Development of A Quality Management System for Maintenance and Repair Work of Electrical Components in The Nusantara Paripurna Building in the Parliamentary Complex Based on Work Breakdown Structure Integrated Building Information Modeling to Improve Maintenance Performance

Yulius Arie Prayoga[1], Yusuf Latief[1]

[1](Department of Civil Engineering, Faculty of Engineering, University of Indonesia, Depok, West Java, Indonesia)

Abstract: *The Nusantara Paripurna Building, as a state building, requires maintenance and repair to preserve its function and value as an asset, one of which is the electrical component. Electrical short circuits within the Nusantara Building can have fatal consequences, such as fires. The government allocates funds to maintain the building's reliability, necessitating the development of a quality management system (QMS) as the foundation and procedure for maintenance and repair workin the Nusantara Paripurna building to continue to meet the requirements for building functions such as safety, health, comfort, and convenience. The research method used in this study is the Delphi method and respondent survey. The result of this research is that the QMS document includes guidelines, standard operating procedures, work instructions, checklists, and quality records for electrical components based on a Work Breakdown Structure (WBS) integrated with Building Information Modeling (BIM) can improve maintenance performance. T-value analysis using Software SmartPLS and the Relative Importance Index (RII) analysis was used to model the relationship between the WBS, QMS, BIM, and maintenance performance. The study concludes that the significant relationship among these variables enhances maintenance performance. After the system trial, the RII increased from 0.70 to 0.92 for maintenance performance.*

Keywords: *building information modeling (BIM), maintenance performance, Nusantara Paripurna building, quality management system (QMS), work breakdown structure (WBS)*

I.INTRODUCTION

The parliamentary complex is the seat of government for the Indonesian legislative body, which consists of The People's Representative Assembly (MPR), The House of Representatives (DPR), and The House of Regional Representatives (DPD). The Republic of Indonesia parliament complex has several buildings, the most important of which is the Nusantara Paripurna Building, which is the main and annual meeting place for the legislative body of the Republic of Indonesia. Based on the regulation of the Minister of Public Works no. 22/2018 [1], the Nusantara Paripurna building is a state building that, in its implementation, requires building maintenance and repair activities. The British Standard (BSI, 1993) [2] states that building maintenance and repair is a combination of the activities needed to maintain the condition of a building component or restore the building component to an acceptable condition. Law no. 28/2002 concerning building construction and Ministerial regulation No. 24/2008 concerning guidelines for maintenance and repair state that the purpose of maintenance and repair work is to meet building reliability requirements, such as safety, health, comfort, and convenience [3,4]. Buildings that meet the 4 (four) requirements for building function suitability will positively impact the satisfaction of building users, thereby increasing their productivity. The Nusantara Paripurna building has very important electrical components to support the activities of building users, such as electricity, sound system, telephone, fire alarm, internet network, conference delegates, TV Wall, and LED Display Videotron (electrical component data, Division of building and installation, 2022). According to Park, J., & Seo, D.(2022) [5], the work of electrical components in the building is very important, so the need for design, construction, management, and repair must be arranged correctly to avoid problems with the quality of the work. Issues with electrical components that cause damage, such as corrosion, malfunction, short circuits, overheating, open circuits, overload, and incorrect installation. The most significant impact of problems with electrical components is fires that cause loss of life. Data from the International Association of Fire and Rescue Service (CTIF, 2023) [6] on damage to electrical components that cause fires in buildings and housing in several countries in 2021; for example, in Bulgaria in 2021, there were 7485 fire incidents, of which 29,3% or 2194 fire incidents were caused by electrical components, Malaysia in 2021 there were 7477 fire incidents of which 60,9% or 4558 fire incidents were caused by electrical components, Latvia in 2021 there were 6717 fire incidents of which 19,1% or 1283 fire incidents were caused by electrical components. Referring to several literatures, some of the causes of damage problems to electrical components are lack of inspection of work results [7] (Morais, G. A.T. de., & Junior, A. C. L., 2018), non-compliance with material specifications [8] (Dahal, R. C. & Dahal, K. R. et al., 2020), non-compliance of electrical work results with quality requirements [5] (Park, J. & Seo, D., 2022), and lack of implementation of new technology [9] (Asma et al., 2021). For this reason, a management system is needed that is able to provide solutions to the maintenance and repair work of electrical components that guarantee the satisfaction of building users; according to Ferreira et al., 2020 [10], the PDCA Cycle (Plan, Do, Check, Act) Cycle is a process from Quality Management System (QMS) which is helpful in improving organizational performance in carrying out maintenance and repair activities. According to Olowoake et al., 2022 [11], using a quality management system (QMS) as a framework for building asset management in an organization will help to improve building maintenance efficiency, user satisfaction, and continuous improvement.

The structured arrangement of electrical components in the Nusantara Paripurna building can use the Work Breakdown Structure (WBS) form, which, according to Al-Kasasbeh et al. (2020) [12], a WBS-based framework can be used for asset management during the operational stage and the maintenance and repair stage of building facilities. Information systems in the form of Building Information Modeling (BIM) can be used as a technological means to manage and maintain building components which according to Abanda et al. (2015) [13], the use of BIM for building management is very important because BIM is not only a software system or 3D modeling but can be used as a place to store data on building maintenance and repair work information, as well as providing assistance to technical staff for maintenance and repair planning, which is then able to avoid over-budget. According to Al-Kasasbeh et al. (2020) [12], integration of WBS into BIM can increase the effectiveness of building management during operation and maintenance, which covers all building components.

Work Breakdown Structure (WBS), integrated with Building Information Modeling (BIM), is intended as a building modeling process that combines structured data of components from a building in the form of WBS to produce a complete digital representation so that it can be used from the planning and design stages to the construction and O/M (operation and maintenance) stages. Through QMS based on WBS integrated with BIM, electrical component data and QMS documents from the Nusantara Paripurna building can be accessed more quickly and accurately, allowing information sharing in management and monitoring for maintenance and repair work, which is expected to improve maintenance performance.

II. THEORETICAL STUDY

2.1 Nusantara Paripurna Building In The Parliamentary Complex

The parliamentary complex is the seat of government for the Indonesian legislative body, which consists of the People's Representatives Assembly (MPR), the House of Representatives (DPR), and the House of Regional Representatives (DPD). The Republic of Indonesia parliament complex has several buildings, the most important of which is the Nusantara Paripurna Building, which is the principal and annual meeting place for the legislative body of the Republic of Indonesia.

