Development of Risk-Based Standardized WBS (Work Breakdown Structure) for Preparatory, Instrumentation and Control Works of Coal-Fired Steam Power Plant Construction Project in Indonesia to Improve Time Performance

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Abstract

There is always uncertainty when implementing a project using an EPC contract, as the projects involved are very complex and risk affecting the performance of the project. Since one of these is the time performance of the project, it is necessary to identify the risks that may affect the time performance in order to minimize the decrease in the time performance so that the project can proceed according to the goal. It is necessary to develop a risk-based WBS to avoid poor time performance in the project implementation process. Because WBS is an effective tool for project management in planning and implementing a successful project. This study aims to develop risk-based WBS standards for CFSPP construction project preparatory, instrumentation and control works to improve time performance. The results of this study are WBS standards for the preparatory, instrumentation and control works of CFSPP construction projects consisting of eight (8) levels up to resources, 14 risk factors with the highest ranking in all risk categories, and 5 groups of risk response recommendations for improving time performance as the development of WBS standards

Keywords
WBS, risk factors, Preparatory work and instrumentation control work, Time performance and Coal-Fired Steam Power Plant.

1. Introduction

In engineering procurement construction (EPC) contracts, the project execution process is tied to a very complex project, so there is always uncertainty that can affect project performance, such as project time performance. Therefore, it is necessary to identify risks that may have an impact time performance to minimize declining time performance (Putra, 2013) so that the project can run according to targets and plans (Zegordi et al., 2012).

Some effective techniques that can be applied for planning in EPC projects are developing WBS, arranging activities in sequence, establishing activity relationships, setting duration, setting milestones, planning resources, and determining project critical paths (Ud & Tahir, 2004). Because WBS is an effective tool for project management in planning and implementing a successful project (Burghate, 2018) and risk management needs to be well planned for the CFSPP project, because being able to manage the impact of risk on the project is a key factor for the success of project management (Iranmanesh et al., 2007).

The object of this research is CFSPP which uses coal as fuel with a capacity of 50 MW – 100 MW, boiler with PC (Pulverized Coal) type and located on the coast of Indonesia, development of risk-based standardized WBS (Work Breakdown Structure) for Preparatory, Instrumentation and Control Works only focuses on the main process areas of CFSPP, namely Boiler & Auxiliary System and Steam Turbine Generator & Auxiliary System because they are in the critical path of the project schedule.

1.1 Objectives

This study aims to establish the WBS standard for preparatory work, instrumentation and control of CFSPP Project, identify risk factors that can affect the time performance for preparatory, instrumentation and control work of CFSPP construction project, as well as establish the Development of Risk-Based Standardized WBS (Work Breakdown Structure) for Preparatory, Instrumentation and Control Works.

2. Literature Review

2.1 Work Breakdown Structure (WBS)

The WBS is the foundation for project planning, cost estimate, scheduling and resource allocation, and risk management. WBS is a determinant of project success (Devi & Reddy, 2012). Create WBS is the process of subdividing project deliverables and project work into smaller, more manageable. The WBS is a hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables. The WBS organizes and defines the total scope of the project and represents the work specified in the current approved project scope statement. The planned work is contained within the lowest level of WBS components, which are called work packages. A work package can be used to group the activities where work is scheduled and estimated, monitored, and controlled. In the context of the WBS, work refers to work products or deliverables that are the result of activity and not to the activity itself. (*A Guide to the Project Management Body Of Knowledge (PMBOK) Guide Sixth Edition*, 2017).

