelines for maintenance and repair of green buildings in WBS-based government buildings; (3) data checklist in conducting every maintenance and repair of green buildings of government buildings; and (4) information related to the maintenance and repair of green buildings of government buildings and forms / templates for the needs of maintenance and repair activities.

Flowcharts that describe the process of developing a WBS-based information system (e-maintenance) by integrating BIM can be seen in Fig. 5. While the results of the e-maintenance interface for the maintenance and repair work of green buildings of government buildings can be seen in Fig. 6

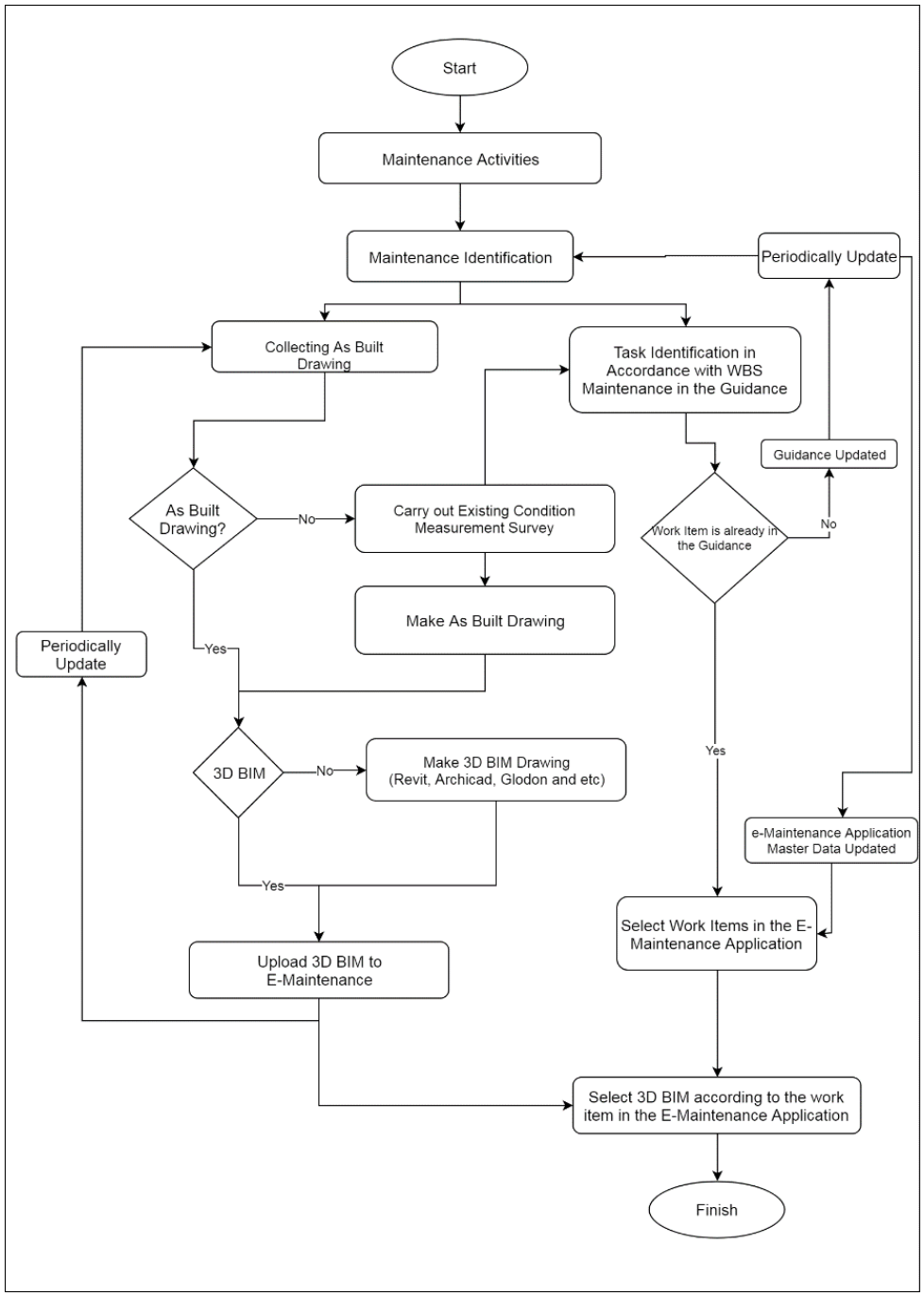

Fig. 5 Information System Development (E-Maintenance) Flowchart Based on WBS by using BIM

