Development Of Risk-Based Work Breakdown Structure (WBS) Standards For Integrated Design And Construction Phase On Design-Build Method Of Architectural Works Of High-Rise Building To Improve Construction Safety Performance

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Abstract.

Design-build methods are one of the options in carrying out the construction of high-rise buildings with a high level of uncertainty from design phase to construction, which also affects the safety performance of the project itself. Therefore, a prevention standard for a high-risk event is needed based on project activities. This research was prepared using a descriptive qualitative method with expert validation process through Delphi method and completed with a questionnaire survey to conduct a risk assessment. The output in this research is a development of risk-based standard work breakdown structure for architectural work, which generated from 39 high level risk. Based on the results of the mapping of preventive and corrective actions at high-level risks, 5 types of WBS development can be carried out at levels 3 to 6 of the WBS to prevent and minimize the impact of risk so that safety performance could be improved. The novelty in this research lies in the form of design-build project delivery activities which has not been widely discussed in previous work breakdown structure research and risk identification based on the activities listed on the WBS.

Keywords: *Architecture work, construction risk, construction safety performance, risk management and work breakdown structure.*

I. INTRODUCTION

Indonesia government decided to use the design-build methods to accelerate IKN development and is undoubtedly very complex and uncertain, especially for a high-rise building for city infrastructure with the benefits of this method include faster completion of work, as well as the ability to launch projects without creating detailed design documents [1].While in real practice, the construction of high-rise buildings has a high level of complexity both in the initiation, design, and construction stages so that it needs a clear description to accomplish the expected conditions. According to records, the implementation or construction stage of architectural work entails about 258 highly technical tasks which refer to strictly working drawings [2]. A detailed job or activity description should be contained in a project document known as a Work Breakdown Structure. Work Breakdown Structure (WBS) is a hierarchical division of tasks that is deliverable-oriented and should be carried out by the project executor to meet project objectives and requirements [3]. Despite being prepared, WBS does not eliminate the possibility of risks and accidents that are frequently encountered in the construction of high-rise building projects.In November 2022, the number of construction accidents increased to 265,334 cases [4]. According to Maulana & Latief's research findings [5], there were 45% more construction accidents in 2018 caused by a lack of work standards.

Additionally, Berawi [6] asserts that planning designs that fall short of the standards and requirements or called under designed are to blame for work accidents. One of the studies conducted by Elsye & Latief [7] states that the risk of work accidents can be prevented by identifying and analyzing potential risks in each activity in a WBS. WBS can be used as a planning approach to improve project performance, the practice reportedly reduces rework to quality performance—largely related to reduced scope of work changes and increased on-site control for industrial construction projects [8] which this

problem often found in design build method.To correct flaws in the work safety plan document and keep project safety performance, a standardized WBS which is based on construction safety risk analysis is needed. In previous studies, the development of the WBS was limited to conventional methods and the breakdown of the WBS was only at the construction stage. The gap in the literature found that there has been no study that comprehensively examines risk in planning, designing, until the construction stage of high-rise building using integrated building design method. So that the novelty in the research comes from the different types of delivery methods used, namely design-build and the risk identification process carried out in detail in each activity starting from the planning, design, and construction stages based on the document of the Minister of Public Work and Public Housing (PUPR) Regulation Number 10 of 2021.

Based on the background that has been stated, the objectives of this research are:

1. To formulate work breakdown structure standards for integrated design development and construction phase on design contracts for architectural dan exterior work in design-build high-rise building project.
2. To Identify the risks for design development and construction phase for architectural dan exterior work in design-build high-rise building project which affect construction safety performance.
3. To develop a risk-based work breakdown structure standard for high rise building construction using design-build method

II. METHODS

This research uses a qualitative descriptive approach to achieve the objectives through three main stages of research. Each main steps correspond to each research question which started by reviewing relevant literature, analysing archives for data and information from earlier research-related projects to complete a content construct process before validating through Delphi Method.For first research question in setting a standard work breakdown structure, a deep interview was conducted by means of a structure questionnaire to five experts in construction with more than 10 years experiences in high rise building projects to form a standardized WBS on architecture and exterior work design development phase and construction phase, starting from level 1 to 4, and then continued for level 5 for activity and level 6 for resources.

