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Development of Work Breakdown Structure (WBS) and Standard Operating Procedure (SOP) for Architectural Work Components of High-Rise Buildings with Risk-Based Design-Build Contracts to Improve Project Time Performance

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Abstract
This research aims to develop a WBS-based Standard Operating Procedure (SOP) for architectural work components in high-rise buildings with risk-based design contracts. The main problem faced in high-rise building projects is uncertainty that can affect project time performance, which often causes delays and cost overruns. Therefore, risk management is important to improve the efficiency and effectiveness of project implementation. This research is applied to a risk-based WBS and SOP, which is expected to minimize potential risks and improve project time performance. The WBS serves as a tool to break down large jobs into smaller and more structured parts, while the SOP will provide clear operational guidance for each stage of the job. Thus, the synergy between WBS and SOP is expected to provide better control over the implementation of architectural works in high-rise construction projects. The results of this study will show the relationship between risk-based WBS and SOPs in improving project time performance. This research also provides recommendations regarding the proper implementation steps of WBS and SOP for risk-based design-build contracts, which can be applied to similar projects in the future.

Keywords: Work Breakdown Structure (WBS), Standard Operating Procedure (SOP), Risk, Design Build, Architecture, Project Time Performance

INTRODUCTION

Indonesia is the 15th largest country in the world with a total area of 1,904,569 km2. Based on data from the Central Statistics Agency (BPS), Indonesia's population is estimated to reach 278.69 million people by mid-2023 and 285 million people in 2030, meaning a population density of 150 people per km2 (Indonesia, 2020, 2022). Of these, 52% or around 150 million people are productive workers who need jobs, so the need for office buildings will increase (Atmaja & Latief, 2022).

According to Rahmawati (2018), high-rise buildings can be a solution for buildings that have large usable capacity, but the land area is inadequate, so the majority of land can be used for green and blue open space to support a sustainable environment. High prices and limited land availability, growth, and increasing diversity of human needs trigger the increasing need for high-rise buildings (Chaher & Soomro, 2016). Technological advancements, a variety of available materials, and adequate economic factors make high-rise buildings one of the development opportunities in major cities around the world, including in Indonesia (Ardiansyah et al., 2022).

The construction of high-rise buildings has a high level of difficulty, both in the initial stage and in the construction stage, so it must be carried out effectively and efficiently to manage risks due to uncertainty during the implementation process (Damanik, 2023). The construction of high-rise buildings involves several fields of work, such as architecture, structure, mechanical, electrical, and landscaping (Syifa, 2021). Architectural work is used as a limitation in this study because the scope of the field is more important than other fields of work (Mintoharjo & Latief, 2022; Murat & Isik, 2023; Naufal et al., 2021; Ogunsanmi et al., 2011). Architectural work encompasses the main concepts of building design, including layout, aesthetics, spatial function, and interspatial relationships. According to Vitruvius' Theory (1486), architecture is the unity of strength/solidity (*Firmness*), beauty (*Squirt*), and uses/functions (*Utility*). Architecture forms a link that unites space, form, technique, and function. Architectural work also pays attention to the comfort of users, both in terms of spatial planning, natural lighting, air circulation, and human interaction with space, which are important elements in architecture (Rianty et al., 2018; Serdar & Hosseini, 2020; Sitohang et al., 2019; Soemohadiwidjojo, 2024; Tsai & Yang, 2010). Creating a building's visual and aesthetic identity, how users perceive space, moving from one area to another, and ergonomic aspects are the responsibility of architecture (Izzario, 2024). It is proven that the implementation stage of architectural work has around 258 technical activities related to construction drawings, so the understanding of each work depends not only on the site engineer, but also on the architect who designed it (Syifa, 2022). The areas of structural, mechanical, electrical, and landscaping work have an important role to play in supporting the function, robustness, and beauty of buildings, but they work according to the direction of the existing architectural design (Das, 2019).

