The Development of Risk-Based Standardized WBS (Work Breakdown Structure) for Cost Estimation of Concrete Precast Bridge Construction

Remi Fitriadi Kurnia[1], Yusuf Latief[1], and Leni Sagita Riantini[1]
Department of Civil Engineering
University of Indonesia
Depok 16424, Indonesia
remifitriadi@gmail.com, yusuflatief73@gmail.com, leniarif@gmail.com

Abstract

The proper Work Breakdown Structure (WBS) is very important in project planning so that deliverables and project work can be broken down into smaller components, more easily to construct and costs can be better controlled. Construction of concrete precast bridges is the dominant type of bridge construction used in Indonesia because it provides many advantages over the other types of construction. Although the project is unique, the works on the construction of Precast bridges and their elements are relatively similar, so they can be standardized and used as a basis for project control. This study aims to create WBS Precast Bridge construction standards and identify risk variables on the work packages, activities and resources on the construction of concrete precast bridges for improved project cost performance. This study provides results that the WBS standard of concrete precast bridge construction consists of 6 levels, with 13 dominant risk variables and 5 risk response recommendation groups against project cost estimates as the development of WBS standards.

Keywords
WBS, Precast Bridge, Risk, Cost Estimation

1. Introduction

The advancement of precast concrete technology has been the key to accelerating infrastructure development which is the main focus of government development until 2019 [5]. The Ministry of Public Works and Housings (PUPR) will build about 11,855-meter bridge infrastructure, including the long spans of Teluk Kendari Bridge, Holtekamp Bridge, and Balang Island Bridge [9]. Precast concrete is a concrete element or component without or with a molded reinforcement before being assembled into a building [14]. The development of precast concrete technology in the construction of this bridge has developed quite rapidly in the world, including in Indonesia in the last decade. Because precast construction on the bridge provides many advantages over conventional construction. The advantages of this precast system are construction carried out unaffected by the weather, efficient man power, good quality and maintained, mass production, shorten duration of work, saving the amount of material resources [2].

Work Breakdown Structure (WBS) is a work-oriented, hierarchically oriented decomposition to be implemented by the project team to achieve the project objectives and produce the required deliverables [5]. The deliverable is a unique product, result, or capability to display services that must be generated to complete the process, phase, or project. Without create WBS or inaccuracy in defining WBS can lead to cost overruns project, this is due to the definition of the cost structure of each work package is not accurate. To achieve good project cost performance targets can result from a good cost estimation in the planning process. WBS has a major role in a project, so the creation of WBS is an obligation in project management both in the planning and execution phases. But in practice in Indonesia there are still many projects that do not use WBS or rarely made WBS in the formal form [15]. Although known to be an important input base in many project management processes, there are still many projects that do not use the WBS in detailing the work or making mistakes in making it [17].

Although each project is unique, most building construction works can be standardized to enable the provision of basic activities to have robust estimates for project management [12]. Therefore, the development of risk-based standardized WBS for cost estimation construction of precast bridge is proposed. This study aims to create standardized WBS precast bridge construction and identify risk variables on the work packages, activities and resources of the standardized WBS construction of the precast bridge for improved project cost performance and to develop risk-based standardized WBS for construction of precast bridge. 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 research conducted on precast bridge project in Indonesia for the last 5 years
3. The performance of the project referred in this study is the achievement of the cost performance of the construction work.

2. Risk Based-Standardized WBS for Cost Estimation

WBS is the basic document in project management as it serves as the basis for planning and setting up schedules, costs and changes. A project manager believes that activities should not be undertaken in the project when such activities are not included in the WBS. The WBS is an outward-oriented analysis of the work involved in the project that defines the overall scope of the project. The most critical planning process in the construction sector is the definition of activity, so a Project Manager must spend more effort to identify the project activity using the work breakdown structure or WBS [19].

In its several studies have issued WBS generalist proposals for the ease of project control such as by Blyth, et al. [12] explain that standardization of activities enables the automation of project planning processes and will it will reduction of administrative and management costs; Hewitt [6] developing WBS combined with updated RBS can greatly facilitate initial project planning; Ibrahim YM, et al. [8] which proposed the WBS standardization framework for projects in the United Kingdom construction project; and also Irdemoosa, et al. [9] which developed WBS standards for underground tunnel construction work, the development of a hierarchical neural model with 6 BPN networks, each with a different configuration. This WBS standardization research generally uses the data analysis methods from WBS previous projects that have been successful construct. Based on some reference studies and supported by the relevant methodology, the development of WBS standardization for precast bridge construction research needs to be done.