The result of the first stages in this research is a standardized design-build WBS which will serve as base for risk identification in stage two.In the second stage of this research, literature review was conducted to identify risk variables for each activity from the WBS which affect safety performance. Then validation and content construct process were conducted by five experts with minimum of 10 years' experience in risk management of construction project, generating 362 risk variables to weighted by respondent risk score survey. The result is a list of risk events with high risk which may result in construction accidents. This list will then be analyzed for causes and impacts so that preventive and corrective actions can be produced.As in Figure 1, the third stage of this research begins with the processing and development of the WBS based on the results of research question 2. The results of the development were then validated by experts before a respondent survey was conducted as the final stage. Gap analysis will be conducted after the respondent survey.

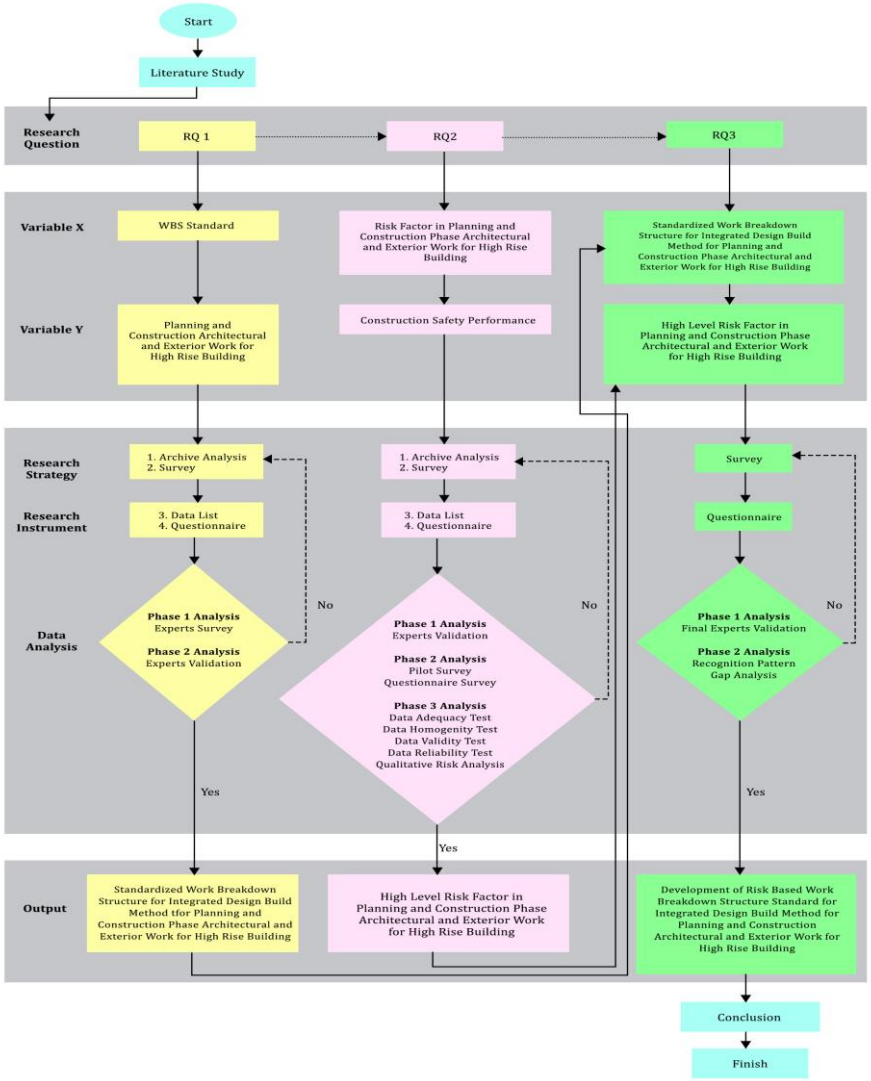

Fig 1. Research Process Diagram

III. RESULT AND DISCUSSION

Result of Research Question 1: WBS Standards

The following are the results from expert validation through Delphi Method in constructing standardized WBS for architectural and exterior work in high rise building integrated with design build method.

