Development of Risk-Based Standardized WBS (Work Breakdown Structure) for Safety Planning of Cable Stayed Bridge Project

Gilang Satrio
Department of Civil Engineering
University of Indonesia
Depok, Jawa Barat, Indonesia
giohitam@yahoo.com, gil.satrio@gmail.com

Prof. Dr. Ir. Yusuf Latief, MT.
Department of Civil Engineering
University of Indonesia
Depok, Jawa Barat, Indonesia
yusuflatief73@gmail.com

Abstract

In a project plan, the Work Breakdown Structure (WBS) has been defined as the total representation of the work or stage, including from start to finish the project has a role in project quality. WBS has many roles in every construction project such as buildings, bridges, roads, and many more. In many condition, many bridge construction projects in Indonesia are not in line with planning in terms of schedules and costs, therefore the importance of WBS development especially the risk-based bridge construction project. The result of the following research are expected to be a reference in bridge construction projects. The result indicates taht standarized WBS consist of 4 primary level and 2 complementary levels, with 9 dominant risk variables on safety performance, and recommended risk responses as the developement.

Keywords
Project Management, Cable Stayed Bridge, Risk Management, Safety Plan, Work Breakdown System

1. Introduction

Successful project management depends on a well-planned for assigning, scheduling, and controlling progress of the resources [1]. One importnat factor of a construction project performance is the compliance with safety plan and safety procedure [2]. In case of safety, the high number work accidents and casualties caused many negative impacts, such as financial loss [3]. In addition, work accidents can also lead to prosecutions and claims that will have an impact on additional costs, job delays, bad publicity, and can threaten the corporate financial [4]. To realize a safety of construction project, it is necessary to have a well-planned safety planning that have been prepared before the construction phase begins [5].

The developement of Work Breakdown Structure (WBS) is the first step in the planning process after defining project requirements. The definition of activity is the most critical in planning process, that a project manager should spend more effort to identify the project activity using the WBS [6]. WBS is breakdown of project works into smaller components so it can be better managed and measured against the ultimate completion [7]. Although each project is unique, most of bridge construction works can be standardized to enable the provision of basic activities to have robust estimates for project management [8].

Therefore, the development of risk-based standardized WBS of construction of bridge for safety plan is proposed. The objectives of this research are to identify the following:

1. To identify standardized WBS for bridge construction
2. To identify methods that used for every work package in cable stayed bridge
3. To identify any activities based on WBS in cable stayed bridge

4. To identify every resources based on activity in every work packages in cable stayed bridge
5. To identify risks from the standardized WBS that may cause safety incompliances
6. And to develop risk-based standardized WBS for cable stayed bridge construction.

The scope of the study is limited to the following:
1. The research is directed to practitioners of the construction project or main contractors
2. The bridge that used in this research is cable stayed bridge
3. The standarized WBS is dominant items which have the highest risk.

2. Risk Based-Standardized WBS for Safety Planning

2.1 Standardized WBS

PMBOK (Project Management Body of Knowledge) as the set of standard terminologies and guidelines for Project Management define Work Breakdown Structure (WBS) as 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 lowest level of WBS components is called work packages. A work package can be used to group the activities where work is scheduled and estimated, monitored, and controlled [9].

The approach followed by the project team to develop WBS revolves around the application of previous WBS with some changes, progressive breakdown of the works required for the project, and the development of WBS-based deliverables with focus on the basic function of final product [10]. Instead of developing WBS for each project, it is sometimes appropriate to develop a general WBS for typical project, then the necessary segment can be modified. It is suitable for organizations which perform similar projects [11]. Construction activities are highly predictable and there are consistent rules that governs the selection of activities, so it is feasible to develop standard activity [12].

2.2 Risk-Based Standardized WBS

Project risk is an uncertain event which has a positive or negative impact towards project objectives. If the event occurs it can affect project scope, schedule, cost, or quality. The risks can be prioritized by assessing the probability of occurrence and impact through qualitative risk analysis [9]. Since a regular standardized WBS might not consider the risk response of the project, the risk based-standardized WBS is the enhancement of the standardized WBS which is added with risk responses related to project objective, in this research is the risk response on quality performance.

2.3 Benefit of WBS for Safety Planning

The WBS identifies the deliverables and the work packages used to measure project performance on safety planning. WBS can be used as a planning approach and the practice was reported to reduce probability of work accident, and increased control on site for industrial construction projects [13]. The WBS standardization framework is also recommended to support integrated planning and supervision [14]. A WBS-based planning with risk considerations had been developed for software projects, which were found to increase modification flexibility so as to reduce risk of change in planning [15].