WBS is structured on the basis of learning of all project documents including contracts, drawings, and specifications. Projects are then broken down into sections by following certain structural and hierarchical patterns into fairly detailed work items, called Work Breakdown Structures. The development of WBS a construction work may specify the work package to be an activity, the determination is not bound by payment items such as Bill of Quantity (BoQ), but depends on the method of work which used. Therefore, in addition to work packages, please also note the methods which used to the implementation of such work [18]. Based on the process of concrete bridge construction, the concrete precast method is more favored for reasons of speed of work, quality control and friendliness to the environment. Beginning in the 1970 the precast system was introduced and applied in Indonesia, for example: construction of Sarijadi apartment, bridge girder and others [20].

WBS is provide a basis for estimating, allocating resources, preparing schedules, and calculating costs. Estimates/cost estimates is important role in the implementation of the project. In the early stages used to determine the amount of funds that must be provided for building or investment. Inaccuracy in the calculation can affect the success of the project implementation and affect the parties involved. For the implementing contractor, cost estimates are required as a basis for offering price at the auction stage and can serve as a reference for cost structure in the implementation phase [16].

3. Research Methodology

To identify the standardized WBS of precast bridge construction work, the data were collected from archieve analysis of based on two regulatory references that is general specification road and bridge from Bina Marga [4] and general and special specifications for highways and toll road from BPJT [5], contractor's estimate and engineer's estimate archives, WBS benchmarks for 22 bridge construction project and also 5 road highway construction, interviews of 6 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 especially from construction of road and bridge project. Respondents consist of 7 Supervisor, 15 Engineer and 10 Project Manager, which come from 5 different contractor companies, consist of 3 graduated from D3, 26 graduated from S1 and 3 graduated from S2. 4 respondents with experience behind 5 years, 15 respondents with experience 6-10 year and 13 respondents above 10 years experiences. The questionnaires were distributed with total 45 questionnaires and 32 questionnaires were returned. Then a tested homogeneity, reliability, validity was conducted to the data obtained using software SPSS 23 and Excel 2013. A qualitative risk analysis was conducted using PMBOK risk matrix to seek dominant risk variables.

To develop risk-based standardized WBS, the highest ranked risk variables were analyzed for their preventive and corrective actions through pattern recognition, and also through RBSxWBS matrix. RBSxWBS matrix was using dominant risk variables for the RBS input, and Pareto method as an approach to select certain precast bridge work which dominant on 80% project cost for the WBS 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

The result of standardized WBS of Precast Bridge Construction consists of 4 primary levels and 2 complementary levels. Alternative of work methods become the shape of work activity and resources breakdown.

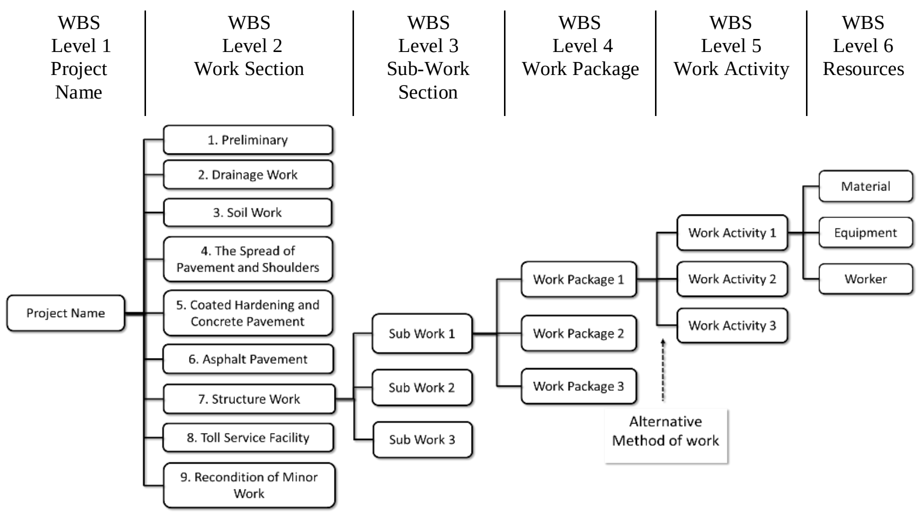

Fig. 1. Diagram tree of standardized WBS of Precast Bridge Construction

After review of analysis theory, archive analysis, expert validation and benchmarking of different types of bridges such as: precast bridges, steel bridges, cable stayed bridges, flyovers and road construction have similarities and differences in the WBS standard form, especially on WBS level 2 work section, which can be seen in the following table 1:

Table 1. Dominant Risk Variables on Cost Performance

WBS Level 2 Work Section	**Construction Type**				
	Precast Bridge	**Steel Bridge**	**Cable stayed Bridge**	**Flyover**	**Road**
•1 Preliminary	Same	Same	Same	Same	Same
•2 Drainage work	Same	Same	Same	Same	Same
•3 Soil work	Same	Same	Same	Same	Same
•4 The spread of pavement and shoulder	Same	Same	Same	Same	Same

WBS Level 2 Work Section	Construction Type				
	Precast Bridge	**Steel Bridge**	**Cable stayed Bridge**	**Flyover**	**Road**
•5 Coated hardening and concrete pavement	Same	Same	Same	Same	Same
•6 Asphalt pavement	Same	Same	Same	Same	Same
•7 Structure work	Different	Different	Different	Different	Different
•8 Toll Services Facility	Same	Same	Same	Same	Same
•9 Recondition of minor work	Same	Same	Same	Same	Same

Here is the work breakdown of structure work of precast bridge construction (Figure 2).

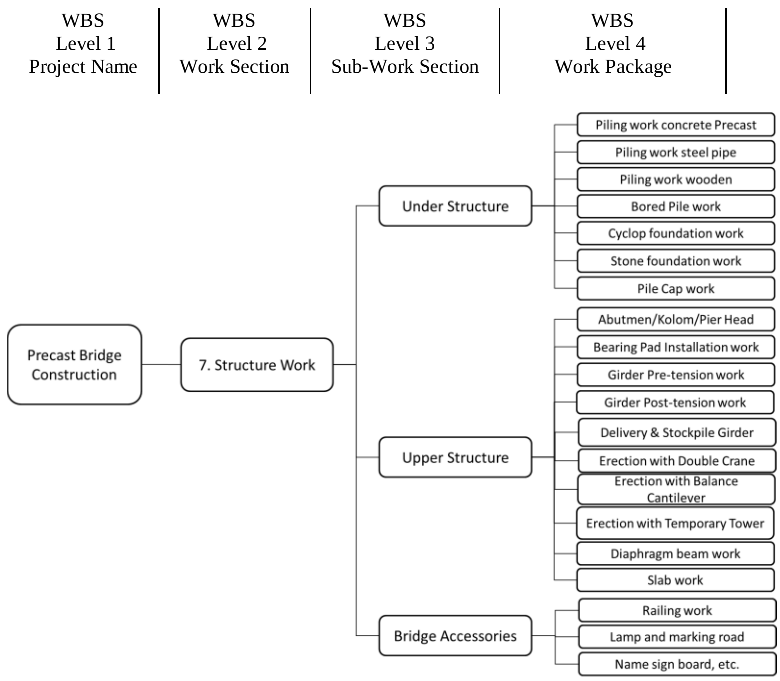

Fig. 2. Diagram tree of standardized WBS of Structure Work Precast Bridge

4.2 Risks Dominant on Cost Performance

Risk is a potential event that can be harmful, causing no achievement of the desired target. Risks that have been identified should be made a good plan even if necessary to make a system to be reduced to a minimum to the acceptable limits [1]. Project risk management is a systematic process of project risk identification, analysis, response, and control. The objective of risk management is to maximize the probabilities and consequences of positive events and minimize the probability and consequences of negative events on the project objectives [11].

The standardized WBS framework for precast bridge construction is used as risk category which consist of 7 risk category that is work package, alternative method, activity, resources material, labour, equipment and environment. There are 31 risk variables that are narrowed to 13 dominant risk variables after conduct of qualitative risk analysis.