1. A common work breakdown structure for construction process of high-rise building project using design bid-built method mainly consists of Site Work Cluster, Structural Work Cluster, Architectural Work Cluster, Mechanical Work Cluster, Electrical Work Cluster, Plumbing Work Cluster, Exterior Landscape Work Cluster, and Miscellaneous Work Cluster. In the design build method, there are some additional work clusters which need to be implemented in planning phase such as Design Development Work Cluster and Construction Safety Management System Work Cluster. Figure 2 describes one example of a WBS tree diagram in design development cluster.
2. Design Development Work Cluster intended to give a larger perspective and knowledge to various stakeholders of high-rise building projects to assure the performance of the project.

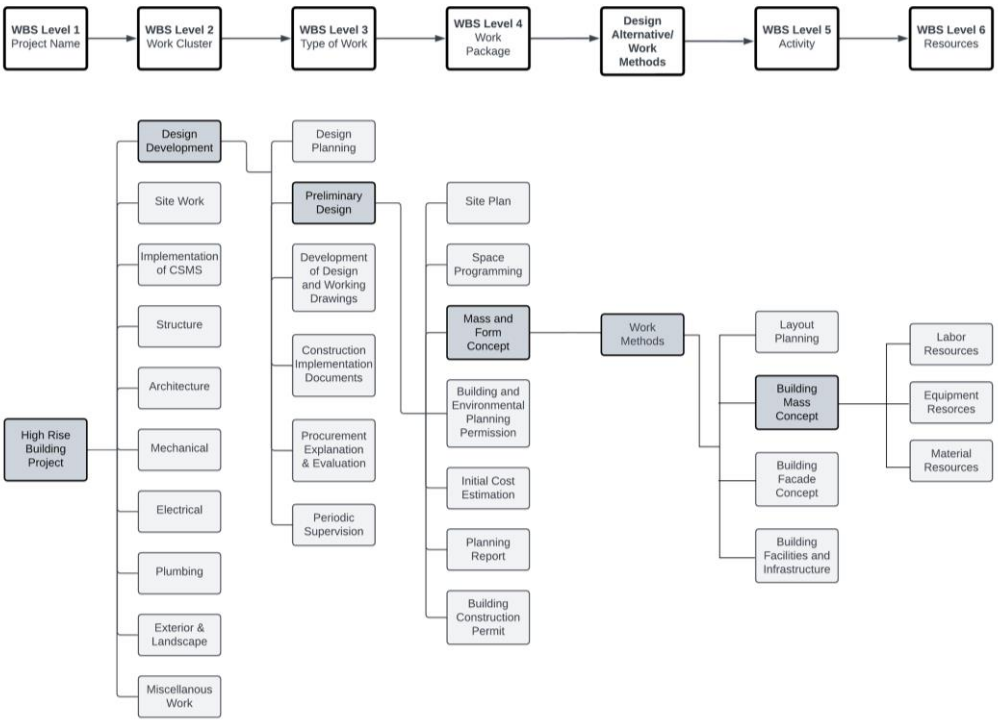

Fig 2. Tree Diagram of Design Development phase in WBS Standard Architectural Work in High Rise Construction

3. Design Development Work Cluster intended to give a larger perspective and knowledge to various stakeholders of high-rise building projects to assure the performance of the project.

4. In every project, a work breakdown structure should at least decompose into 6 level hierarchy based on their work cluster. The following are results from content construct and validation process with expert.

- WBS Level 1 : Project Name
- WBS Level 2 : Job Clusters

Job clusters are the primary decomposition of the construction project goal [2,10,11]. In this study, ten job clusters were listed for a design-built construction project. Design Development became the additional cluster to be included in the WBS Level 2.

- WBS Level 3 : Type of Work

Type of Work in level 3 were the smaller part from Job Cluster [2,10]. In this study, Design Development Cluster had six types of work, Architectural Work Cluster had seven types of work, Exterior and Landscape Work Cluster had 2 types of work, and Miscellaneous Work Cluster had ten.

- WBS Level 4 : Work Package

The most common hierarchy in WBS to be distributed to each team based on their job description. An example of WBS Level 3 Door and Window Work decomposition are Door Work Package and Window Work Package. Work package would adjust from design development documents and other construction documents.