2.2 Maintenance and Repair Work System in Parliamentary Complex

An organization is a group of people arranged in groups who work together to achieve specific goals (KBBI.web.id) [14]. In the project, organization is used as a means of achieving goals by managing and organizing resources, labor, materials, equipment, and capital effectively and efficiently by implementing a management system according to project needs. The Decision of the Secretary General of the House of Representatives no. 2194/Sekjen/2023 [15] states that a work system is a series of procedures and work systems that form a process of carrying out organizational tasks and functions. Regulation of the Secretary General of the House of Representatives no. 6/2021 [16] states that the implementation of duties and functions, especially in the maintenance and repair of the parliamentary complex, is carried out by the Buildings and Official Residence Management Bureau, which is headed by Head of Bureau, who oversees 3 (three) work areas, one of which is the Building and Installation Division. Maintenance and repair work in the parliamentary complex is a working system that requires collaboration between and within organizational units so as to encourage the realization of quality output that is oriented toward results. This system ensures effective and efficient working relationships between organizational units to carry out their duties and functions. In terms of fulfilling the aspects of the building's functional feasibility through Law no. 28/2002 [3], the implementation of the Nusantara building as a state building requires utilization and preservation activities. Government Regulation No. 16/2021 [17] explains that the utilization of a building is an activity to utilize a building in accordance with its designated function, including periodic maintenance, repair, and inspection activities, while preservation is an activity to maintain, restore, and maintain the building and its environment to restore the reliability of the building according to its original condition or according to the conditions according to the desired period. The scope of maintenance and repair of electrical components of the building in the parliament complex includes :

1. Building maintenance is an activity to maintain the reliability of a building and its infrastructure and facilities so that the building is always functional (preventive maintenance),
2. Repair work includes repairs and/or replacement of building parts, components, building materials, and/or infrastructure and facilities based on building maintenance technical planning documents, taking into account construction implementation documents.

2.3 Building Maintenance and Repair Performance (Y Variable)

Law no. 28/2002 [3] concerning building structures and Ministerial regulation no. 24/2008, the guidelines for building maintenance and repair management are to maintain and improve reliability so that it is always functionally fit. Functional feasibility is a condition of a building that meets administrative and technical requirements in accordance with the determined function of the building. The reliability of a building is realized by fulfilling requirements such as safety, health, comfort, and convenience.

Standard quality requirements are needed for electrical components used in the parliamentary complex building so that the result of maintenance and care work have equivalent quality and are in accordance with applicable building reliability requirements. Electrical components for this building will use the following criteria:

1. PUIL (General Requirements for Electrical Installations) 2011 contained in SNI 0225:2011

[18]. These requirements refer to the international standard IEC (International Electrotechnical Commission)

2. Minister of Public Works regulation No. 45/2007 [19] concerning technical guidelines for building construction, which explains the specifications of the main components.

2.4 Work Breakdown Structure (X1 Variable)

According to PMI 3rd ed.,2019 [20], WBS is a hierarchical decomposition of the total scope of work that must be carried out by the project team to achieve the project objectives and required deliverables. WBS helps reduce uncertainty in the scope of work into smaller pieces by changing the scope of work into a series of smaller components called work packages so that they are easier to assess, measure, manage, and communicate. WBS for electrical components of a building can be explained as follows: Level 1 is the Project Name, Level 2 is the Work Group, Level 3 is the Work Element and Level 4 is the work packages (Pradipta & Latief, 2019) [21].

2.5 Quality Management System (X2 Variable)

Based on ISO 9001:2015 [22], A quality management system is a standard that helps organizations improve their performance, increase customer confidence, and commit to quality. Commitment to quality is the process of effective and continuous implementation of a quality management system to gain customer confidence and meet applicable legal and regulatory requirements, asseen in Fig. 1 PDCA Cycle

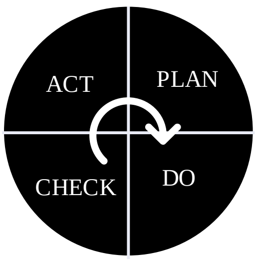

Fig. 1 PDCA Cycle

The PDCA Cycle process of the Quality Management System, namely :

1. Plan: the planning process begins with problem identification.
2. Do: the process of carrying out a plan that has been drawn up.
3. Check: the process of checking the actions that have been carried out.
4. Act: is a process of improvement based on the evaluation of the “do” and “check” phases that identify problems in the implementation of the plan.

The PDCA Cycle process is carried out repeatedly to produce continuous improvement using the Quality Management System (QMS) documentation hierarchy, which consists of Level 1: Guidelines, explaining policies and regulations, organizations, and their objectives; Level 2: Standard Operating Procedures, explaining the process stages of existing activities, Level 3: Work Instructions, describing how to carry out activities, Level 4: Check List, explaining the items or components of activities, Level 5: Quality Records (quality targets), explaining the functional testing or commissioning test of the activities carried out.

There are seven basic principles of the Quality Management System, namely: focus on consumers, leadership, engagement of people, process approach, relationship management, improvement, and Evidence-Based Decision Making.

2.6 Building Information Modeling (X3 Variable)

BIM is a digital transformation in the construction sector that utilizes technology that aims to increase efficiency by automating, integrating work, and enabling collaboration between stakeholders, starting from the technical planning, construction, operational, and maintenance stages, meanwhile, according to Salman Azhar, 2011 [23], BIM is digital innovation in the form of a system, management, method or sequence of work on a project that is applied which is then projected into a 2D or 3D model that influences the design, construction, operation, maintenance, repair, destruction or replacement stages of physical; assets in the architecture, engineering, construction and operational industries. Building Information Modeling as a digital technology innovation provides technological support to process and organize information that will be needed in all phases of building assets more efficiently and productively.

2.7 Theoretical Framework or Relationship Between Variable X and Variable Y (Synthesis)

This study is intended to improve the performance of maintenance and repair work for electrical components in the Nusantara Paripurna building with a quality management system based on WBS integrated with BIM. The hypothesis is that the maintenance performance of the Nusantara Paripurna building in the parliament complex will increase if the quality management system for maintenance and repair work for electrical components based on WBS integrated with BIM is implemented, as seen in Fig. 2 Research Concept Framework.