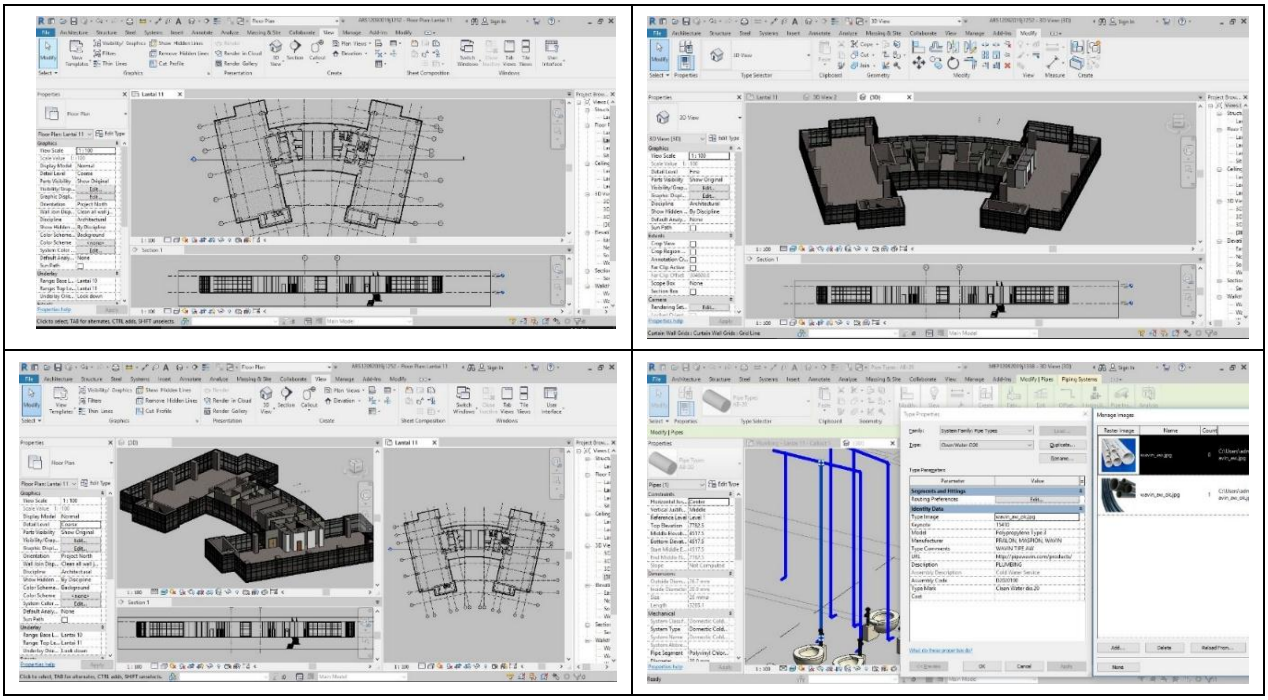

Fig. 6 WBS-Based E-maintenance Interface Using BIM on the Maintenance and Repair Work of Green Buildings in Government Buildings

VI. CONCLUSION

The purpose of this study was to develop e-maintenance in the maintenance and repair work of green buildings of WBS-based government buildings using BIM through 4 (four) RQ stages. Policies related to building maintenance and repair can affect the performance of government buildings' green buildings, namely safety, health, security and comfort (Ministry of Public Works and Housing, 2018) so that building maintenance and repair performance increases.

Whereas the existence of WBS-based guidelines is able to improve the performance of building maintenance and repair because it is able to improve the accuracy of the estimated costs and duration of the WBS elements, find out precisely the internal time of the work process of the WBS elements, and organize to monitor the process between realization and work plans for costs and work-related schedules (Project Management Institute, 2017).

The development of an information system (e-maintenance) based on WBS and integrated with BIM is expected to improve the performance of building maintenance and repair.The purpose of this study is to develop e-maintenance in the maintenance and repair work of green buildings of WBS-based government buildings using BIM. With the development of the system, BM can identify the scope of work and Standard Operational Procedures that must be obeyed. Information and systems are one of the dominant factors that affect the performance of building maintenance and repair (Adam & Latief, 2018). WBS-based information systems that are integrated with BIM can improve the performance of building management by integrating and automating scope management and scheduling management (Watchson & Latief, 2019).

The development of this system is able to bring benefits such as saving maintenance and repair costs, reducing paper usage, restructuring human resource management as well as the role of personnel and job descriptions (Watchson & Latief, 2019).

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