- Alternative for design or methods

Based on expert opinion in validation process, this section in WBS is not mandatory to follow. Each design or method from specific work packages have been set since design development process and listed in construction documents. It's not very necessary to present alternatives in WBS for ease of use on site. All types of design used in the project would mainly be listed in WBS Level 4.

- WBS Level 5 : Activities

Activities were more detailed descriptions from work packages at level 4 which contains steps to accomplished goal that can be monitored by project managers [11, 12].

- WBS Level 6 : Resources (Human, Material, Equipment)

Resources were the lowest level of WBS, containing human resources, materials resources, and equipment resources [2,10] needed to accomplish activities. In Table 1, describe the findings of work packages of architectural work breakdown structure using design-build method.

Table 1. Number of work packages found based on type of work

	Number of Type of Works	Number of Work Packages
Design Development	6	31
Architectural Work	7	28
Exterior Facility	2	11
Miscellaneous Work	10	24

Result of Research Question 2: High Level Risk Identification

Twenty-five respondents, in rating hazard and risk event based on each activity from WBS for architectural and exterior work in high rise building integrated with design build method, which have been simplified and validated by experts in earlier phase.

Table 2. Total of high-level risk identification and categorization

	Number of Low Risk	Number of Medium Risk	Number of High Risk	Total Risk
Worker	122	102	24	248
Material	19	20	6	45
Equipment	16	36	9	61
Public/ Environment	11	17	0	28

From Table 2, 39 high risks from all categories can be identified. It is founded 15 high risk variables which located in design development phase and 14 others in construction phase. Risk related to data collection in design development phase hold the highest rank, resulting in inaccurate design drawings and non-compliance with regulatory standards. Meanwhile during construction phase, the high-risk possible risk to be occur is falling from certain height which cause worker's death. Unfortunately, the identification of risks based on activities and factor groupings has not been carried out by Jati [13] and Nugroho [3].

Table 3. High-level risk identification based on WBS Level 2

	Number of High Risk	Risk Variables
Design Planning	4	X'22, X'48, X'38, X'6, X'45, X'47, X'41, X'31, X'11, X'23, X'42, X'53, X'50, X'10, X'52
Development of Design and Working Drawing	11	X'48, X'6, X'45, X'47, X'41, X'11, X'42, X'53, X'50, X'10, X'52
Ceiling Work	5	X'152, X'144, X'147, X'153, X'158
Wall Construction Work	9	X'128, X'136, X'65, X'83, X'129, X'71, X'112, X'140, X'68
Roof Work	1	X'238
Landscaping Work	5	X'313, X'270, X'315, X'312, X'294
Miscellaneous Work	4	X'377, X'372, X'380, X'347

From Table 2 and 3, can be seen that worker is still the top factor which was mentioned by Haslam et al [14] and reaffirmed in Gambatese [15] not only in construction phase, but also planning and design development phase.All high-risk variables that have been assessed and ranked are then analysed for causes and impacts so that preventive and corrective actions can be determined. This determination process is based on a literature study which will then be validated by experts to ensure the accuracy of the literature study with the current conditions in the field.Table 4 explained one of high-risk in early stage of design development phase in architectural scope of planning high rise building project.

Table 4. Mapping of risk event, cause, preventive action, impact, and corrective action

Variable	Risk Score	Aspect	Potential Risk	Cause (P)	Action Type	Preventive Action (TP)	Impact (D)	Corrective Action (TK)
X'6	0.26	Material	Primary data and literature not yet updated	Not conducting field surveys	Substitution	Investigation of the project environment (soil	Disrupt other work sequences	Increase overtime to replace idle work