The Government of Indonesia has made various efforts to carry out infrastructure development to support inclusive and sustainable economic growth (Anggraini & Latief, 2021). One of the innovations to accelerate the development process is to use the design method, which is one of the advantages of having efficiency in terms of time and cost compared to construction methods, *design-bid-build* (Aldesty & Latief, 2018; Alsadila & Latief, 2019; Amin et al., 2020)One reason for the difficulty of achieving the desired level of quality according to the project owner's expectations is the lack of coordination and sometimes communication between designers and contractors (Esat Gashi & Marjan Ivezaj, 2023).

Build plan (*design and build)* According to Article 1, Paragraph 16 of the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 25 of 2020, all works related to the construction of buildings, whose providers have a single responsibility for the design and implementation of construction (Alam et al., 2011; Putro et al., 2022). The design method provides a better approach to quality and design changes (Das, 2024). When design errors occur, error correction can be made without intensive communication between engineers and contractors because the contractor is responsible for the design and construction (*Plant and Design-Build Contract*, 2nd ed, 2017).

The design method has positive aspects and advantages over conventional methods. According to 78% of project owners, the quality of design work is better than the traditional system, which is only 51% (Ojo et al, 2011). Communication between the design team and the construction team can be better established in the design contract, thus allowing for more effective implementation of design concepts (Pratama et al., 2019; Putritama & Machfudyanto, 2022; Ramadella et al., 2021; Ramli et al., 2018; Riantini et al., 2017). Design specification requirements can be met, resulting in faster and more cost-effective construction (Tarigan et al. 2018). Projects can be started without detailed design documents (Culp, 2011).

However, the design method also has negative aspects and disadvantages. The increasing complexity of the design and scope of the project increases the risks and difficulties for the design contractor in finding and integrating design expertise to ensure the successful implementation of the project (Doloi et al., 2012). The contractor is responsible for the entire process from the planning stage to construction, so risk management is more complicated than conventional systems, where failure at one stage (design or construction) affects only the same stage (Mariana et al., 2023). Design and implementation are carried out simultaneously, so that good coordination between designers and contractors is needed, and a team that has the ability and knowledge in various fields (multidisciplinary) is needed (Pratiwi et al., 2018). Unclear contracts and unqualified design teams can lead to delayed project completion (Liu, et al, 2017). The criteria for a design project are usually described broadly and generally, not specifically, thus allowing design changes to be made dynamically during the construction process (Khaerani et al., 2020; Liu et al., 2017; Messah et al., 2013; Sanni-Anibire et al., 2022). This adds flexibility but increases project management's complexity as changes must be immediately integrated into the construction process. In addition, uncontrolled expansion of the scope according to the final goal of the project can lead to additional costs and time (Hasanzadeh & Esmaeili, 2021). Liu (2017) and Willian and Johnson (2013) stated that the design method has the risk of rework, cost overrun, schedule delays, and project failure.

According to media reports, between 2023 and 2024, many government projects were not completed on time due to contractors' inability to properly manage construction implementation. The construction project of ten schools in Kapuas Hulu, the Mukomuko Bengkulu Pratama Hospital, the construction of Wing B of Muara Teweh Hospital, the outpatient building of Adjidarmo Rangkasbitung Hospital, and the new building of the Jakarta Satpol PP are some examples of government projects that were not completed on time. Marwendi, Putra (2019) said that at the end of every year, there is a lot of construction service procurement work that has not been completed 100% according to the schedule in the contract (Fijriyani & Isvara, 2023; Ganesdhi et al., 2023; Herzanita, 2019b, 2019a; Hidayah et al., 2018). This incident not only occurred in one region but also in several regions in Indonesia with funding sources from the State Budget/Regional Budget. This development project is considered crucial for the region, so the delay in the project's completion time will impact improving the economy in the region (W, Edi, 2022). When selecting service providers, the company must pay attention to the service providers' track record and credibility. Because the non-completion of the project work will have an impact on the postponement of further activities, thereby disrupting the sustainability of development in the area (Abdullah, 2023).