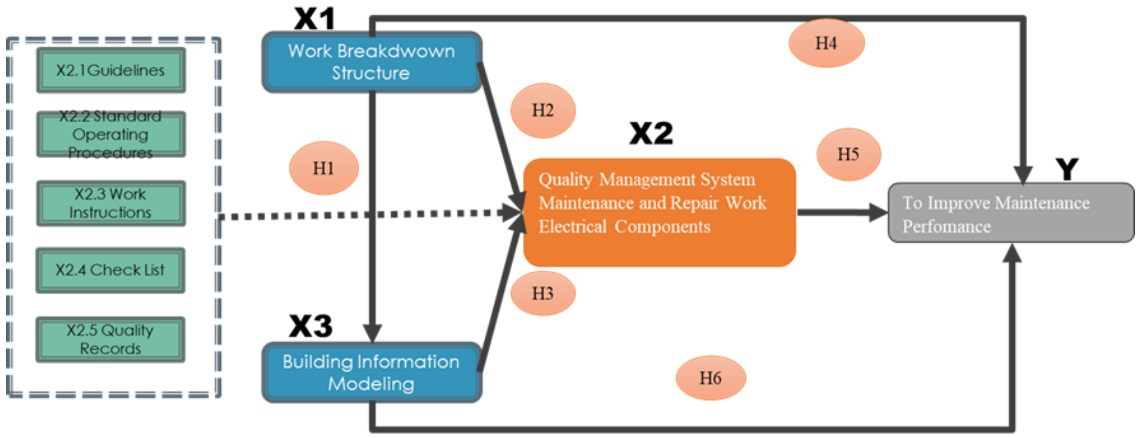

Fig. 2 Research Concept Framework

III. METHODOLOGY

Research strategy explains the work process of researchers conducting research, which includes procedures for finding answers to research questions, the instruments used, and how to process data (Kumar, 2011) [24]. The research methods used in this research are archive analysis, literature study, survey, case study, and expert judgment. This research process is carried out to search, explore, or find answers to the formulation of questions consisting of 12 research questions to validate the components of the quality management system, such as policies and regulations, organizations, guidelines, standard operating procedures, work instructions, checklist, and quality record based on WBS of electrical components. After the quality management system document has been compiled and validated, the next step is to create a BIM model for the Nusantara Paripurna building. In the final stage, an analysis was carried out using Smart PLS software to see the significance of the relationship between variables using T-test and RII (Relative Importance Index) analysis to see the increase in performance from existing conditions to the development of quality management system based on WBS integrated with BIM as in Fig.3 Research Process.

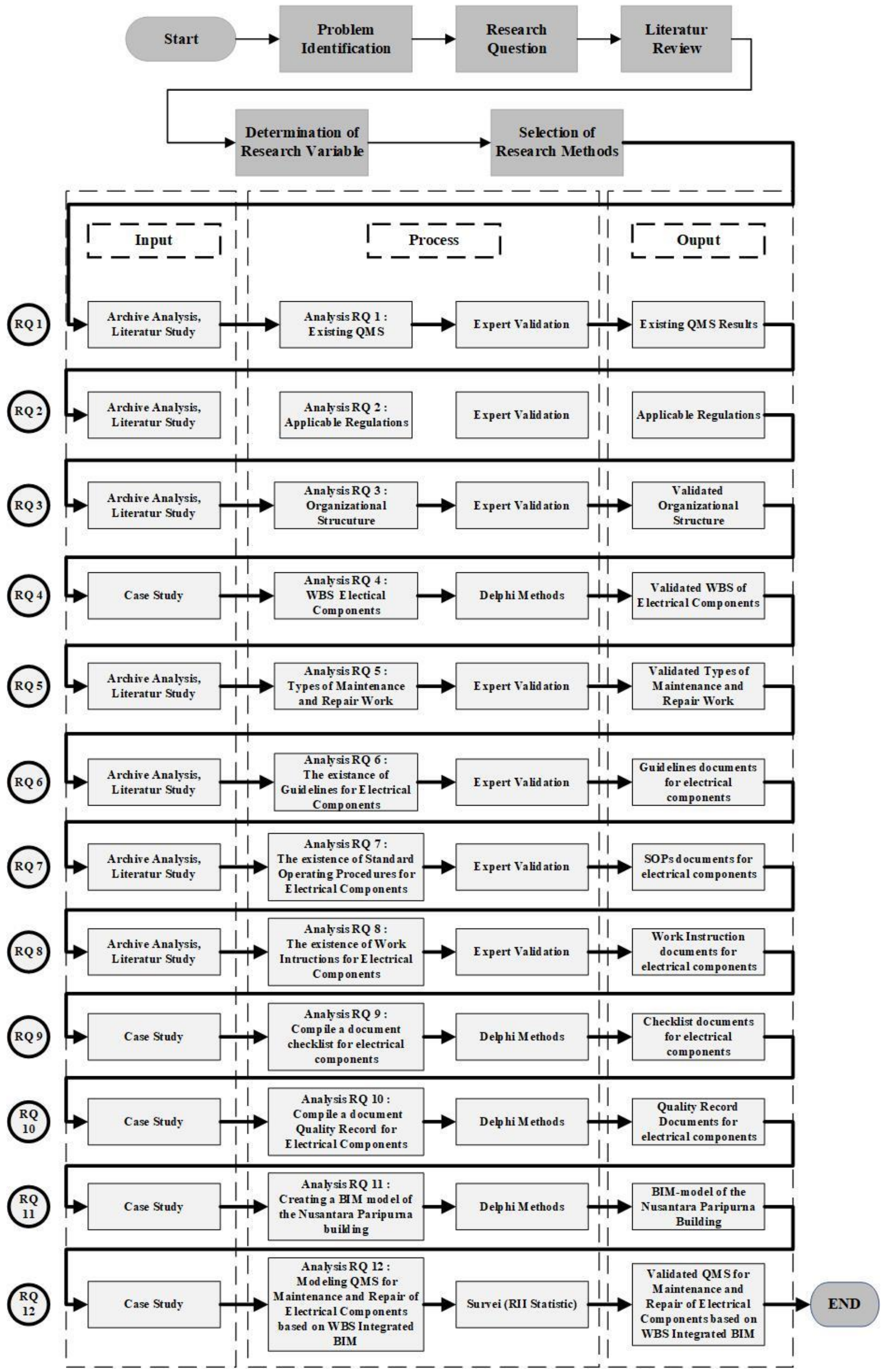

Fig 3. Research Process

IV. RESULTS AND DISCUSSION

The data collected based on validated findings from research questions in RQ 1 – RQ 12 are as follows :

RQ1: In existing QMS forms, there are already QMS components such as policies, regulations, guidelines, SOPs, and work instructions (WI), but there are no checklists and quality records yet.