Variable	Risk Score	Aspect	Potential Risk	Cause (P)	Action Type	Preventive Action (TP)	Impact (D)	Corrective Action (TK)
						conditions, rainfall etc.) before the start of the project.		
					Substitution	Exploring field data information based on historical data		Conduct a review and efficiency of the remaining work
					Substitution	Perform weather prediction by periodically searching for climatological data from Climatology and Geophysics Meteorology Department		Adjust the number of workers as needed
				Inexperienced contractors	Administrative	Use subcontractors or other consultants who are more qualified	Rejection by owner and relevant stakeholders	Replace planning staff / labour with new ones according to the desired competencies
								Subcon improves competency to carry out work
				Lack of contractor communication with vendors and owners	Administrative	Periodically check for changes in data so that action can be taken immediately.	Project objectives (cost, time, and quality, as well as safety) are not achieved	Conduct joint evaluation meetings with relevant stakeholders to ensure design improvements to the critical activity path plan
					Administrative	Conduct good project management and periodic Focus Group Discussions.		Evaluate the safety plan / RKK against field conditions during the construction period
					Administrative	Evaluate and recheck the scope of the design before it is detailed		

It is found that outdated literature from the company, that is used without caution can cause design output of the building not comply with the regulations and may lead to un-constructability design and construction failure. This risk event occurred in one of the activities in planning phase. As a result of this fatal impact, preventive and corrective measures were developed as a plan to ensure the safety performance of the construction project. This finding supports research by Gambatese [15] and Nugroho [16], which mentions that the design process can affect and create hazardous conditions in construction. Hazard identification and control must be conducted before the construction phase begins to ensure that safety

challenges are avoided [16].Pattern recognition is done after the causes, impacts, preventive, and corrective actions of the highest risks are determined. The following is an example of mapping the relationship of each risk event related to the mapping of causes, impacts, preventive and corrective actions in the form of pattern recognition to give graphical illustration of mapping process.

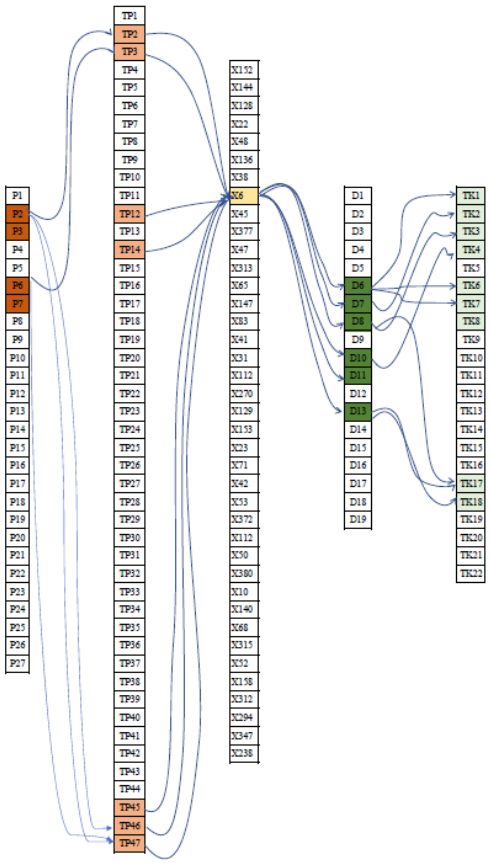

Fig 3. Pattern Recognition of X'6

From Figure 3, it can be explained that X'6 (Primary data and literature not yet updated) could risk the site design output does not meet applicable regulatory standards. As in P2 as one of the causes, it has preventive actions TP2, TP3, TP46, and TP47. Then risk variable X'6 is detailed more specifically so that the impacts D4, D7, D8, D11, and D12 are recorded. Each impact has its own corrective action, in D4 the corrective action is TK1, TK4, and TK7.

Result of Research Question 3: Risk-Based Standardized WBS

After obtaining the causes, impacts, preventive actions, and corrective actions of each high-value risk from the previous stage, the WBS that has been obtained from RQ 1 is developed based on preventive and corrective actions that have gone through expert validation.

According to Yufrizal [17], Mintohardjo [10], and based on expert input, the work breakdown structure development was grouped into:

a. Addition to Managerial Item

Addition to managerial item is required to respond to the risks associated with the management of project activities since the initial stage of planning. This is done with the aim of implementing prevention, which begins with the structure and project organization.

b. Addition to Other WBS Element

Additional activities or work items that are added to WBS elements outside the related WBS, for example at the level of a different work package or even at the level of another work cluster [10].

c. Addition to Relevant WBS Element

Adding activities into related WBS work package that have a high risk to control specific item and influenced by organizational policies.

d. Addition to Project Requirement Document

These are additions to work requirements that can be included in work plans and specifications, work instructions, BoQ/ RAB, or contracts [10].

e. Influencing WBS Coefficient

To anticipate risk events related to the performance/ productivity of resources in the form of human resources, materials, and equipment used in each work unit [10].

