Development of Work Breakdown Structure (WBS) dictionary and checklist for safety planning on dam construction project

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Abstract. As one of the essential infrastructures needed for water resources, dam construction project requires comprehensive planning and effective standardization to accommodate the needs during the construction process. Also, the construction plan should be developed to minimize failures that can cause work accidents or other safety issues. Therefore, the development of WBS (Work Breakdown Structure) is a vital component in the planning process. In supporting these, a WBS dictionary and checklist are also needed to support the planning and control process of the project. Studies have found that these documents provide the details of deliverable, activity, and schedule information of each WBS components of the project. Also, these can be used for safety planning due to the hierarchy structure of each work package, hence making it easier for safety planning in each activities. This study was conducted by expert validation method through a semi-open questionnaire and analyzed using a descriptive statistical analysis method. The results of the study are the WBS dictionary and checklist for dam construction project, that can be the guideline for its safety planning. The study had also found the details of the construction method and resources for every work package in the dam construction project.

1. Introduction

Dam is one of the essential infrastructures that has several functions to capture, store, and manage large amounts of water for various purposes. Many work accidental cases or other safety issues in dam construction are caused by a lack of comprehensive planning and standardization during the construction process. In addition, there are other factors such as poor safety planning and ignorance about the implementation of the safety system that can cause work accidents or safety issues to occur. Accidents that occur are closely related to the implementation of procedures that are not right or not run well on a project.

Work Breakdown Structure (WBS) has an important role in the construction works as a controller and guidelines for the implementation of construction to minimize the potential things that will hamper the project. The development of WBS that is not standardized and not well-defined can also lead to work accidents and missteps in the construction process. The solution to overcome these problems by developing a WBS dictionary and checklist for safety planning on dam construction work.

The WBS dictionary is needed to define each work package from WBS in detail [1]. The WBS dictionary is a document that explains each element of WBS including scope, deliverable(s), specifications, resource requirements, technical explanations, and so on [2]. Checklist is a document created to help break down activities until the preparation of resources and costs needed in a project [3].
WBS, WBS dictionary, and checklist are important documents for planning and controlling the construction project that is being worked on. The purpose of this research is to create, identify, and develop a WBS dictionary and checklist for safety planning on dam construction project.

2. Literature Review

2.1. Dam
Dams are the reservoirs formed behind embankments that have many functions not limited as a catcher and storage large amounts of water from upstream catchment or rain but also the management (in terms of the time and quantity of the releases) as well [4]. There are two types of dams based on their forming material, rock fill/embankment dam and concrete dam. Rock fill/embankment dam was built from extracting soil and rock materials from borrow area without much chemical mixture.

2.2. Work Breakdown Structure
WBS is a hierarchical breakdown of all scope of work that must be done by the project team to achieve the goals and create the required results. Creating WBS is the process of dividing project deliverables and work into smaller, become more easier-to-manage components [5]. WBS can be made with several approaches forms there are outline, table, and tree diagram forms [6]. The lowest level in WBS is a work package, each of work package have unique identifier which is part of a control account.

2.3. Safety Planning
Based on OHSAS 18001:2007, safety plan is prepared and determined by the Health, Safety, and Environment (HSE) team. Safety plan made according to the results of the initial review, identification of potential hazards, risk assessment, and risk control. Safety plan refer to existing policies or designed safety policies. Safety planning is all planned activities to guarantee the safety and health of the workers through preventive and corrective actions [7-9].

2.4. WBS Dictionary
The WBS dictionary is a supporting document for WBS that provides detailed work information, activities, and scheduling about the components in WBS. WBS dictionary is a document that describes each element of WBS including scope of work, resource requirements, terms of technical content, and the relationship with other element, also a written description of the elements. WBS Dictionary is a list containing WBS elements with its resources and the activities required to produce each of these elements, it also describes a hierarchical relationship between the elements [10].

2.5. Checklist
A checklist is a list of items, actions, or other points to be considered. It is also used as a reminder that may guide the project manager to develop the plan or help them to verify all the required information is included in the project management plan. A checklist is also a document that contains a description of the elements in WBS that have a function to evaluate the completeness described in WBS. Create a checklist is arranged systematically by including a description of the work that has been identified in the WBS or each scope of work [7].
3. Methodology
The research methods used to develop the WBS dictionary and checklist for safety planning on dam construction projects include:

- The standardized WBS for dam construction project developed through the archive analysis, which was compiled based on benchmarking from 13 Bill of Quantity (BoQ) of the dam construction projects in Indonesia.
- The standardized WBS will be the input in creating of WBS dictionary and checklist according to the template that has been approved in the previous research. Development of WBS dictionary and checklist then need to be validated by 5 experts with minimum of 25 years work experience in construction projects in Indonesia. The validation process was analysed from the semi-open questionnaires to the experts, and further analyzed using descriptive statistical analysis (using the mode and mean analysis for each work package, activities, and resources).
- After being validated, the WBS dictionary and checklist are revised following the suggestions from the experts and other considerations.