According to (Rianty et al., 2018) there are two formats that can be used in creating WBS, namely in the form of tables and graphs. The WBS in the form of a table is numbered according to its level. While the WBS in the form of a graph is made like a tree diagram. The following is an example of a WBS format in the form of a phase-oriented graph and deliverables starting from the phases of the project cycle to product deliverables:

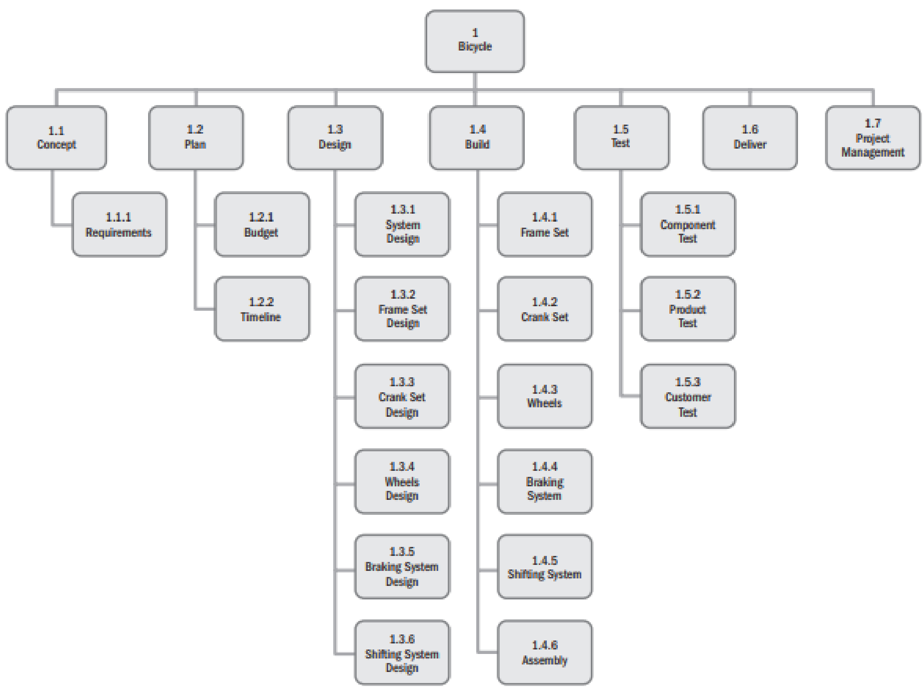

Figure 1. Example of Phase-Oriented WBS Format and Deliverable
Source: (Project Management Institute, 2019)

WBS with phase decomposition – deliverables will be used in this study because it is structured per phase, it will be very easy to manage this very complex EPC project so that project objectives can be achieved (Yahya, 2011).

2.2 Time Performance for Preparatory, Instrumentation and Control Works of CFSPP Construction

Many significant factors arise during project implementation that can affect project time and cause delays, so identifying these problems is very important in the project preparation stage (Le-Hoai et al., 2013). Time performance is one of the key criteria to measure project success (Memon et al., 2014). Estimated project duration becomes a benchmark for measuring time performance, where the factors that affect the duration of the project are project scope, project complexity, management attributes and project environment (Hoffman et al., 2007). Methods that can be used to improve the time performance of a project proper planning, good leadership and management, strict supervision, effective communication and coordination, hiring skilled workers to achieve good progress and avoid quality bad work (Memon et al., 2014).

The factors causing delays in the CFSPP project in Indonesia are transportation and shipping of imported goods, equipment that must be imported, delays in forwarding materials to the field due to remote area that are difficult to reach, delays in providing the main equipment needed, an agreement when consortium to import equipment (Sodikin, 2013). The factors of delay in the EPC project in Oman according to (Ghaithi et al., 2017) are shortage of materials and labor, late design drawings, scope changes during the design process, delays in vendor mobilization during testing and commissioning. process, delay in approval documents. There are problems in instrumentation and control work, namely design errors and poor maintenance that have an impact on the reliability of instrumentation and control component failures that can obstruct the implementation of power plants, as well as some incomplete specification requirements (Brill, 1998).