According to Abdulrahman Al-Mafrachi (2023), the micro-impact of untimely project completion is the problem of delays causing cost overruns, loss of resources, rework, and customer dissatisfaction. The impact of MIDI on companies based on Fashina, A.A., Fakunle, F.F., Omar, M.A. (2020) is the non-fulfillment of client and owner expectations. It can encourage owners and clients to take legal action against the project manager, potentially causing substantial disruption to business operations. Meanwhile, national macro impacts include construction delays causing excess time and costs that will negatively impact the success of projects and state development (A. Salunkhe, Rahul S. Patil, D. Patil, 2014). The impact of excess time and costs can be enormous, affecting project profitability and delaying loan repayment in cost recovery-based projects (Anjay, K.M., P.S. Aithal, 2020).

The complexity of design contracts in construction projects is a problem that has many aspects, influenced by problems of control, coordination, and adaptation (Wang, 2018). Many projects in Indonesia do not accurately utilize WBS, causing problems such as delays, change orders, construction claims, and contract disputes, the main source of which is the form of change (Budi S, 2016). There are still problems related to the implementation of WBS, where all implementing parties involved do not accurately understand the scope and objectives of the project (Putro, 2020).

A Work Breakdown Structure (WBS) is a project document containing a detailed work or activity description. According to Devi (2012), WBS is the basis for project planning, cost estimation, scheduling, and resource allocation, so that the efficiency of WBS standardization determines the project's success. WBS creates a work package (*Work Package*), which is a collection of related work or tasks placed at the end of the work detail structure to facilitate management by project team members (Rianty, 2017). Each identified WBS level is further broken down to a more detailed level or activity.

Even if a WBS is created, it does not eliminate the possibility of risk arising in any activity. Project work is about completing work on time and producing quality work (Thariq, 2023). Project quality is associated with poor WBS planning processes (Ponticelli, 2015). In Indonesia, many projects still do not use WBS to describe the details of their work or make mistakes in their creation (Widayati, 2011). Due to the high complexity of high-rise construction projects based on Design-build contracts, the existence of WBS makes the construction team's work easier. Creating WBS can facilitate systematic risk identification, prevent the loss of some unidentified risk factors, and prevent the recurrence of risks (Li, Q.F., Zhang, P., & Fu, Y.C., 2013). This is supported by the opinion of Ponticelli (2015), who states that WBS can be used as a planning approach to improve project performance. This practice reportedly reduces rework in quality performance, especially by reducing the scope of job change work and increasing control at the construction project site.

Because the design project is executed by a single provider, it is vulnerable to program—and management-level risks, which can result in incomplete bid documents. One of them is time and cost control documents, which should be detailed to ensure project time compliance. Therefore, risk-based WBS is necessary to keep the project time.

There is an urgent need to develop a risk-based WBS standard that initiates the decomposition of WBS from the architectural design stage to the integrated construction stage in accordance with the Design-Build contract. Studies of WBS are still often carried out on contracts *designed in a design-bid-build manner, so* it only focuses on the construction stage with the contractor as a construction service provider. In addition, non-optimal WBS standards can cause the scope of work to expand uncontrollably, jeopardizing the project's success in terms of time, cost, and quality. Su Lei (2012) stated that WBS can support the project risk analysis process from the beginning of the project planning stage, which is carried out before the design by the design team. Each activity grouped in the WBS standard makes it easy to identify potential risks and allows project implementers to prevent them early (Danang & Latief, 2020). The development of WBS standards for high-rise buildings is expected to be a reference for achieving project results in accordance with project regulations, especially for design contracts in construction work.