4. Result and Discussion
The WBS on dam construction project resulting from archival analysis and several bills of quantity (BoQ) have 6 levels of WBS, consisting of:

- WBS level 1: Sub-project Name
- WBS level 2: Work Division
- WBS level 3: Type of Work
- WBS level 4: Work Package
- WBS level 5: Activity
- WBS level 6: Resources (Labour, Materials, Equipment)

According to the WBS dictionary format template that has been validated in the previous researches, the WBS dictionary provides detailed work information such as the WBS code, work package description, deliverables, and references also activities that are needed for the work package and the resources needed for each activity. The dam construction project is one of the big construction projects.
consisting of several main structures as the sub-projects with a total of 223 work packages which are divided into 4 sub-projects, there are:

- Main dam: 65 work packages
- Spillway structure: 37 work packages
- Intake structure: 46 work packages
- Public facilities: 75 work packages

Based on the experts' validation results, all of the experts mostly agree on the contents of the WBS Dictionary and Checklist (based on descriptive mode and mean analysis). Also, there were no suggestions regarding the format of the WBS dictionary or its contents. The experts only gave additional information that is not included in the WBS dictionary elements. According to experts, work methods in dam construction projects generally use mechanical work methods because they are considered to be far more effective and efficient than conventional work methods for big construction projects. Based on the development of WBS dictionary and checklist, here are the illustrations of the documents showed in Figure 3 and Figure 4.

![Figure 3. Example of a WBS dictionary from consolidation grouting work package](image1)

![Figure 4. Example of checklist from drilling & grouting work division](image2)

Figure 3 is an example of a WBS dictionary from a consolidation grouting work package that has been validated. WBS dictionary is mainly used to describe each elements of work package’s activities (WBS Level 5) and the resources (WBS Level 6) that required to do each of activities. Hence, the dam WBS dictionary is necessary to ease potential problems as it is easier to read and understand. Most can be used effectively during the construction process, particularly for monitoring each work package.

Figure 4 is an example of a checklist from a drilling & grouting work division that has been validated. The format of the checklist in this research is in the form of a table with work sequences based on the level at WBS, namely level 1 (sub-project name) to level 4 (work package), the table also includes codes following the standardized WBS. The description in the checklist contains a description that explains...
the definition, function, work methods, and stages of work. Based on the experts' validation results, there were no significant changes to the contents of the checklist format nor the job description itself.

The specialty works on the rock fill/embankment dam is cut and fill as well as drilling and grouting. This is because the cut and fill are not enough to hold the water seepage in the ground which is generally water permeable. Therefore, drilling and grouting are needed on dam foundation to prevent seepage and increase the bearing capacity of the soil. Grouting work is the process of injecting pressurized cement into the cavities soil and rocks which will then fill the cavities and solidify [8]. In this research there are two types of grouting, curtain grouting and consolidation grouting.

The correlation between the WBS dictionary and checklist with safety planning is that we can easily identify risks/hazards that can occur from every component/element in the WBS dictionary and checklist. The WBS dictionary and checklist are made to make it easier to identify hazards because the contents are more detailed compared to WBS. In the WBS dictionary and checklist, all activities for the work packages and the resources needed for each activity are known, so that hazards can be identified in detail and risk control can be implemented correctly. Following Table 1 is an example of one hazard identification in safety planning based on the WBS dictionary and checklist on dam construction project:

| Code | Work Package | Activity | Hazard Identification | Risk Assessment | Risk Control |
|------|--------------|----------|-----------------------|----------------|--------------|
| E.2.2. | Soil Excavation | Mechanical Excavation | Workers are exposed to heavy equipment maneuvers | Frequency 3 | Severity 2 | Impact 6 | Risk Level 2 (Medium) | Preventive Actions: |
| 1     |              |          |                       |                |              |              |                     | - Safety morning talk & toolbox meeting. |
|       |              |          |                       |                |              |              |                     | - Installing safety signs. |
|       |              |          |                       |                |              |              |                     | - Heavy equipment inspection. |
|       |              |          |                       |                |              |              |                     | - Supervising the implementation of safety plan. |
|       |              |          |                       |                |              |              |                     | Corrective Action: |
|       |              |          |                       |                |              |              |                     | - Handling the victims ASAP. |
|       |              |          |                       |                |              |              |                     | - Contacting the authorities & make an accident report. |
|       |              |          |                       |                |              |              |                     | - Evaluating & auditing the safety systems and its implementation. |

The table above is a modification for the safety planning table format from the Minister of Public Works Indonesia regulation number 21/PRT/M/2019. In the process of identifying potential risks, it is necessary to identify in advance the possibility of accidents, impacts, and severity that can be caused by
an event then it can then be given an assessment of the severity over its safety risks that occur due to accidents in the project. The hazards were identified based on the given information from the WBS dictionary’s code, Level 4 (work package), and Level 5 (activity). The risk assessment and risk control analyses can also be based on the information given by the WBS dictionary and checklist (its work descriptions, references, and resources). The risk level is determined from the result of the frequency value multiply by the severity value. The results of the calculation of the level of the construction safety risk are divided into three, namely the scale of numbers 1 to 4 is a low risk, numbers 5 to 12 is a moderate risk, and 15 to 25 is a high risk. From the table above, after we determine the hazard that can be occurred then we can specify the actions to control the risks which is can be divided into two, there are preventive actions and corrective actions.

5. Conclusion
According to the results of this research, the WBS dictionary and checklist of dam construction projects have 223 work packages divided into 4 sub-projects that are the main dam, spillway, intake structure, and public facilities. The WBS dictionary and checklist can provide detailed information to identify hazards because the contents are more comprehensive compared to the WBS. The implementation of WBS dictionary and checklist in the project can be useful for a more detailed safety planning, and to minimize failures that can cause work accidents or other safety issues in dam construction projects.

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