3. Research Metodology

To identify the standardized WBS of cable stayed bridge construction, the data were collected from analysis of contractor's estimate and engineer's estimate archives, WBS benchmarks, and interviews of 5 experts from academician and construction practitioners with experience of more than 20 years, through Delphi method to validate result.

The risk identification derived from the standardized WBS category and the variables were obtained from literature analysis, then questionnaires were distributed to respondents such as engineer, supervisor, and project manager from 5 construction projects of cable stayed bridge. From 30 returned questionnaires, a qualitative risk analysis was conducted using PMBOK risk probability and impact matrix to seek dominant risk variables.

To develop risk-based standardized WBS, the highest ranked risk variables were analysed for their preventive and corrective actions through pattern recognition, and also through RBSxWBS matrix. The RBSxWBS matrix is

the mapping of risk variables (Risk Breakdown Structure) which has impact on WBS item. The matrix was using dominant risk variables for the RBS input, and Pareto method as an approach to select certain work which dominant on 80% project cost for the WBS item input. Result of the risk responses from interviews of 5 experts from construction practitioners and academics background with experience of more than 20 years was used to develop the standardized WBS.

4. Findings

4.1 Standardized WBS

According to PMBOK the lowest level of WBS is the work packages, thus generate the result of standardized WBS which consists of 4 primary levels from Level 1: Project Name to Level 4: Work Package and 2 complementary levels of Level 5: Activity and Level 6: Resources. The primary levels are:

- WBS Level 1: Project Name
  It is the highest level of the WBS structure, a representation of the entire project.
- WBS Level 2: Work Section/Division
  Level 2 is the decomposition of the construction elements of the project, it can be divided into 9 sections: preliminary, drainage, earthworks, pavement widening & shoulder widening works, concrete pavement works, asphalts pavement works, structural works, reinstatement & minor works, and toll road facility.
- WBS Level 3: Sub-Work Section
  It is the further decomposition of work section/division, example: Structural works: Upper Structure, Sub Structure, and accessories.
- WBS Level 4: Work Package
  This is the lowest level of WBS components, it represents the degree to which the performance of each work package can be assigned to an individual or organization. It groups the activities where work is scheduled and estimated, monitored, and controlled.

The complementary levels are:

- WBS Level 5: Activity
  Activity is not part of WBS, it is added to the WBS template to help the project manager identify the work to be done on the lower level of work package. Project managers can add as much of the activity as they need to understand the details of the work to be done in order to properly deliver the project. Activity refers to the things that the project team does to complete the deliverable.
- WBS Level 6: Resources
  This level divide the resources needed to perform the activity, it is the materials, equipment, and labor.

The activity level is highly dependent on the alternative of design or method. The alternative must be set first in order to breakdown the activity up to the resources, thus it is not a hierarchy within the WBS structure, but as a determinant to detail the activity.

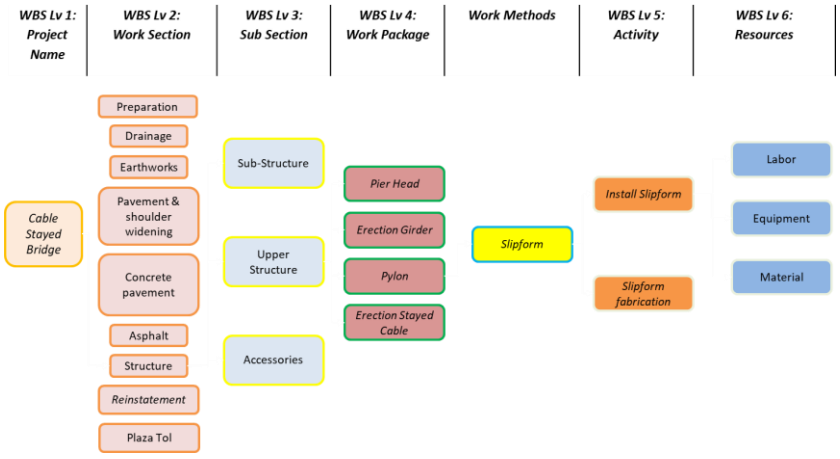

Figure 1. Diagram tree of Cable Stayed Bridge Standardized WBS

4.2 Dominant Risks on Safety Performance

Safety planning is concerned with the conditions required for each WBS work package. Since the risk relate with safety requirements, the conformance of safety specifications is an important measurement of construction project performance.

To identify the risk variable, the standardized WBS framework was used as risk category towards safety performance from the last primary level of 'Level 4: Work Package', then 'Alternative Method/Design', 'Level 5: Activity', and 'Level 6: Resources'. There are 20 risk variables that are narrowed to 9 dominant risk variables after qualitative risk analysis.