RQ2: Applicable policies and regulations, Validated policies and regulations are used, such as Law No. 28/2002 [3], Government Regulation No. 16/2021 [17], Regulation of the Minister of PU no.24/2008 [4], Regulation of the Minister of PUPR no.10/2021 [25], Decision of the Minister of Manpower no. 3/2023 [26].

RQ3: An organization regulates and manages maintenance and repair work in the Nusantara Paripurna building, including electrical components, namely the electrical subdivision of the building and installation division in the building and the official residence management bureau. See Fig. 4 Structure Organization

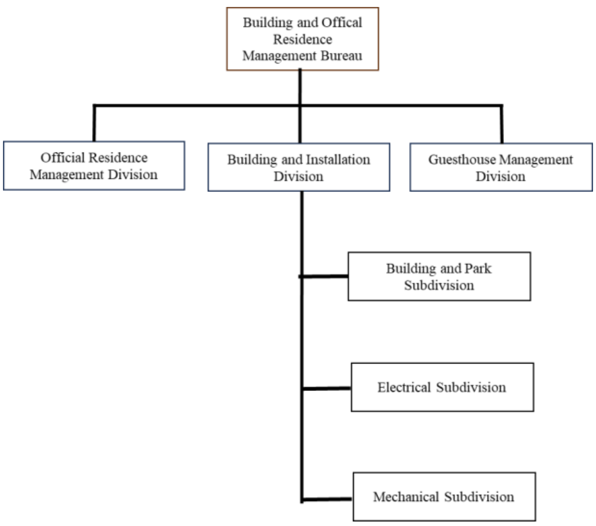

Fig 4. Structure Organization

RQ4: WBS Electrical Components, based on literature studies and previous research, the WBS electrical components in the Nusantara Paripurna building were validated using the Delphi method, consisting of 37 work packages, as seen in Table1. WBS Electrical Components.

RQ5: Types of maintenance and repair work of electrical components, based on literature studies and previous research, 4 types of work on electrical components were validated, namely inspection, maintenance, repair, and testing.

RQ6: Guidelines documents for maintenance and repair work of electrical components, based on literature studies and previous research, each of the 37 guidelines for electrical components maintenance and repair work was identified in the Nusantara Paripurna building and validated based on WBS level 4 (work packages). The guidelines contain activities for inspection, maintenance, repair, and quality requirements for work. Examples of Guidelines for Transformers can be seen in Table 2.

Table 1. WBS Electrical Components

Electrical Components of Buildings (WBS Level 1, Project Name)					
Code	Work Group (WBS Level 2)	Code	Work Element (WBS Level 3)	Subcode	Paket Pekerjaan (WBS Level 4)
1.	Electrical System Components	1.1	Power Supply	1.1.1	Tranformator
				1.1.2	UPS
				1.1.3	Genset
		1.2	Distribution System	1.2.1	Cubicle
				1.2.2	LVMDP Panel Body
				1.2.3	LVMDP Protection Component
				1.2.4	LVMDP Busbar
				1.2.5	LVMDP Measurement Device
				1.2.6	LVMDP Pilot lamp & Fuse
				1.2.7	LVMDP Feeder TR Cable
				1.2.8	LVMDP Busduct
		1.3	Electrical Load	1.3.1	LP Panel (Switch & Stop Contact)
				1.3.2	Mechanic Panel (AHU,AC, Escalator & Lift)
				1.3.3	Lighting System (Lamp)
				1.3.4	Lamp Dimmer Lighting System
				1.3.5	Grounding System
				1.3.6	Lightning Protection System
2.	Electronic System Component	2.1	Fire Alarm System	2.1.1	MCFA + Power Supply
				2.1.2	Heat, Smoke Sensor
				2.1.3	Alarm System
		2.2	Telephon System	2.2.1	PABX
				2.2.2	MDF
				2.2.3	Telephone Devices
		2.3	Audio System (Public Address)	2.3.1	Sound Output System
				2.3.2	Sound Input System
		2.4	Audio System (Conference System)	2.4.1	Sistem Central Processing & Interface
				2.4.2	Sound Input/Output System
				2.4.3	Delegate Unit
		2.5	Visual System (LED Display)	2.5.1	Video Controller System& Antarmuka
				2.5.2	Video Input/Output System
				2.5.3	LED Display
		2.6	Network Computer System	2.6.1	Komputer
				2.6.2	Network
		2.7	Master Antenna Television System (MATV System)	2.7.1	Signal processor (Modulator& Attenuator)
				2.7.2	Signal Amplifier
		2.8	Building Automation System	2.8.1	Controller System & Interface
				2.8.2	Input/Output System

RQ7: Standard Operating Procedures documents for maintenance and repair work of electrical components, based on literature studies and previous research, 37 maintenance work SOPs and 37 repair work SOPs were identified in the Nusantara Paripurna building and validated based on existing work packages electrical components. The SOPs contain information such as activities, unit organization, and documents needed. Examples of SOP For Transformers can be seen in Table 3.

Table 2. Guidelines for Transformer

Power Supply		
Description		
An electrical devices that can provide electrical energy for other electrical or electronic devices		
Transformer		
Job Cluster	**Electrical**	
Type of Work	**Power Supply**	
Work Package	**Transformer**	
Alternative Design	**Dry Transformer**	
Activity	**Inspection and Maintenance Actions**	**Regular Schedule**
Inspection	Check safety relay	6 month
	Check bushing	6 month
	Check terminal	6 month
	Check transformer base	6 month
	Check physical condition transformer	6 month
	Check transformer temperatur	6 month
	Check safety devices and measuring	6 month
	Check temeperatur and room condition transformer	6 month
	Check cable connection in bushing terminal and system	6 month
Service	Clean up outer part transformer	6 month
	Adjust temperature and room condition transformer	6 month
	Turn ratio test at each tap position	6 month
	Surge arrester test	6 month
	insulating liquid test with DGA test	6 month
Repair	Change device and spare part, if damage is found	yearly
Quality Requirements		
a. SNI 0225:2011 standards or the latest regarding "General Requirements for Electrical Installations"		
b. SNI IEC 60076:2012 standards or the latest about "Power Transformer"		

RQ8: Work Instructions documents for maintenance and repair work of electrical components; based on literature studies and previous research, 3 types of work instructions (WI) were identified and validated: WI inspection, WI maintenance, and WI repair. The WI contains information such as activities, unit organization, input activities, duration, and output activities. Examples of WI Maintenance for Electrical Components can be seen in Table 4.