2.3 Risk Factors Influencing Time Performance for Preparatory, Instrumentation and Control Works of CFSPP Construction

Risks or uncertainties that occur in EPC projects exist at every stage, especially at the construction stage which can affect the project implementation time (Maddeppungeng & Bethary, 2015). Risk management is a process of risk management planning, risk identification, analysis, risk response planning and implementation, as well as monitoring in a project. The goal is to increase the probability or impact of a positive risk, reduce the probability or impact of a negative risk so as to optimize the success of a project (*A Guide to the Project Management Body Of Knowledge (PMBOK) Guide Sixth Edition*, 2017). In implementing WBS in CFSPP construction projects, it is necessary to identify the risks that affect project time performance and manage these risk factors so that the project can run successfully. In this research, several categories of risk events that affect project time performance for identification are divided into work packages, methods and designs, activities, resources (material resource, equipment resource, labor resource) and environment.

3. Methods

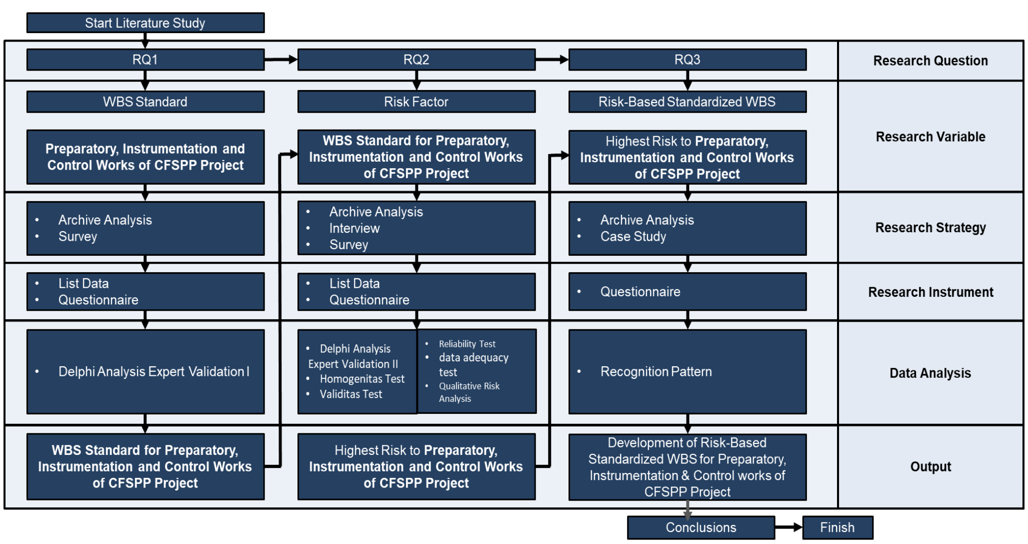

Figure 2. Research Method

This research used descriptive qualitative method. Descriptive research is research conducted to determine the value of independent variables, either one or more variables without making comparisons with other variables (Amini, 2018). The research instrument used in this study is a questionnaire. The definition of a questionnaire quoted from (Amini, 2018) according to Riduan, 2008 is a list of questions posed to other people who are willing to respond (respondents) according to the request of the researcher or user. In this study, there are 5 stages of a questionnaire made with the aim of answering the formulation of the problem or research question. The data used in this study are primary data and secondary data. Primary data obtained from the results of direct interviews with experts and answers from the results of questionnaires or respondents. While secondary data is data obtained from related projects, lessons learned, best practices, historical data, journals, reference books, and other supporting literature (Yahya, 2011).

Research method to answer research question 1 “WBS Standard Form for Preparatory, Instrumentation and Control Works for CFSPP Construction Projects” : there are 2 stages of research conducted, namely in the first stage of data collection in the form of archive analysis of 10 Bill of Quantity and WBS data for preparatory work, instrumentation and control work for CFSPP past projects from contractors, and standard bid documents from PT. PLN with a capacity of 50 – 100 MW after the data is compiled, then validated to experts in the form of an initial questionnaire from WBS level 1 – level 3. Then in the second stage, final expert validation is carried out by making WBS standards for preparatory work, instrumentation and control work in accordance with the recommendations in the initial stage and distributing questionnaires to experts for the next WBS level, namely the work package level – the resource level. The questionnaire in this study was validated by 3 experts with a description of the expert profile as follows:

Table 1. Expert Profile for Validation

No.	Experts	Position	Work Experience	Education
1.	Expert 1	Principal for Project Management	33 Years	S2
2.	Expert 2	Partner Project Advisory Group	25 Years	S2
3.	Expert 3	Managing Director	35 Years	S3

Research method to answer research question 2 "Highest Risk Factors That Can Affect Time Performance for Preparatory, Instrumentation and Control Works of CFSPP Construction Projects”: there are 3 stages of research conducted the first stage is the validation of risk factor identification to experts related to content and constructs with questionnaire method. After experts agrees on the risk variables, the second stage is conduct pilot survey to 10 respondents to clarify the respondent’s understanding of the questionnaire questions so as to produce valid data conclusions. Furthermore, in the third stage a respondent survey was conducted to 25 respondents related to 70 risk variables that had been validated with the requirement that respondents have at least 3 years of experience in CFSPP project. The results of the respondent's questionnaire were analyzed using SPSS version 22. At the respondent survey stage several qualitative analyses were carried out such as homogeneity test using Kruskal Wallis (based on educational background, work experience, company, and respondent's position), validity test, reliability test, data adequacy test, and qualitative risk analysis. The risk score can be calculated with following:

$$R = P \times I \qquad (1)$$

Where R = risk factor, P = probability and I = impact.

Research method to answer research question 3 “Risk-Based standardized WBS for Preparatory, Instrumentation and Control Works of CFSPP Construction Projects” At this stage, a literature study is conducted to map the analysis of causes, impacts, preventive actions and corrective actions of the highest risk rankings that have been validated by experts before. The results of development of risk-based standardized WBS are made by including input from preventive and corrective actions which become additional items according to their grouping, namely addition to management item, addition to other WBS elements, addition to related WBS elements, addition to RKS requirements, addition to productivity coefficients.

4. Results and Discussion

4.1 Standard WBS of Preparatory, Instrumentation and Control Works for CFSPP Project

From the results of discussions with the three experts related to the results of RQ 1 "WBS Standard Form for Preparatory Work, Instrumentation and Control Work for CFSPP Development Projects in Indonesia" it was found that the WBS standard was decomposed into 8 levels to resources with an explanation of each level as follows:

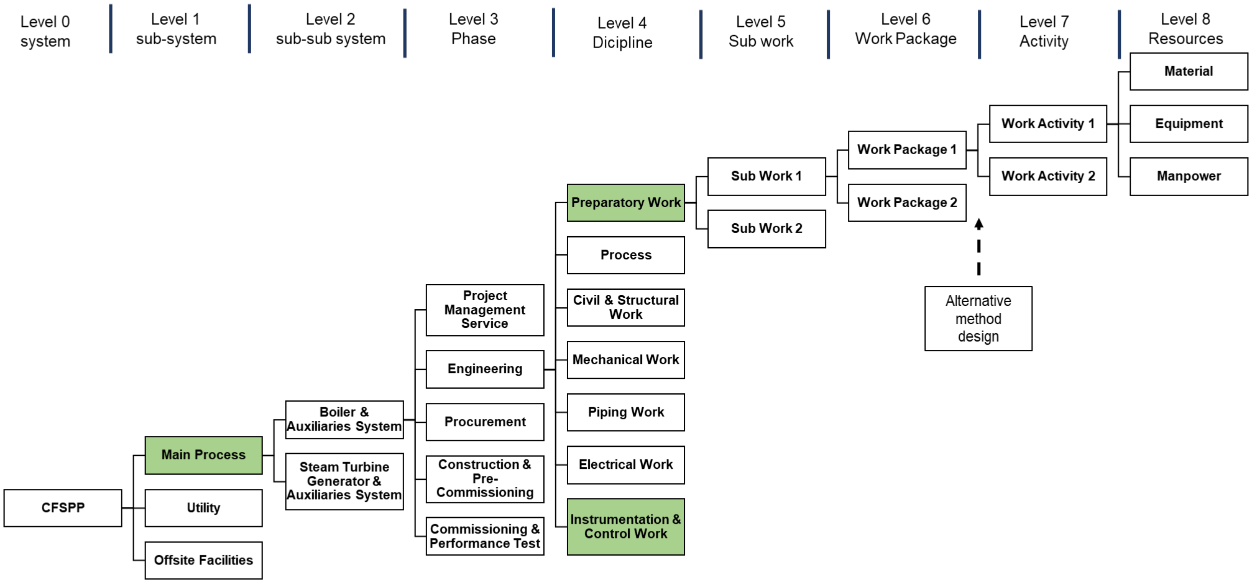

Figure 3. Diagram Tree for Standard WBS of CFSPP Project

The following is an example of the results of the work breakdown structure for preparatory work, instrumentation and control work of CFSPP project from the final expert validation results from level 4 – level 8 on Boiler & Auxiliaries System sub-systems in the engineering phase:

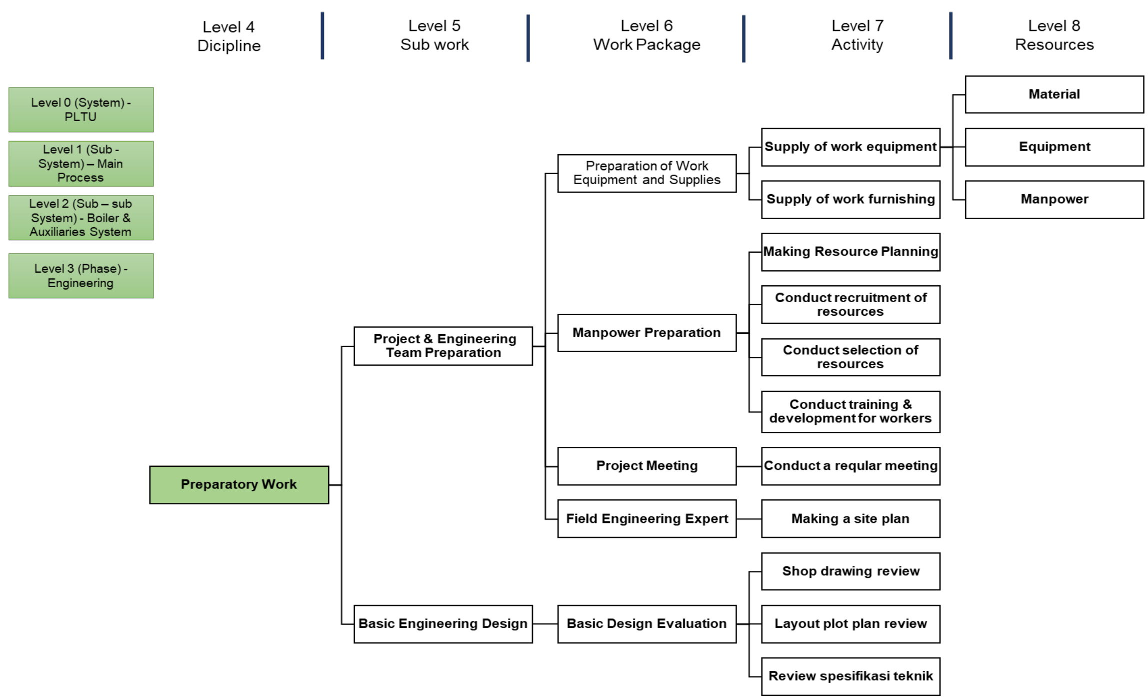

Figure 4. Standard WBS for Preparatory Work of CFSPP Project Engineering Phase Level 4 – Level 8