Table 1. Dominant Risk Variables on Safety Performance

RISK VARIABLE		SCORE	RANK	LEVEL
RISK CATEGORY: WBS LEVEL 4 WORK PACKAGE				
X2	Crashing program not paying attention to the safety procedure	0.137	6	Moderate
RISK CATEGORY: ALTERNATIVE METHOD/DESIGN				
X5	Safety Plan not appropriate with the planned methods	0,345	1	High
RISK CATEGORY: WBS LEVEL 5 ACTIVITY				
X6	Work sequence is not risk-based planned	0.153	5	High
RISK CATEGORY: WBS LEVEL 7 MATERIAL RESOURCES				
X7	Material testing not comply with procedure	0.107	10	Moderate
RISK CATEGORY: WBS LEVEL 7 EQUIPMENT RESOURCES				
X11	No quality control in using a heavy equipment tools	0.110	7	Moderate
RISK CATEGORY: WBS LEVEL 7 LABOR RESOURCES				
X13	Toolbox meeting not regularly programmed	0.108	8	Moderate
ENVIRONTMENT FACTORS				
X18	No evaluation according a safety plan	0,179	4	High
X19	Demontration of people around the project	0,207	2	High
X20	Weather/climate affected to the project	0,201	3	High

The highest risk score obtained from the category of design & method factor. The result shows the risk level of the dominant risk variables ranging from moderate to high.

4.3. Risk-Based Standardized WBS

The analysis resulting risk responses that can be distinguished into 5 different categories:

1. *Addition to managerial item*: Items required to execute a project or a risk response related to project managerial from the initial stage to project closure.
2. *Addition to another WBS*: Items added to another sub-work package (Level 3) different than the related WBS which is exposed to risk, or additions to Preliminary, Structure, or Earthworks WBS (Level 2). Infrastructure facilities to support project operational can be included to Preliminary, and if a managerial activity is considered as overhead item it can also be included in Preliminary.
3. *Addition to related WBS*: Items added to related WBS element which is exposed to risk. This is related to organizational policies regarding how far they decide to control the items. It can be included into the WBS element by some consideration, whether the risk response is a specific item for a particular job so it is always be done and largely affecting project costs. This decision may vary depending on the project conditions.

4. *Addition to activity requirement*: Items added to requirements, which can be incorporated into Work Instructions, specification, or contracts. It is also related to organizational policy. There are some considerations such as whether the risk response affects resources in certain condition so it does not largely affecting cost, thus it merely be included in Work Instructions, or when the work is transferred to another party so the executor just needs to make sure the price-forming has considered the risk response.
5. *Affecting WBS coefficient*: Risk response can also affect the coefficients related with the structure of resources. The coefficient on the material relates to waste and material composition, the coefficient on the equipment relates to equipment capacity, and the coefficient on labor relates to labor productivity. In this case, if the risk response affects the WBS coefficients, it is important for the project executor to concern regarding the costing strategy since it is tied to the structure of unit price, so that the risk response can be considered for bidding whether it is included in unit price structure or not.

The pattern recognition analysis resulting 16 Preventive Actions and 12 Corrective Actions as risk responses.

Table 2. Risk Response Category Mapping for Preventive Action

NO	PREVENTIVE ACTION	CATEGORY					RECOMMENDATION
		1	2	3	4	5	
P1	Establish a safety program / manual before project implementation begins	●			●		Contract/WBS Prelilminary/Work Instruction
P16	Conduct project environmental investigations (soil, rainfall, etc.) before the project starts	●	●				Manajerial & WBS Preliminary

Table 3. Risk Response Category Mapping for Corrective Action

NO	CORRECTIVE ACTION	CATEGORY					RECOMMENDATION
		1	2	3	4	5	
C1	Melakukan pengawasan ekstra terhadap pekerjaan-pekerjaan kritis	●		●			Contract/WBS Prelilminary/Work Instruction
C12	Melakukan pelatihan cepat tanggap bencana terkait perubahan kondisi cuaca	●					Manajerial

There are 9 dominant risk variables for the RBS input, and there are Structural, earthworks, concrete pavement, and asphalt pavement as the dominant work section resulting from Pareto analysis for the WBS input of RBSxWBS matrix. The results are 6 risk responses.