Control tools are needed to ensure the process is as needed when implementing WBS. *Standard Operational Procedure* (SOP) according to Laksmi (2008) is a document related to procedures that are done chronologically to complete a job that functions to get the most effective work results from workers at the lowest cost. Moekijat (2008) said that SOPs are the sequence of steps in which the work is done, how to do it, when, where, and who does it. The implementation of SOPs is an important tool to achieve optimal results, ensuring clear procedures to achieve efficiency and reduce work errors. Meanwhile, according to Susilowati (2017), SOP is defined as a document that describes operational activities carried out daily, with the aim that the work is carried out correctly, precisely, and consistently, to produce products according to predetermined standards. Outdated SOPs can create inconsistencies in the procedures of a job, so it is very important to update the SOP documents to increase productivity and the quality of the desired product (Hadiwiyono, 2013). Work activities are expected to be faster, precise, meticulous, and in accordance with the intended goals and targets. With well-standardized procedures, it can increase the efficiency and effectiveness of work due to the continuous learning process during the implementation of the work (Anggriani, Herfianti, 2017). SOPs are a way to avoid problems in the implementation of work (Anggriani, Herfianti, 2017).

Recent studies have explored the importance of the Work Breakdown Structure (WBS) in construction projects. Prabowo et al. (2021) emphasized that the lack of standardized WBS often leads to inefficiencies and delays in construction project execution. Similarly, Anugrah and Latief (2020) highlighted that applying risk-based WBS in early planning stages significantly reduces the occurrence of rework and schedule deviations. However, most existing studies focus on construction stages under traditional contracts (design-bid-build), not addressing the complexities found in design-build contracts, especially for high-rise buildings. The novelty of this study lies in the development of a WBS model that incorporates risk analysis and links it with Standard Operating Procedures (SOPs) specific to architectural work under design-build contracts, aiming to enhance time performance outcomes in high-rise construction projects.

The objectives of this research are; (1) To analyze the current use of WBS and SOP standards in the architectural components of high-rise buildings under design-build contracts in Indonesia. (2) To identify key risk factors in architectural work that affect the time performance of high-rise building projects. (3) To develop a risk-based WBS model tailored to the architectural work scope in design-build projects. (4) To construct SOP guidelines aligned with the identified WBS for better execution control. (5) To model the relationship between risk-based WBS, SOP application, and project time performance in high-rise building construction.

This study is expected to provide a strategic framework for practitioners and policymakers to improve project time performance through structured planning. The findings offer contractors a practical tool to enhance work efficiency and reduce rework.

For project owners and consultants, the integration of SOP and risk-based WBS contributes to clearer role delineation and better control mechanisms, especially in design-build contracts for complex architectural projects.

RESEARCH METHODS

The method (Nasir, 1983) involves applying logical principles to find, verify, and explain the truth. Research is a necessary process for planning and carrying out research (Ibid, p. 99).

Research Strategy

Research strategy is collecting, analyzing, and combining quantitative and qualitative research into one study to understand a problem or research study. Robert K. Yin (2002), in *Case Study Research Design and Methods*, mentioned several factors that affect the type of research strategy and the type of questions asked, such as who, what, where, and how much can be done with survey research methods. Second, how much control the researcher has over the behavioral events to be studied, and third, whether the emphasis is on current events and not the past.
The strategies that will be used during this study are:

1. Archive analysis is research conducted using data records stored in physical or digital form. The records were analyzed to obtain conclusions about behavior, attitudes, beliefs, and others (Schweigert, 2021).
2. Questionnaire is a data collection technique that presents a series of questions to respondents to be answered (Sugiyono, 2017).

Research Stages

The research stages are processes carried out by the author sequentially to achieve the research objectives (Syifa, 2022). According to Kumar (2011), there are three stages of research, namely:

1. The first stage is to decide on the object to be studied, identify the problem, as well as what will be studied and the object of the research, to determine the research methodology to be used to achieve the research objectives.
2. The second stage is to establish a research plan by compiling research methods to determine how steps are taken to answer the problem formulation.
3. The third phase involves carrying out research instruments, collecting, analyzing, processing data, and drawing conclusions.