RQ9: Checklist documents for maintenance and repair work of electrical components; the preparation of the electrical documents was carried out according to the result of RQ 2 to RQ 8, which were then validated by experts using the Delphi method. Checklist documents contain fill-in sheets for activities based on WBS level 4 (work packages).Examples of Checklists for Transformers can be seen in Table 5.

RQ10: Quality records documents for maintenance and repair work of electrical components; the preparation of the quality records documents was carried out according to the result of RQ2 to RQ 9, which were then validated by experts using the Delphi method. Quality records documents contain fill-in sheets for quality results after work. The result was 37 quality records for each electrical component. Examples of Quality Records can be seen in Table 6.

RQ11: BIM-model Nusantara Paripurna building, creating a BIM model of the Nusantara Paripurna building using 3D modeling software, then modeling electrical components is carried out, after which information such as QMS documents can be linked to electrical components. Examples of BIM model Nusantara Paripurna Building can be seen in Fig 5. BIM-model Nusantara Paripurna building. Finally, the BIM-model results were validated to be used for maintenance and repair work on electrical components.

Table 3. SOP (Repair Work) For Transformer

SOP ELECTRICAL SYSTEM REPAIR (CARE) - TRANSFORMER											
		PERAWATAN									
No.	Activity	Bureau Chief	Committed Officer	Head of Devision	Head of Sub-devision	Technical Supervisor / Maintenance Coordinator	Technical Team	Third Party (Contractor)	Document	Frequency	Note.
1	Provide a schedule or work instructions for maintenance and repair								Official Memo		
2	Preparing maintenance and repair equipment										
3	Replace damaged equipment and spare parts if damage occurs										
4	Checking the work results								Checklist		
5	Reporting work results										

Table 4. Work Instruction Maintenance for Transformers

WORK INSTRUCTIONS FOR ELECTRICAL COMPONENT MAINTENANCE WORK IN THE NUSANTARA PARIPURNA BUILDING										
		Maintenance					Standard Quality			
No.	Kegiatan	Chief Bureau	Head of Division	Head of Sub-division	Technical & Admin Team	Analysis	Input	Duration	Output	Note
1	Create a maintenance schcedule						Schedule list	1 day	Maintenance Schedule Draft	
2	Head of Sub-division checks the schedule planning						Schedule list	2 day	Maintenance Schedule Draft	
3	Submit a proposed schedule						Documentation	1 day	Schcedule document	
4	Discuss and wait for approval						Documentation , report	1 day	Work report	
5	The Bureau gives approval for the maintenance schedule						Documentation , report	1 day	Work report	
6	Carry out the work						Work order note	depends on the job	Record of Proceedings	
7	Make a realization plan report						Survey data, report	1 day	Work report	
8	The Bureau check realization plan report						Survey data, report	1 day	Work report	

Table 5. Checklist For Transformer

TRANSFORMER					
Location					
Room No.					
Primary voltage (volt) / Secondary voltage		/			
Capacity (KVA) / Factory made		/			
Installed (year)					
Damage Type		No	Light	Medium	Heavy
Component	Insulator	☐	☐	☐	☐
	damaged casing	☐	☐	☐	☐
	Bushing	☐	☐	☐	☐
	Insulation quality	☐	☐	☐	☐
	Dust/dirt accumalation	☐	☐	☐	☐
	Air fan	☐	☐	☐	☐
	Resource Capacity	☐	☐	☐	☐
	Mounting	☐	☐	☐	☐
	Temperatur	☐	☐	☐	☐
General Condition			Bad		Medium
			Good		Prime
Estimates can still be used (tahun)					
Note					

Table 6. Quality Records For Transformer

WORK QUALITY RECORD			
WBS LEVEL 4 : TRANSFORMER			
Contractor :	No. :		
	Date :		
	No. Contrac / contract date:		
Project name :			
Work Activity :		Work location :	
Item : a. Oil transformer; b. Terminal; c. Mur/baut; d. Packing; e. Grounding; f. Sensor; g. Temperatur; h. Transformer body; i. Bushing; j. Cable; k. Busbar			
Activity :	Reference	Conformity to requierments	
		Suitable	Not Suitable
Quality defect record / Lack of jobs			
Approved by :	Implemented by :	Person in Charge :	
Handover Team :	**Work Service Provider :**	**Responsible :**	
Name :	Name :	Name :	
Date :	Date :	Date :	