Table 4. Risk Response Category Mapping for Architectural Works (RBS x WBS Matrix)

NO	RBS	WBS	ADDITIONAL RISK RESPONSE
1	X7	Piling Dolken Pile	Checking age and quality of the wood
2	X19	Piling Spun Pile	Reduce vibration with hydraulic hammer
3	X2	Wash Drilling / Dry Drilling	Dewatering after drilling
4	X5, X11	Delivery *Cable Stayed*	Control process of storing *Stayed Cable*
5	X13	Erection *Cable Stayed*	Training for process of erection *stayed cable*
6	X19	Land compacting/ filling	Permit for quarry legality

Here is the sample of standardized WBS which is enhanced by the risk responses obtained for Sub work section : Excavation and erection of stayed cable.

Table 5. Risk-Based Standardized WBS

* : Risk response (development of the standardized WBS)

WBS Level 4 Work packages	Work Methods	WBS Level 5 Activity	WBS Level 6 Resources	Requirements
Excavation	Mechanic	Marking& bouwplank		
		Excavation with heavy equipment		
		Sheet Pile Protection	**Steel Sheet Pile**	
			Hydraulic hammer	
			Operator	
Stayed Cable Works		Stayed Cable Fabrication	Wire Strand	Tensile test in independent lab
			HDPE Pipe	Coating 200 micron

7. Conclusion

The first research objective indicate that standardized WBS consists of 4 primary level and 2 complementary level, it is also found that the alternative of design or method is not a hierarchy within the WBS structure, its importance is to be functioned as determinant to detail the WBS level 5 activity. The second research objective generates 9 dominant risks towards safety performance after qualitative risk analysis, the highest risk score obtained from the category of design or method. The third research objective shows that not every risk responses can be adopted directly into related WBS structure. There are 5 different categories and the application becomes project executor decision which is heavily influenced by corporate policy such as the organizational strategy, financial accounting policy, or project conditions (eg. how large the risk response will affect the project cost).

Risk-based standardized WBS can be utilized for the basis of safety planning, helping project executor identifies project works to the smallest items and setting safety performance for each items in greater accuracy as a tool to ensure every work has considered the requirements to respond safety-related risks.

References

1. F.D. Postula, WBS Criteria For Effective Project Control, AACE Tran.., 16, 1-7 (1991)
2. K.N. Jha, K. Iver, Critical Factors Affecting Quality Performance in Construction Projects, Total Quality Management, 17. 9, 1155-1170 (2006)
3. Lingard, H and Rowlinson, S M. Occupational Health and Safety in construction project management; UK Taylor & Francis. (2005)
4. Holt, A. S. J. The Safety Policy, in Principles of Construction Safety, Blackwell Science Ltd, Oxford, UK. doi: 10.1002/9780470690529.ch5. (2001)
5. Endroyo B. Keselamatan Konstruksi: Konsepsi dan Regulasi. UNNES: Semarang;. 2009.
6. O. Zwikael, Critical Planning Processes in Construction Projects, Cons. Inn., 9, (2009)
7. T. Leemann, Managing the Chaos of Change, J. of Bus. Strategy, 23.5, 11-15 (2002)
8. K. Blyth, J. Lewis, A. Kaka, Developing Framework for Standardized Work Programme for Building Project, Cons. Inn., 4, 193-210 (2004)
9. Project Management Institute. (2013). Project Management Body of Knowledge Guide - Fifth Edition.

10. J.V. Tonder, M. Bekker, African Rhythm Project Management Conference. Johannesburg South Africa, 1-13 (2002)
11. 1B. Atkin, Stereotypes and themes in building designs: insights for model builders, Cons. Mngmt. and Eco., 11, 119-30 (1993)
12. C. Gray, J. Little, Occasional paper No. 18 (Department of Construction Management and Economics University of Reading, Reading, 1985)
13. W. S. Andi, Y. Hendarlim, Faktor-Faktor Penyebab Rework pada Pekerjaan Konstruksi. Civil Engineering Dimension/CED, 7.1, 22-29 (2005)
14. Y.M. Ibrahim, A. Kaka, G. Aouad, M. Kagioglou, Framework for a generic work breakdown structure for building projects, Cons. Inn., 9.4, 388-405 (2009)
15. S.T. Lai, A WBS-Based Plan Changeability Measurement Model for Reducing Software Project Change Risk, Lecture Notes on Software Eng., 2.1, 94-99 (2014)

Biographies

Gilang Satrio is a Master Student in Graduate Program of Civil Engineering in University of Indonesia. He graduated from Civil Engineering Department in University of Brawijaya. He also works in Owned Stated Company in Construction Services.

Yusuf Latief is a Professor at the Faculty of Engineering, University of Indonesia. He teaches for Undergraduates, Graduate and Doctoral Programs. He actively writes articles in natinal and international journals with specifications in the areas of Project Management and Construction.