Researchers can develop and determine research strategies based on the nature of the research, so they can accurately collect data and compile research instruments. Here are some types of research used in a study:

1. Descriptive research aims to describe characteristics or phenomena systematically and objectively, without manipulating variables. This method often provides a detailed picture of a population or phenomenon based on available quantitative and qualitative data (Kemparaj & Chavan, 2013).
2. Qualitative research is used to understand meaning, experience, and social phenomena in a given context. This research emphasizes the in-depth exploration of non-numerical data

such as interviews, observations, and documents to gain a broader understanding of human behavior, perception, or social dynamics (Aspers & Corte, 2019).

3. Quantitative research is an approach that uses numerical data to measure relationships, patterns, or influences between variables. This research is objective and is often used to test hypotheses or draw generalizations based on representative samples. Data in quantitative research is collected through surveys, experiments, or statistical measurements (Fossey et al., 2002).

The explanation of the research flow above is as follows:

1. Research Question 1 (RQ1) regarding the application of WBS, was answered by conducting a questionnaire to experts with experience in design and project construction for high-rise building architectural work. The questionnaire contains questions related to the application, constraints, and strategies in applying *the Work Breakdown Structure* (WBS) to high-rise building architectural work. The questionnaire results were processed by statistical methods to find out what the implementation was like and how important WBS was in the implementation of the project.
2. Research Question 2 (RQ2) regarding risk identification, was answered by validating experts through a questionnaire on risks in the previous research WBS for design and construction work on high-rise building architectural work. Each element of the WBS is identified with its hazards and risks. Expert validation is carried out to analyze and refine risk factors and determine the frequency and impact of risks. The questionnaire results will be statistical analysis to obtain outputs in the form of high risk for the design and construction stages of high-rise building architecture work in design projects that affect time performance.
3. Research Question 3 (RQ3), the result of RQ2 in the form of high-risk WBS, is used to compile risk-based WBS. From each high risk, the cause (P), impact (D), preventive measures (TP), and corrective actions (TK) were analyzed. Expert validation was carried out for the analysis of preventive actions and corrective actions that correlated with the WBS architecture.
4. Research Question 4 (RQ4) concerns the preparation of Standard Operating Procedures based on risk-based WBS as a guide for implementing WBS and achieving time performance according to project objectives.
5. Research Question 5 (RQ5) investigated the relationship between risk-based WBS, SOPs, and project time performance. Statistical analysis was carried out to determine this relationship.

RESULTS AND DISCUSSION

This stage is carried out to determine the relationship between risk-based WBS, Standard Operating Procedures (SOP) and project time performance. The questionnaire to the respondents used a Likert scale (1-5), where scale 1 was very disagreeable, and scale 5 was very agreeable. Profile of respondents on this questionnaire are as follows:

Table 1. Respondent Profile of WBS Relationship Based on Risk, SOP and Time Performance

Yes	Respondents	Final Education	Company	Work Experience	Position
1	R1	S2	PT. W	23 years old	Project Manager
2	R2	S1	PT. T	26 years old	Design Manager
3	R3	S2	PT. MCA	20 years	Project Manager
4	R4	S2	PT. A	15 years	Project Manager
5	R5	S2	PT. A	16 years old	Project Manager
6	R6	S2	PT. AXLE	17 years	Project Manager
7	R7	S1	PT. AXLE	22 years old	Project Manager
8	R8	S1	PT. A	18 years old	Project Manager
9	R9	S2	PT. A	27 years old	Project Manager
10	R10	S2	PT. A	14 years	Project Manager
11	R11	S1	PT. A	17 years	Project Manager
12	R12	S1	PT. A	15 years	Project Manager
13	R13	S1	PT. A	12 years	Project Manager
14	R14	S1	PT. MCA	30 years	Project Manager
15	R15	S2	PT. A	27 years old	Project Manager
16	R16	S1	PT. A	38 years old	Project Manager
17	R17	S1	PT. MCA	29 years old	Project Manager
18	R18	S2	PT. A	11 years old	Architect
19	R19	S1	PT. G	17 years	Project Manager
20	R20	S1	PT. A	22 years old	Project Manager
21	R21	S1	PT. AN	11 years old	Architect
22	R22	S1	PT. AN	11 years old	Architect
23	R23	S1	PT. AN	8 years	Architect
24	R24	S1	PT. AN	9 years	Architect
25	R25	S1	PT. AN	10 years	Architect
26	R26	S1	PT. AN	9 years	Architect
27	R27	S1	PT. AN	15 years	Project Manager
28	R28	S1	PT. AN	9 years	Architect
29	R29	S1	PT. AN	11 years old	Architect
30	R30	S2	PT. AXLE	15 years	Project Manager