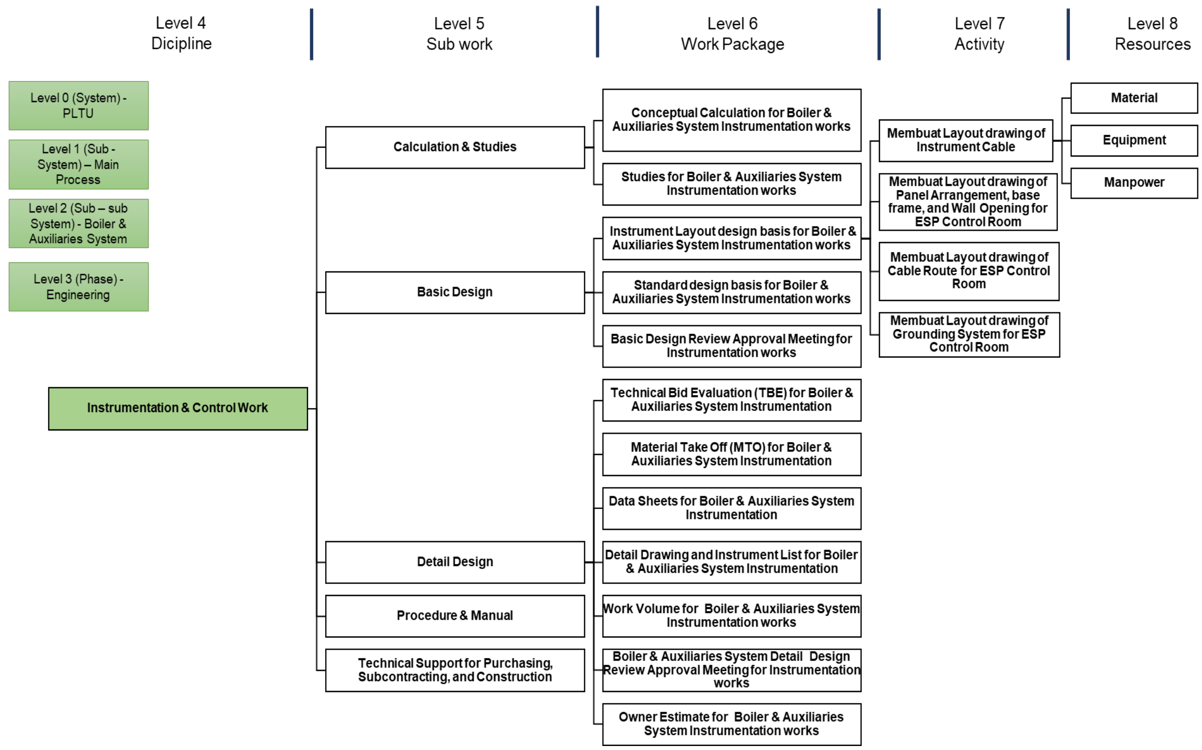

Figure 5. Standard WBS for Instrumentation and Control Work of CFSPP Project Engineering Phase Level 4 – Level 8

4.2 Highest Risk Factors that Improve Time Performance

At this stage, a qualitative risk analysis is obtained from the results of questionnaires distributed to respondents on the frequency and impact rating in each risk category, then the probability and impact numbers are multiplied to see the ranking of the risks of each category which includes high, medium levels. Based on the results of the calculation of the qualitative risk analysis, from 70 risk variables distributed to 25 respondents, 59 risk variables with a high level of risk were obtained, and 11 risk variables with a moderate level of risk. The following are the results of the ranking of the two (2) highest risks that affect time performance for preparatory work, instrumentation and control work of CFSPP project in each risk category that has been validated by experts:

Table 2. The Highest Risk Factor that Influences Time Performance

Variable	Risk Events that Influence Time Performance for preparatory work, instrumentation and control work of CFSPP Construction projects
Category : Work Package	
X8	Work process of making road/bridge access and temporary jetty to the site delay
X4	An error occurred while creating the Instrument Layout Drawings for Boiler & Auxiliaries System Instrumentation work
Category : Activity	
X20	Financial limitations from main contractor
X18	WBS planning is not mature so that the project scope is not fully defined
Category : Alternative Methode Design	
X49	Distributed Digital Control System (DCS) design is not in accordance with specifications in the contract