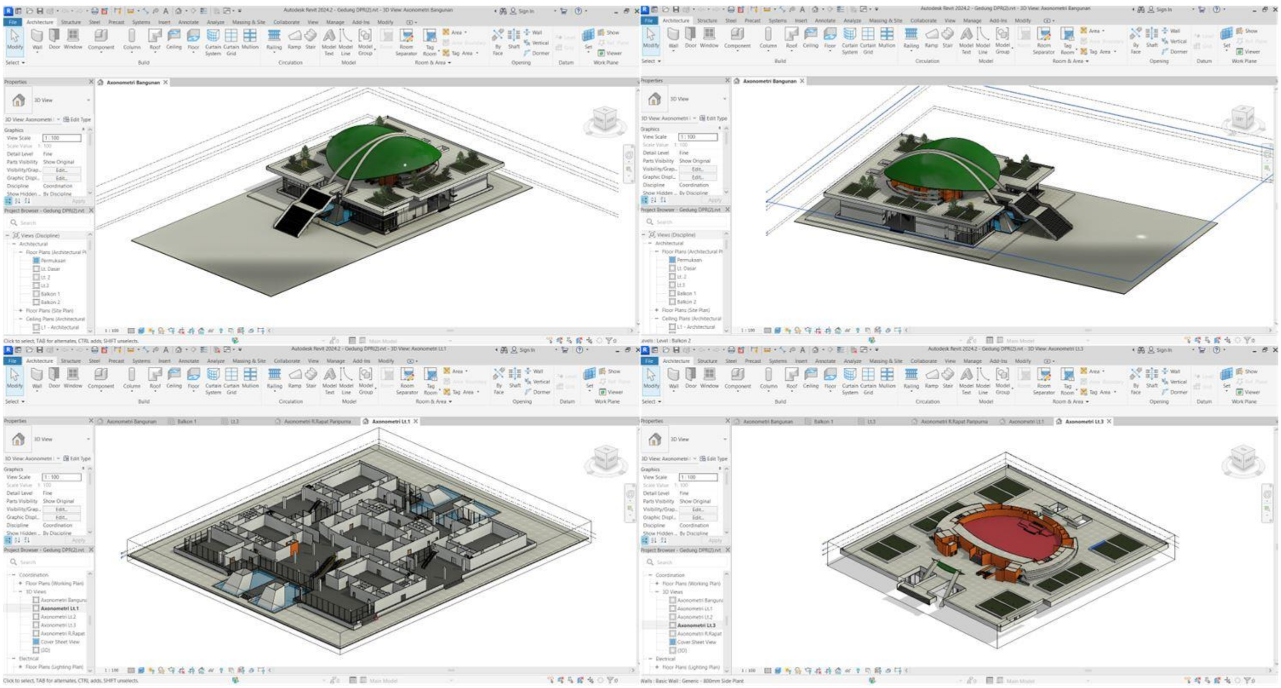

Fig. 5 BIM Model Nusantara Paripurna Building

In the RQ 12 analysis in this study, the improvement of the quality management system performance and maintenance performance were analyzed using the T-value from SmartPLS Software and the Relative Importance Index (RII). The T-value is used to see the significance of the influence between variables and confirm the theory used, while the RII is used to analyze the improvement of the performance of the WBS and BIM-based management system and maintenance performance against existing conditions in the Nusantara Paripurna building. Analysis of the research model was conducted on 70 respondents with category can be seen in Table 7.

Table 7. Category Respondents

No.	Category	Information	Number of Samples
1	Position Level	Administrative Staff	23
		Technical Staff	21
		Supervisor	17
		Manager	9
2	Education Level	Diploma	6
		Bachelor	54
		Master	8
		Doctor	2
3	Experience Level	1 – 5 year	12
		5 – 10 year	16
		> 10 year	42

Significance Testing (T-value) using SmartPLS

Before significance testing (T-value) is carried out, the following Outer Model tests are carried out:

The Outer model test is a test that must meet good criteria based on the following tests: convergent test, discriminant test, and reliability test.

1. Convergent Validity

   Convergent validity is a measurement of the validity of a reflective indicator that determines the ability of an indicator to be in the latent variable. Standardized outer loading > 0.8, according to various literature, shows that a loading factor above 0.8 is ideal while 0.7 is valid (Ghozali, I., 2016) [27]. Meanwhile, if the outer loading value is between 0.6 and 0.7, it can be tolerated for analysis, but if the value is below 0.6, it can be dropped from the analysis. In addition, from the outer loading value, convergent validity testing is also carried out with the Average Variance Extracted (AVE), which can be met when each variable has an AVE value above 0.5. According to Hair et al., 2017 [28], AVE > 0.5 means that the latent variable can explain an average of more than half of the variance of its indicators. The results of the convergent test can be seen in Table 8. and The result of the AVE test can be seen in Table 9.

2. Discriminant Validity

   For this study, discriminant validity testing used Cross-loadings and Fornell Larcker.

   a. Cross Loading

      The expected cross-loading value of each construct is greater than 0.7 (Ghozali, 2021, p. 68) [27] to ensure that the correlation of theconstruct with the measurement items is greater than other constructs. The result of the Cross Loading test can be seen in Table 10.

   b. Fornell Larcker

      This method compares the square root value of the AVE of each construct with the correlation between other constructs in the model. If the square root of the average variance extraction (AVE) of the construct is greater than the correlation with all other constructs, it is said to have good discriminant validity. The result of the Fornell Larcker test can be seen in Table 11.

Table 8. Convergent Test Result

Indicator	X1 Variable WBS	Indicator	X2 Variable QMS	Indicator	X3 Variable BIM	Indicator	Y1 Variable Maintenance Performance
X1.1.1	0.853	X2.1.1	0.829	X3.2.2	0.851	Y1.1	0.872
X1.1.2	0.840	X2.3.1	0.812	X3.2.3	0.866	Y1.2	0.858
X1.2.1	0.880	X2.5.5	0.818	X3.4.3	0.869	Y1.3	0.874
		X2.6.1	0.801			Y1.4	0.823

Table 9. AVE Test Result

	AVE
BIM X3	0.742
QMS X2	0.664
WBS X1	0.736
Y. Maintenance Performance	0.735

Table 10. Cross Loading Test Result

	BIM X3	QMS X2	WBS X1	Y Maintenance Performance
X1.1.1	0.466	0.608	0.851	0.411
X1.1.2	0.581	0.558	0.843	0.391
X1.2.1	0.458	0.489	0.879	0.349
X2.1.1	0.481	0.829	0.469	0.406
X2.3.1	0.443	0.813	0.521	0.299
X2.5.5	0.464	0.818	0.577	0.492
X2.6.1	0.497	0.800	0.536	0.309
X3.2.2	0.850	0.552	0.524	0.380
X3.2.3	0.866	0.437	0.524	0.328
X3.4.3	0.869	0.499	0.476	0.392
Y1.1	0.408	0.404	0.316	0.883
Y1.2	0.310	0.357	0.396	0.847
Y1.3	0.386	0.467	0.400	0.876
Y1.4	0.348	0.366	0.400	0.821

3. Reliability Test

Reliability testing is done by looking at the composite reliability value of the indicator block that measures the construct. The composite reliability results will be satisfactory if it is above 0.7. Reliability testing can also be strengthened with Cronbach's alpha, with the recommended value above 0.6. The result of the Reliability test can be seen in Table 12.

Table 11. Fornel Larcker Test Result

	BIM X3	QMS X2	WBS X1	Y. Maintenance Performance
BIM X3	0.862			
QMS X2	0.578	0.815		
WBS X1	0.590	0.647	0.858	
Y. Maintenance Performance	0.427	0.469	0.450	0.857

Table 12. Reliability Test Result

	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)
BIM X3	0.827	0.828	0.896
QMS X2	0.832	0.836	0.888
WBS X1	0.820	0.823	0.893
Y. Maintenance Performance	0.880	0.888	0.917

The results of the outer model test show that a model has been obtained that meets the criteria of convergent validity, discriminant validity, and reliability so that it can be continued with the inner model analysis.

Inner model tests or structural model tests can be evaluated by looking at the stability of the estimates assessed using the bootstrapping procedure to predict causal relationships between latent variables (Ghozali, 2021, p. 67) [27]. Inner model analysis in SmartPLS 4.0 is evaluated using the t-value test on outer loading and the t-value test on the path coefficient.