Source: Processed Author, 2025

The questionnaire was distributed online to all respondents via WhatsApp. Respondents were classified based on education level, work experience, and job title.

Table 2. Classification of Respondents by Education

Yes	Final Education	Number of Respondents	Percentage
1	S1	20	66.7%
2	S2	10	33.3%
	Total	**30**	**100%**

Source: Primary Data, 2025

Table 3. Classification of Respondents Based on Work Experience

Yes	Work Experience	Number of Respondents	Percentage
1	<15 years	11	36.7%
2	15 – 20 years	10	33.3%
3	>20 years old	9	30.0%
	Total	**30**	**100%**

Source: Primary Data, 2025

Table 4. Classification of Respondents by Position

Yes	Final Education	Number of Respondents	Percentage
1	Project / Design Manager	21	83.3%
2	Architect	9	16.7%
	Total	**30**	**100%**

Source: Primary Data, 2025

Data Analysis

Factor Analysis

Table 5. Factor Analysis

Descriptive Statistics			
	Mean	**Std. Deviation**	**Analysis N**
X26	.3967	.19205	30
X31	.3400	.20103	30
X32	.3900	.16049	30
X43	.3700	.19853	30
X227	.4067	.19815	30
X229	.3767	.17357	30
X231	.3833	.21509	30
X234	.3400	.17340	30
X332	.3567	.18511	30

Source: Primary Data, 2025

Descriptive statistics provide an overview of each variable's average (mean) and Data Distribution (Standard Deviation), as well as the amount of data analyzed (N).

- All mean values are between 0.34 – 0.41, meaning the data is fairly homogeneous.
- The standard deviation is between 0.16 – 0.21, indicating that no data spread is too extreme.
- X32 is the most stable variable (smallest deviation), while X231 is the most variable.
- X227 has the highest average value.

All variables had an average value between 0.34 to 0.41 and a consistent sample count. The variation in the data is not too extreme, showing that the data is relatively consistent between variables, although there is a slight difference in the distribution.

Table 6. Factor Analysis

SME and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.921
Bartlett's Test of Sphericity	Approx. Chi-Square	331.402
	Df	36
	Sig.	.000

Source: Primary Data, 2025

Interpretation of the value of the SME:

Table 7. Factor Analysis

SME Value	Interpretation
0.90 - 1.00	Marvelous
0.80 - 0.89	Very good (meritorious)
0.70 - 0.79	Good (middling)
0.60 - 0.69	Medium (mediocre)
0.50 - 0.59	Miserable
< 0.50	Unacceptable

The value of KMO = 0.921 indicates that the data is very feasible to analyze using factor analysis. This test aims to determine if the correlation between variables is strong enough to be explored further in factor analysis.

- Null hypothesis (H_0): The correlation matrix is an identity matrix (there is no relationship between variables).
- Alternative hypothesis (H_1): A correlation matrix is not an identity matrix (there is a relationship between variables).

Because significance value (Sig.) = 0.000 < 0.05so H_0 rejected, meaning there is enough correlation between variables to proceed to factor analysis. With SME = 0.921 and Sig. Bartlett's Test = 0.000**,** this data It is worth doing a factor analysis**,** because the correlation between the variables is strong and the sample is adequate.