Variable	Risk Events that Influence Time Performance for preparatory work, instrumentation and control work of CFSPP Construction projects
X50	Continuous Emission Monitoring System (CEMS) design is not in accordance with specifications in the contract
Category : Material Resource	
X54	Type of material is not fully defined in the contract
X52	Vendor is late in delivery PLC for Boiler + Steam Turbine & Auxiliaries System to project site
Category : Equipment Resource	
X61	Installation equipment and critical Bulk Materials such as DCS for Boilers + Steam Turbine Generator & Auxiliaries System are difficult to obtain
X60	Specification of the field instrument for Boiler + Steam Turbine Generator & Auxiliaries System is not in accordance with the plan
Category : Labor Resource	
X68	Lack of workforce Engineer Team / Procurement team / Construction Team / Commissioning Team on site
X67	Lack of main project workforce competencies so further training is needed
Category : Environment	
X69	The project site is located in a remote area and access to the site too difficult
X70	There is a disturbance from the local communities

The results of these 14 highest risk ranking variables will be studied further to answer RQ 3 because according to Tan, 2011 mapping the causes, impacts, preventive and corrective actions can be analyzed by taking a sample of 10% of the total number of risk events in each category, namely a number of ±1 risk events (quoted from (Amini, 2018).

4.3 WBS Development Based on Risk Response

Based on study literature, pattern recognition analysis that produces causes, impacts, preventive actions and corrective actions to prevent and reduce the highest risks that may occur in this study found 16 preventive actions and 16 corrective actions as risk responses. These answers are added to the WBS sub work or additional work activity. Risk management is a risk mitigation that is added as an improvement and advancement to this study when compiling a WBS at the work package, activity, and resource levels. Since these activities are still necessary, it can be concluded that there are some recommendations for standard WBS development as not all risk responses can be incorporated directly into the WBS structure. As a result of the analysis, risk responses can be divided into five different categories, as follow:

1. Addition to management item

In the form of activities required to run the project or risk response related to the governance of project activities from the initial planning stage to project implementation. With the example in this study grouped preventive actions such as "Hiring experienced and competent engineers" this risk response can be added to WBS activities with related work to prevent the risk of errors occurring when designing instrument layout drawings for boiler & auxiliaries system instrumentation works so that projects can run smoothly so that activities downstream of the project are not disrupted due to delays in upstream activities.

2. Addition to other WBS elements

In the form of activities or work items that become sub-works or WBS level after the work package, namely the level of activities other than the work in question that is still in the WBS of structural work, such as additions to WBS for preparatory work, architecture, or M/E. For example, in this study the preventive action "To conduct an investigation of the project environment (houses of local residents, stakeholders, soil conditions, rainfall, etc.) before the project starts" this risk response is included in the WBS activity of project preparatory work in the work package ; Surveying and setting out work in order to minimize the risk of disturbance from the surrounding community so that the project start time is not delayed and time performance can be improved.

3. Addition to the relevant WBS element

The addition to the relevant WBS element relates to the company or organization's policy regarding the extent to which the work wants to be controlled.

4. Additional to the Work Specification Requirements.

Some considerations about how a company determines risk response related to company policies as job requirements. Risk responses affect resources, but occur under certain conditions, such as when certain responses are specified in a work order, or when work is assigned to another party (subcontractor) so that project implementers only need to consider the risk response and ensure that work assignments are carried out.

5. Affects Productivity Coefficient

This risk response related to activities to anticipate resource productivity. The coefficient on material resources is related to waste material and material composition, the coefficient on tool resources is related to tool capacity, and the coefficient on labor resources is related to labor productivity in the field.

The following is an example of grouping risk responses from the results of preventive actions from the highest risk:

Table 3. Example of Risk Response Category Grouping for Preventive Action

Preventive Actions	Development Categories					Recommendation
	R1	R2	R3	R4	R5	
Conduct an investigation of the project environment (houses of local residents, stakeholders, soil conditions, rainfall, etc.) before the project starts (Kurnia,2017)		✓				Addition to other WBS element
Establishing a clear project scope for each project partner (Sodikin,2013)	✓					Addition to managerial item

The following is an example of grouping risk responses from the results of corrective actions from the highest risk:

Table 4. an example of Risk Response Category Grouping for Corrective Action

Corrective Actions	Development Categories					Recommendation
	R1	R2	R3	R4	R5	
Assign project management personnel who have sufficient experience (Yahya,2011)					✓	Affect Productivity Coefficient
Sharpen the specifications in the contract (Amalia,2016)				✓		Addition to the Work Specification Requirements.