The t-value test is a hypothesis test. The significant values used (two-tailed) t-values were 1.65 (significance level 10%), 1.96 (significance level 5%), and 2.58 (significance level 1%). This study's significant level is 5%, using a t-value of 1.96. The results of the T-value from the Outer Loading Bootstrapping results can be seen in Table 13. and The Path Coefficient Results From the Bootstrapping Model can be seen in Table 14. Finally, the research model resulting from the significance analysis (T-value) with SmartPLS software can be seen in Fig 6.

Table 13. T-value from Outer Loading Bootstrapping Result

	Original Sample	T-values	Result
X1.1.1 <- WBS	0.851	24.726	Significant
X1.1.2 <- WBS	0.843	21.718	Significant
X1.2.1 <- WBS	0.879	28.058	Significant
X2.1.1 <- QMS	0.829	17.156	Significant
X2.3.1 <- QMS	0.813	14.487	Significant
X2.5.5 <- QMS	0.818	18.188	Significant
X2.6.1 <- QMS	0.800	16.742	Significant
X3.2.2 <- BIM	0.850	23.601	Significant
X3.2.3 <- BIM	0.866	25.752	Significant
X3.4.3 <- BIM	0.869	24.417	Significant
Y1.1 <- Y1.	0.883	24.770	Significant
Y1.2 <- Y1.	0.847	14.751	Significant
Y1.3 <- Y1.	0.876	24.908	Significant
Y1.4 <- Y1.	0.821	13.778	Significant

Table 14. The Path Coefficient Results From the Bootstrapping Model

	Original Sample	T-values	Result
BIM -> QMS	0.301	2.633	Significant
QMS -> Y	0.470	5.377	Significant
WBS -> BIM	0.590	8.025	Significant
WBS -> SMM	0.469	4.215	Significant

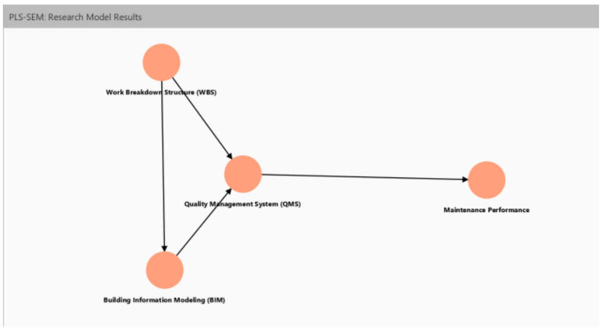

Fig.6 Research Model Result

RII (Relative Importance Index) Analysis

RII (Relative Importance Index) analysis is a method of analyzing the relative importance level for each factor and variable based on the respondent's opinion. The RII value ranges from 0 to 1; the higher the RII level, the greater the influence of the factor or variable on improving maintenance performance. In this study, RII analysis will be used to measure the success of developing a quality management system (QMS) for electrical component maintenance and repair based on WBS integrated with BIM and the resulting improvement in maintenance performance against previous existing conditions.

The results of the RII analysis on conditions before and after the simulation trial can be seen in Table 15.

Table 15. RII Analysis On Conditions Before and After the Simulation Trial

Variable	Before	After
WBS (X1)	0,69	0,88
QMS (X2)	0,74	0,88
BIM (X3)	0,70	0,88
Maintenance Performance (Y)	0,70	0,92

V. CONCLUSION

The accepted hypothesis using the T-value from SmartPLS found a significant relationship between the following variables:

1. WBS→ QMS → Maintenance Performance.
2. WBS→ BIM → QMS → Maintenance

Perfomance.

Improving maintenance and repair performance is done by developing a quality management system based on WBS integrated with BIM by compiling documents such as: guidelines, standard operating procedures, work instructions, checklists, and quality records. Improvement of maintenance performance must also be supported by an organization tasked with managing and organizing the maintenance and repair work process, including electrical components in the Nusantara Paripurna building, as well as the need for policies and regulations that assign tasks and responsibilities to each role in the organizational unit so that communication flows can be implemented to achieve quality requirements that meet the suitability of the building's function.

The Project Management Institute (2019) [20] concluded that the WBS is able to represent the entire work that is defined and organized in the total scope of work so that it represents an increasingly detailed definition of work so that the accuracy of making the cost budget plan and work schedule can be increased. The integration of QMS based on WBS into the BIM model can facilitate the coordination of information and knowledge sharing between stakeholders in the management of the Nusantara Paripurna building so that there is no overlapping of responsibilities or missed work due to lack of coordination.

Finally, the results of the maintenance and care work of the Nusantara Paripurna building can run well and according to plan. The trial simulation with the RII method showed a significant increase in the WBS variable indicator (X1), which was initially 69% to 88%. There was a substantial increase in the QMS indicator (X2), initially 74% to 88%. There was a significant increase in the BIM indicator (X3), initially from 70% to 88%. Then, the trial simulation of the maintenance performance indicator (Y1) also experienced an increase of 22%, which was initially 70% to 92%.

VI SUGGESTION

It is necessary to carry out BIM modeling with continuous updates that function as living documents containing accurate information data from the life cycle of building components so that relevant stakeholders can evaluate various maintenance and repair approaches and then analyze the data to implement continuous improvements that are centered on quality. The implementation of the quality management system (QMS) must always be socialized by those responsible for maintenance and care work at every level of the organizational structure so that contractors, supervisors, consultants, technical and admin teams always use QMS documents such as checklists and quality records at the work handover stage to comply with the quality that has been standardized.

REFERENCE

[1] Ministry of Public Works and Housing, *Peraturan menteri pekerjaan umum dan perumahan rakyat No.22/PRT/M/2018 tentang pembangunan gedung negara berita negara Republik Indonesia tahun 2018, no. 1433* (DKI Jakarta, Indonesia: Kementerian Hukum dan Hak Asasi Manusia, 2018).

[2] British Standards Institution, *Glossary of terms in terotechnology - BS 3811: 1993* (London, 1993).

[3] Government of Indonesia, *Undang - undang No. 28 tahun 2002 tentang bangunan gedunglembaran negara Republik Indonesia tahun 2002 No. 134*(DKI Jakarta, Indonesia: Sekreatriat Negara, 2002).

[4] Ministry of Public Works, *Peraturan menteri pekerjaan umum No.24/PRT/M/2008 tentang pedoman pemeliharaan dan perawatan bangunan gedung*(DKI Jakarta, Indonesia: Kementerian Pekerjaan Umum, 2008).