Table 8. Anti-image Matrices

Anti-image Matrices										
		X26	**X31**	**X32**	**X43**	**X227**	**X229**	**X231**	**X234**	**X332**
Anti-image Covariance	X26	.100	-.009	-.018	-.020	-.051	-.028	-.016	.010	-.019
	X31	-.009	.159	.037	-.032	-.042	-.057	-.001	-.026	.016
	X32	-.018	.037	.245	-.032	.012	-.033	.027	-.049	-.034
	X43	-.020	-.032	-.032	.083	.041	.019	-.065	-.021	-.036
	X227	-.051	-.042	.012	.041	.144	.048	-.033	-.044	-.048
	X229	-.028	-.057	-.033	.019	.048	.211	-.048	-.038	-.016
	X231	-.016	-.001	.027	-.065	-.033	-.048	.158	.014	.032
	X234	.010	-.026	-.049	-.021	-.044	-.038	.014	.132	-.015
	X332	-.019	.016	-.034	-.036	-.048	-.016	.032	-.015	.127
	X26	.945a	-.074	-.117	-.222	-.426	-.193	-.129	.091	-.170

Anti-image Matrices										
		X26	X31	X32	X43	X227	X229	X231	X234	X332
Anti-image Correlation	X31	-.074	.941a	.187	-.278	-.277	-.312	-.003	-.181	.110
	X32	-.117	.187	.948a	-.223	.065	-.144	.138	-.272	-.195
	X43	-.222	-.278	-.223	.876a	.374	.140	-.567	-.198	-.349
	X227	-.426	-.277	.065	.374	.871a	.273	-.221	-.319	-.358
	X229	-.193	-.312	-.144	.140	.273	.930a	-.262	-.229	-.097
	X231	-.129	-.003	.138	-.567	-.221	-.262	.905a	.098	.225
	X234	.091	-.181	-.272	-.198	-.319	-.229	.098	.945a	-.116
	X332	-.170	.110	-.195	-.349	-.358	-.097	.225	-.116	.933a

a. Measures of Sampling Adequacy (MSA)

Source: Primary Data, 2025

Anti-image Matrices

Function:

Anti-image matrices evaluate whether the data is suitable for factor analysis. We look at the anti-image correlation matrix and the anti-image covariance matrix. The most commonly viewed part is the anti-image correlation matrix, which shows each variable's Measure of Sampling Adequacy (MSA).

Interpretation:

- The MSA value on the diagonal → ideally above 0.5.
- If the MSA value is low, the variable is not suitable for inclusion in the factor analysis.
- All MSA values > 0.5, meaning:
  - No variables need to be removed.
  - All variables are feasible and contribute well to the structure of the factor.
- The closer it is to 1, the better—and all the values are above 0.87, some are even above 0.94.
- Off-diagonal values (which are not a) show a partial relationship between variables, after controlling for other variables.
- This value is not very important in determining whether a variable is removed or not.
- The main focus remains on the MSA (diagonal) value.

Based on the results of the Anti-Image Correlation Matrix, all variables have very high MSA values (> 0.87), so all variables are worthy of being retained in factor analysis.

Table 9. Factor Analysis

Communalities		
	Initial	Extraction
X26	1.000	.911
X31	1.000	.844
X32	1.000	.741
X43	1.000	.897
X227	1.000	.801
X229	1.000	.794
X231	1.000	.803

Communalities		
	Initial	Extraction
X234	1.000	.882
X332	1.000	.868
Extraction Method: Principal Component Analysis.		

Source : Primary Data, 2025

Table Communalities indicates how much the proportion of variance of each variable (in this case X26 to X332) can be explained by the principal component (factor) in the factor analysis using the Principal Component Analysis (PCA)**.**

- Initial: The initial value is always 1,000 because it is assumed that 100% of each variable's variance is available before extraction (this is the standard in PCA).
- Extraction: This value indicates how much variance of the variable is successfully explained by the extracted factors.