After preventive actions and corrective actions are grouped into 5 previous recommendations, it further makes the results of the development of risk-based WBS standards by including inputs from preventive and corrective actions that are additional WBS elements both to the WBS concerned and into addition to other WBS elements. or additional to elements other than WBS. Here is an example of the result of the development of a risk-based WBS standard from the example of grouping preventive and corrective actions in the previous table:

Table 5. an example of the results of development of risk-based standardized WBS in this study

: Development results based on input from risk response

Level 3 – Phase	Level 4 - Dicipline	Level 5 - Sub Work	Level 6 - Work Package	Level 7 - Activity	Risk Response / Additional Recommended Activities to Improve Project Time Performance		
					Addition to managerial item	Addition to the Work Specification Requirements.	Affect Productivity Coefficient
Project Management Service	Project Management	Project Planning & Control	Schedule Planning & Control	Make a schedule management plan			Assign project management personnel who have sufficient experience
				Make a WBS (Work Breakdown Structure) Planning	Define the project scope clearly for each project partner so that there is no miscommunication and gray area for the project WBS.		
Construction	Preparatory Work	*Site preparation*	Surveying and setting out	Re-survey before execution	Monitor and tighten the Site Survey process before starting the project	Monitor and tighten the Site Survey process before starting the project	Sending skilled workers to the project site from outside the project area
				Accurate location determination of all power plant facilities			
				Conduct an investigation of the project environment (houses of local residents, stakeholders, soil conditions, rainfall, etc.) before the project starts (Kurnia,2017)			
				Determination of BM reference point			

5. Conclusion and Recommendation

From the obtained research results it can be concluded that:

1) WBS Standard Form for Preparatory Work, Instrumentation and Control Work of CFSPP Projects in Indonesia, it was found that the WBS standard was decomposed into 8 levels to resources with an explanation of each level as follows WBS Level 0 – Project Name, WBS Level 1 – Sub System, WBS Level 2 – Sub-sub System, WBS Level 3 – Project Phase, WBS Level 4 – Discipline, WBS Level 5 – Sub Work, WBS Level 6 – Work Package, WBS Level 7 – Work Activity, WBS Level 8 – Resources. Alternative of work methods become the shape of work activity and resources breakdown.
2) The risks in this study that affect time performance are identified based on the critical path of the past CFSPP project schedule. From the results of the survey of respondents and the final expert validation related to the highest risk factor rankings in the preparatory work, instrumentation and control work of the CFSPP project that affect the time performance of the 70 risk variables, 59 variables were found in the high-risk category. Then the 2 highest rankings in each risk category were taken to be studied further in order to answer research questions 3.
3) Based on literature, the preventive and corrective actions taken from an activity with high risk factors to develop the risk-based WBS standard against time performance, then the 14 highest risk factors that have been verified by

the experts got some WBS development input formulated as follows additional management, additional other WBS, additional related WBS, additional job requirements (Technical Specification), affect productivity coefficients. With a risk response, risk events that have a negative impact on time performance can be prevented and the project can run on target.

The following is the author's recommendation so that this research can be further developed:
This research is only limited to the Main Process Area of CFSPP project, then it can be developed for other areas such as Utility and offsite related to the WBS standard starting from level 5 (Sub-sub work) to the resource level, as well as identifying the risks so that the CFSPP project can be easily managed. This research only analyzes project data archives and distributes questionnaires in CFSPP projects in Indonesia, then WBS standards can be developed for other power plant projects. Further studies related to the performance of other projects by considering the existing WBS standards so that risk identification can be appropriate and structured.

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