Development of WBS (Work Breakdown Structure) Dictionary and Checklist for Safety Planning of Tunnel Construction

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Abstract. Indonesia develops tunnel technology due to country’s contours and geological conditions that are rich in minerals, and to overcome congestion problems in big cities. Tunnel is one of the alternative transportation infrastructure in the future that allows to shorten the travel time. Tunnel construction itself is a complex type of construction and requires high managerial and technical capabilities in the process. Therefore, an excellent and detailed planning is needed for each tunnel project, for example by using WBS dictionary and checklist for safety planning in tunnel construction. The purpose of this study is to identify in detail the work packages, methods, activities, and resources to reduce the risk of workplace accidents. This research consists of several stages with qualitative methods. The methodology used is expert validation, respondent surveys and interviews and analyzed using descriptive data mode analysis. The result of this study are WBS dictionary and checklist that provide activities and resources information, which can support the safety planning documents by identifying safety risks on tunnel construction projects.

1. Introduction

Tunnel construction is an alternative transportation infrastructure of the future that allows to shorten travel time [1]. Tunnel has been developed in Indonesia since Dutch colonial period, in the form of tunnel construction for railway. However, the first tunnel construction which designated for highway started as the development tunnel of Cisumdawu highway with 472 m of tunnel length and 14 m diameter [2].

Tunnel construction itself is a complex construction which requires high managerial and technical capabilities throughout the process [3]. The example of high complexity and uncertainty that requires high managerial and technical capabilities, a research found that one impact in managerial aspect is a less precise method for project planning itself [4]. The other example of tunnel construction failure is usually happened because of work tools, unachieved standard for its design for operation and quality, and the delay of the project itself.

In order to satisfy the managerial complexity of tunnel construction, a good planning method and control in the other words as the basic knowledge of Work Breakdown Structure (WBS) development is needed. During the development of WBS for underground structure, there are some essentials things to support its WBS such as a method which able to find the optimal work breakdown structure with all necessary components, sufficient detail and sufficient level of decomposition [5]. Several causative factors of underground construction work accidents are natural disasters, external factors such as economics and politics factors, internal factors i.e. strategic, planning, or even caused by labor factors [6].

As the detail of WBS, there is a WBS dictionary document which provides the details of deliverable, activity, and schedule information of each WBS components [7]. On the other hand, checklist of Work Breakdown Structure is used as a tool to measure WBS compliance with the literal conditions by
loading a self-examination guide at each WBS level to the work package. This checklist refers to the details of activities that exist at each WBS level from WBS diagram and the description of each activity contained in the WBS dictionary [8]. This research is aimed to identify work package from each sub of work then identify the method of work and activities from each work package, and identify resources from each activities defined in tunnel construction. Furthermore, those information are synthesized and developed into a WBS dictionary and checklist

2. Literature Review
2.1. Tunnel Construction
Tunnel construction is an underground construction that might be built in several types of material from soft soil to hard rock [9]. Explained by International Tunneling Association [3], there are three types of tunnel construction methods based on the technology used and the existing location of the tunnel construction. The three types of methods are conventional methods, mechanical methods, and cut and cover methods.

2.2. WBS Dictionary
WBS dictionary is a document which provides descriptions from each WBS components. In ever WBS dictionary, there will be a short definition related to its scope of work, detailed deliverable, activities from each work, and milestones to achieve [10]. There are some essentials things to be provided by WBS dictionary, although it’s not limited to these points [7]:

- Identification Code
- Description of work
- Assumptions and limits of work
- Responsible organizations or stakeholder
- Schedule of activities
- Resources
- Cost estimation
- Quality requirements
- Acceptance criteria
- Technical reference
- Agreement information

Based on the dictionary format provided by the Project Management Institute, the author makes a simplification without reducing the components of the WBS dictionary, so that the format used in the research is as follows:

![Figure 1. WBS Dictionary Format](image)

2.3. Check List
WBS checklist provides a checklist for project teams so it can be used to evaluate the capability of WBS. From its checklist, it will eventually complete the steps of WBS development [8]. According to “Project Management Basics: How to Manage your Project with Checklists [11], WBS checklist is actually be used in 5 phase of a project, there are initiation phase, planning phase, execution phase, work release, and finishing phase. To comply the importance of WBS checklist in a project, author has
discovered a format for WBS checklist to meet its correlation between project milestones and WBS which has been made, as follows:

### Checklist for WBS Format

**Figure 2.** Checklist for WBS Format

3. **Methodology of Research**

   The research to develop WBS dictionary and checklist for tunnel construction as a base for safety planning in this study includes:
   - The identification of standard WBS for each level developed through archive analysis that compared to several project tunnel construction bill of quantity.
   - In order to develop its WBS dictionary and checklist, author did an interview to experts with a minimum of 25 years experience in tunnel construction projects in Indonesia to validate tunnel construction work package, activities, and resource that benchmarked to several project tunnel construction bill of quantity.
   - After each level of WBS has validated, the next interview take place to validate WBS dictionary and checklist to meet every descriptions and details from WBS.
   - By the end of the study, author did an interview to find the originality of tunnel construction which probably different from other construction project.

4. **Results and Discussion**

   Based on the WBS dictionary format that has been validated from previous studies, several things that are components in the WBS dictionary are the WBS code, job package description, deliverables, reference sources, and detailed activities and resources for each defined work package. The tunnel construction itself consists of 7 clusters of work in which 82 work packages are divided. The specialty of tunnel construction project is hard rock excavation work. Some complex aspects that can be a concern during tunnel construction are related to determine method of work such as soil conditions, ground water level conditions, length and diameter of the tunnel, tunnel depth, designation, and shape of the tunnel itself. There are 2 (two) methods that can be used, namely conventional excavation on soft soil and blasting for hard soil parts. Both of these have been included in the WBS dictionary tunnel construction excavation work package rock and hard rock excavation work package, as follows:
Since the excavation work package is included in the cluster of earth work, the checklist of earth work cluster will include the definition of each cluster, work packages, and activities from each work, so as stated in the following format:

**Figure 3. WBS Dictionary of Tunnel: Soil Works**

**Figure 4. Checklist for WBS of Soil Works in Tunnel**
Apart from the content of WBS dictionary and checklist of tunnel construction, there are other findings which obtained from discussion with experts related to conditions in the area. The findings are related to the method used in tunnel construction that divided into two types, namely blasting and mechanical method with the same level of safety risk even with different aspects to note. In addition, excavation work packages in tunnel construction must also go through OSH planning which is more because the work is done underground. Regarding the length and diameter of the tunnel, these two aspects can affect the stability of the tunnel opening and the consistency of rock mass, wall stability, and safety of the tunnel structure itself.

![Figure 5. Hazard Severity Matrix](image)

Once the WBS, WBS dictionary, and checklist of tunnel construction are being validated by experts, the identification of risk can be done. The correlation between WBS and identification of risk is in the way WBS using hierarchy structure to define each level and its derivatives to work package in order to reach project’s end. In the process of identifying potential risks, it is necessary to know 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. Subsequent to the classifying severity of accident and probability of accident, then the safety risk assessment calculation can be done from the calculation of the product of the probability and the severity that occurs.

If the safety risk assessment method implemented in tunnel work, so the following is an example of identification over safety risk hazards:

![Figure 6. Identification of Safety Risk Hazards](image)

Based on the picture above, it was found that the danger of landfill that will be given reinforcement in the anchor bolt installation activity has a risk value of 10 classified as medium risk or at a moderate level which indicates that the risk is acceptable, but further analysis can be done to provide an
estimated risk which is better, so that it can be decided in relation to a redesign or other changes needed after consideration of the most practical decisions and ensure that the lowest possible risks.

5. Conclusion
From the study that has been done, it is found that there are validated WBS dictionary and checklist for tunnel construction project which has 82 work package. WBS dictionary and checklist that has been validated itself further describe the detail of method of work, activities, and its used resourced. The development of WBS dictionary and checklist in project are based on the project bill of quantity. For further use, WBS dictionary and checklist can be used for schedule planning, financial planning, and safety planning whereas the objectives of this study. WBS dictionary and checklist can be used for safety planning because how the hierarchy structure itself decompose each work package to smaller deliverable to make it easier for safety planning in each activities.

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Acknowledgments
The authors would like to thank the financial support provided by University of Indonesia through the PUTI 2020 NKB-1132/UN2.RST/HKP.05.00/2020 funding scheme managed by Directorate for Research and Public Services (DRPM) University of Indonesia.