Table 5 explained one part of the work breakdown structure in the design development phase that has been developed based on risk mapping and assessment in research question number 2.

Table 5. Improvement of work breakdown structure

WBS LEVEL 1: High Rise Building Project							
WBS Level 2	**WBS Level 3**	**WBS Level 4**	**Alternative Design/ Method**	**WBS Level 5**	**WBS Level 6**		**Requirement**
Job Cluster	**Type of Work**	**Work Packages**		**Activities**	**Category**	**Resources**	
Design Development	Design Planning	Preparation		1. Establishment of team	Worker	Team Leader	
					Worker	Administrator	
				2. Administrative and technical preparation	Worker	Team Leader	
				3. Survey preparation and field observation	Worker	Team Leader	
					Worker	Structure/Building Expert	
					Worker	Planology Expert	
					Worker	Architect	
					Worker	Sanitation and Waste Expert	
					Worker	Mechanical and Electrical Expert	
					Worker	Geodesist	
					Worker	Surveyor	
					Worker	Construction Safety Expert	
					Worker	Estimator	
				4. Exploring field data information based on historical data	Worker	Team Leader	
				5. Early investigation of the project environment before the start of the project.	Worker	Team Leader	
					Worker	Surveyor	
				6. Preparation of preliminary report	Worker	Team Leader	Evaluate and recheck the scope of the design before it is detailed
					Worker	Administrator	Scheduled data check in server
				7. Focus Group Discussion and Owner Review	Worker	Team Leader	Construction Safety Procedures Training Certified

In table 4, at WBS Level 5 Activities, there are 3 yellow areas (numbers 4, 5, and 7) which were not included in the previous WBS because the WBS before development was not designed based on risk. Activities 4, 5, and 7 are the result of the processing of preventive actions for risk X'6 that can occur in the preliminary report preparation activity (activities number 6). Adding activities 4, 5, and 7 are categorized as Additions to Relevant WBS Element. After WBS Level 6 Resources, a column titled Requirements is added as a form of Addition to Project Requirement Document.Furthermore, in the Requirements column, can be contained a requirement in the contract document or included in Work Instruction, or even requirements related to resource capability which could be considered also as additional in managerial item. This section will ensure that certain jobs that have high success qualifications and high risks can be guaranteed through preventive measures. The decision made on the identified risks has an immense impact on the project overall performance [16].

IV. CONCLUSION

Based on the findings, it can be concluded that the WBS standard for the design and construction phase of tall buildings in architectural work and miscellaneous work composed of 6 levels where Level 1: the project name, Level 2: work cluster, Level 3: type of work, Level 4: work package, Level 5: activity, and Level 6: resource. The risk of construction accidents in architectural work can arise both during the design and construction phases, as evidenced by the total high risk during planning and design of 15 out of 39 risks, which greatly affects the construction safety performance of the project. Meanwhile the most occurred risk in construction phase is worker fall from height. Each high risk has been mapped with preventive and corrective actions in response to hazards and risk events which are mostly included in the WBS development category Addition to Relevant WBS Element in the form of additional activities at level 5.

Five types of WBS development can be simplified into two actions in enhancing risk based WBS which is adding relevant activities in WBS Level 5 and adding Requirements column after WBS Level 6.This study shows that by developing a risk based WBS based on each activity from design phase until construction phase can specified and facilitate the prevention of construction accidents from all four aspects (workers, material, tools, and environment) through improvement of production of safety documents. With the development of the WBS standard for high-rise buildings, it will serve as a guide for construction implementers who opt to use design-build methods to improve safety performance in future construction projects.The development of risk based WBS for high-rise building construction will also affect the improvement of several safety performance indicators, especially the leading indicators as the main indicators of construction safety performance in Minister of Public Work and Public Housing (PUPR) Regulation Number 10 of 2021 both directly and indirectly.

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