[5] J. Park, and D. Seo, Post-handover quality management index of electric housing work. *Advances in Civil Engineering Vol. 2022*, 2022, Article ID 4690073. https:doi.org/10.1155/2022/46900873

[6] International Association of Fire and Rescue Services, *Center of Fire Statistics World Fire Statistics*(www.CTIF.org 2023 no. 28, 2023).

[7] G. A. T. de Morais, and A. C L. Junior, Building maintenance management activities in a public institution. *Engineering, Construction and Architectural Management Vol. 26 No. 1*, 2019, 85-103. https:doi.org/10.1108/ECAM-01-2018-0024

[8] R. C. Dahal, and K. R. Dahal, A review on problems of the publicbuilding maintenance works with special reference to Nepal. *American Journal of Construction and Building Materials* 4(2), 2020, 39-50. https:doi.org/10.11648/j.ajcbm.20200402.12

[9] S. N. Asma, M. Nashruddin, N. Norazman, A. I. C. Ani, and M. S. Hasim, Occupants satisfaction towards building maintenance of low-cost Building apartment in Kajang: pilot survey. *Turkish Journal of Computer and Mathematics Education Vol 12 No.3*, 2021, 2253-2264.

[10] S. Ferreira, L. Martins, F. J. G. Silva, R. B. Casais, R. D. S. G. Campilho, and J. C. Sa, A novel approach to improve maintenance operations.*30th International Conf. on Flexible Automation and Intelligent Manufacturing, Procedia Manufacturing 51*, 2020, 1531-1537. https:doi.org/10.1016/j.promfg.2020.10.213

[11] Olowoake, M. Adelaja, Otufowora, and O. Adelaja, Framework on building assets maintenance. *African Scholar Publications & Research International Vol. 27 No.2*, 2022, 135-148.

[12] M. Al-Kasasbeh, O. Abudayyeh,and H. Liu, H, A unified work breakdown structure-based framework for building asset management. *Journal of Facilities Management Vol. 18 No. 4*,2020, 437-450. https:doi.org/10.1108/JFM-06-2020-0035

[13] F. H. Abanda, C. Vidalakis, A. H. Oti, andJ. H. Tah, A critical analysis of building information modelling systems used in construction projects. *Advances in Engineering Software Vol. 90*, 2015, 183-201, https:doi.org/10.1016/j.advengsoft.2015.08.009

[14] KBBI, 2018. Kamus Besar Bahasa Indonesia (KBBI).(online).*https://kbbi.web.id/organisasi*.accessed on date 2024, 20 September.

[15] Secretariat General of the Indonesian House of Representatives,*Keputusan sekretaris jenderal Dewan Perwakilan Rakyat Republik Indonesia no. 2194/SEKJEN/2023 tentang sistem dan mekanisme kerja sekretariat jenderal Dewan Perwakilan Rakyat Republik Indonesia* (DKI Jakarta, Indonesia: Sekretariat Jenderal, 2023).

[16] Secretariat General of the Indonesian House of Representatives, *Peraturan sekretaris jenderal Dewan Perwakilan Rakyat Republik Indonesia no. 6 tahun 2021 tentang organisasi dan tata kerja sekretariat jenderal Dewan Perwakilan Rakyat Republik Indonesia* (DKI Jakarta, Indonesia: Sekretariat Jenderal, 2021).

[17] Government of Indonesia, *Peraturan pemerintah Republik Indonesia no. 16 tahun 2021 tentang peraturan pelaksanaan undang - undang no. 28 tahun 2002 tentang bangunan gedung* (DKI Jakarta, Indonesia: Sekretariat Negara, 2021).

[18] Badan Standarisasi Nasional (BSN),*Persyaratan umum instalasi listrik 2011 (puil 2011) amandemen 4*(Jakarta: Standar Nasional Indonesia, 2015).

[19] Ministry of Public Works, *Peraturan menteri pekerjaan umum no.45/PRT/M/2007 tentang pedoman teknis pembangaunan bangunan gedung negara* (DKI Jakarta, Indonesia: Kementerian Pekerjaan Umum, 2007).

[20] Project Management Institute, *Practice standard for work breakdown structures* 3rd ed. (Newton Square, Pennsylvania, USA: Project Management Institute, 2019).

[21] A. Y. Pradipta, *Pengembangan pedoman pekerjaan preventive maintenance komponen elektrikal pada bangunan gedung pemerintah berbasis wbs untuk meningkatkan kinerja pemeliharaan dan perawatan*, master thesis, Universitas Indonesia, Depok, West Java, 2019.

[22] ISO-9001:2015, *Quality Management systems - fundamentals and vocabulary*. (Geneva: International Standard, 2015).

[23] S. Azhar, Building information modeling (bim): trends, benefits, risks, and challenges for the AEC industry. *Leadership and Manage*ment *inEngineering*, 11(3), 2011, 229-290.

[24] R. Kumar, *Research Methodology: A step by step guide for beginners3rd ed* (New Delhi, India: SAGE Publication, 2011).

[25] Ministry of Public Works and Housing, *Peraturan menteri pekerjaan umum dan perumahan rakyat no.10 tahun 2021 tentang pedoman sistem manajemen keselamatan konstruksi* (DKI Jakarta, Indonesia: Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2021).

[26] Ministry of Manpower, *Keputusan menteri ketenagakerjaan Republik Indonesia no. 3 tahun 2023 tentang penetapan standar kompetensi kerja nasional indonesia kategori aktivitas profesional, ilmiah dan teknis golongan pokok aktivitas arsitektur dan keinsinyuran; analisis dan uji teknis bidang building information modelling* (DKI Jakarta, Indonesia: Kementerian Ketenagakerjaan Republik Indonesia, 2023)

[27] I. Ghozali, *Aplikasi analisis multivariate dengan program ibm spss 26 edisi 10* (Central Java, Indonesia: Badan Penerbit Universitas Diponegoro, 2021)

[28] J. F. Hair, G. T. M. Hult, C. M. Ringle, and M. Sarstedt, *A primer on partial least squares structural equation modeling (pls-sem) second edition* (Los Angeles, USA: Sage Publications Inc., 2017)

[29] S. Sterling, L. Plonsky, T. Larsson, M. Kyto, and K. Yaw, Introducing and illustrating the delphi method for applied linguistics research. *Research Methods in Applied Linguistics 2*Issue 1, 2023, 100040. https:doi.org/10.1016/j.rmal.2022.100040

[30] R. K. Yin, *Case Study Research4th edition*(London: SAGE, 1994)