The higher the extraction value, the greater the proportion of information (variance) the factor model can explain. All variables have a Communicability value above 0.70, which means that almost all of each variable's variances are explained by the components/factors that are formed. This shows that Factor models are excellent and efficient in capturing information from data.

- A > value of 0.5 is generally considered good enough
- A > value of 0.7 is more ideal
- A > value of 0.8 indicates a very high contribution of the variable to the factor

In the above results, all variables have an extraction value above 0.74, which means:

- All variables are very well explained by the factors that are formed.
- No variables need to be excluded because the communalities are low.

All the variables in the result of these communalities contribute a very high amount to the structure of the factors because the factors formed explain between 74% and 91% of the variance of each variable. This means that the structure of the factors formed is very representative of the original data.

Table 10. Factor Analysis

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.541	83.789	83.789	7.541	83.789	83.789
2	.372	4.139	87.928			
3	.332	3.692	91.620			
4	.228	2.528	94.148			
5	.151	1.678	95.826			
6	.130	1.439	97.266			
7	.117	1.298	98.564			
8	.080	.891	99.455			
9	.049	.545	100.000			
Extraction Method: Principal Component Analysis.						

Source: Primary Data, 2025

Total Variance Explained is one of the important outputs in Factor Analysis (e.g. Principal Component Analysis – PCA) which shows how much variance (diversity) in the data can be explained by the extracted factors. Variance indicates how spread the data is from the mean. In factor analysis, finding Latent factors (hidden) that can Explain the general pattern of many variables.

The Total Variance Explained table shows:

1. Initial Eigenvalues: The initial variance before the rotation.
2. Extraction Sums of Squared Loadings: The variance described by the retained component only (usually the one with an eigenvalue ≥ 1). According to the table above results, only component 1 meets these requirements. This is great, because it means that all variables tend to measure one major construct

Table 11. Factor Analysis

Component Matrix	
	Component
	1
X26	.954
X31	.919
X32	.861
X43	.947
X227	.895
X229	.891
X231	.896
X234	.939
X332	.932
Extraction Method: Principal Component Analysis.	
a. 1 components extracted.	

Source: Primary Data, 2025

This Component Matrix table shows the results of the Principal Component Analysis (PCA), specifically the loading factor for one main component (since only 1 component is extracted).

- Component 1: Is the only major component taken from the PCA.
- The value below it is the loading factor of each variable against that component. The loading factor measures how strong the relationship between a variable and a component is.

All variables have a very high load on component 1**,** which means that this one component is already very representative in explaining the pattern of the existing variables. PCA manages to reduce data to one very powerful key factor (*A Guide to the Project Management Body of Knowledge (PMBOK Guide)*, 2017; Latief & Sagita, 2019; Putro et al., 2022).

Data Analysis Results

Based on the results of data analysis, the nine high category risks in WBS Architecture that affect time performance have been validated by 5 experts. Therefore, these nine risk factors can be used as the basis for the creation of risk-based WBS for the architectural work component of high-rise buildings with design contracts. The relationship between high risk WBS and time performance is negative, i.e. the higher the risk value of WBS, the lower the project time performance.

Standard Operating Procedures (SOPs) are strongly related to project time performance. With a positive relationship, the better the implementation of SOPs in the project will also have a good effect on the project's time performance.

CONCLUSION

This study concludes that the application of standard Work Breakdown Structure (WBS) in multi-storey building architectural projects with a design contract system plays an important role in supporting project success, especially in scope planning, resource allocation, and time management. The WBS consists of six levels and one alternative method, divided into two main phases: planning and implementation. From the risk analysis, 355 potential risks were found (64 planning risks and 291 implementation risks), with 9 high-profile risks that significantly negatively impact project time performance, especially on pre-design, design development, and façade work. To address these risks, a risk-based WBS was developed that includes the addition of preventive and corrective measures at each WBS level and integration with Standard Operating Procedures (SOPs). The relationship model built shows that the synergy between risk-based WBS and SOPs has been proven to improve the project time performance of multi-storey building architecture significantly.

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