Table 2. Dominant Risk Variables on Cost Performance

CATEGORY	RISK VARIABLE		SCORE	LEVEL
WBS Level 4 Work Package	X2	Volume of work is not in accordance with the planning	0.28	High
	X5	Unscheduled execution of work	0.28	High
Alternative Method of Work	X6	Applied method is not in accordance with the planning	0.27	High
	X7	Limitations of experienced personnel/specialists of precast bridge methods	0.28	High

CATEGORY	RISK VARIABLE		SCORE	LEVEL
WBS Level 5 Work Activity	X8	Sequence of activities is not in accordance with the planning	0.16	High
WBS Level 6 Material Resource	X11	Amount of waste material exceeds the planned	0.21	High
	X13	Material prices more expensive than estimates in planning	0.24	High
WBS Level 6 Equipment Resource	X18	The work accidents due to the condition of equipment	0.19	High
	X19	Actual productivity of equipment is not in accordance with the planning	0.17	High
WBS Level 6 Labor Resource	X25	Labor productivity is lower than planning	0.15	High
	X26	Amount of labour is not available as requirement	0.12	Moderate
Environment Factor	X29	Disruptions (demonstrations) from the community/social community	0.10	Moderate
	X31	Changes in soil conditions during construction	0.09	Moderate

4.3 Development of Risk-Based Standardized WBS

The development of WBS standards for cost estimation can be execute after the Pareto analysis has been done as determining the dominant type of work on precast bridge construction. With the Pareto distribution law approach, it is possible to know the WBS Level 3 (Sub work section) which is the dominant item of the total project cost, where the dominant component is cost-potentially a risk review of its cost objectives. The dominant risks analysed for causes, impacts, preventive actions and corrective actions found from previous research stages may result in recommended activities to supplement standard WBS Precast bridge work on selected types of work from Pareto analysis which mapping through the WBSxRBS matrix.

The pareto analysis generate that dominant item of work for precast bridge construction is upper structures, lower structures and soil works.

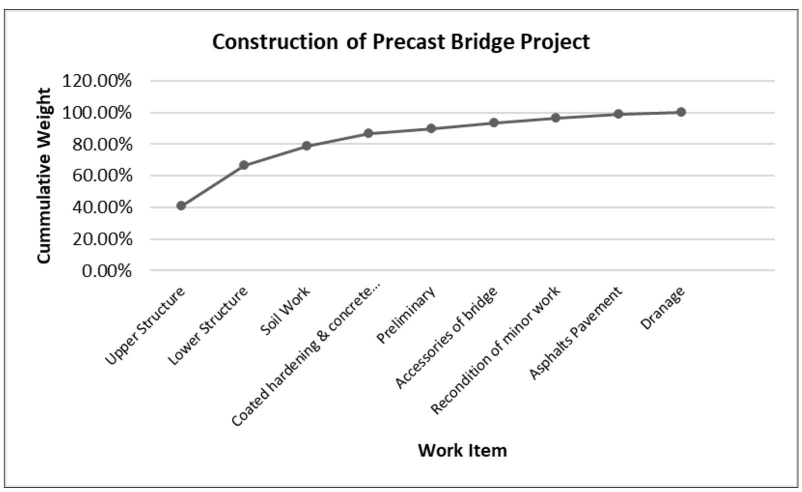

Fig. 3. Diagram of Pareto Analysis of Precast Bridge Construction

Here is the sample matrix of WBS x RBS and additional risk response for the dominant work item (Table 3).

Table 3. Matrix of WBS x RBS

WORK BREAKDOWN STRUCTURE		WBS L. 5 ACTIVITY	*RISK BREAKDOWN STRUCTURE*													ADDITIONAL RISK RESPONSE
			X2	X5	X6	X7	X8	X11	X13	X18	X19	X25	X26	X29	X31	
WBS L. 3 SUB WORK SECTION		UPPER STRUCTURE														
WBS L. 4 WORK PACKAGE	Constrution of Abutment / Column / Pier head	Fabrication & Instalation of Rebar														Additional steel mechanical connector (Coupler) for material connector
		Fabrication & Instalation of Formwork														Additional equipment: temporary support and catwalk for formwork installation
		Pouring Concrete														
	…	…														
	Expansion Joint Work	Installation of Expansion joint work														

After conducted the Delphi analysis with expert validation concluded that not all the risk responses can be directly adopted into the WBS structure as these activities are still required, so it is concluded that some recommendations of standard WBS development. The analysis resulting risk responses that can be distinguished into 5 different categories:

1. **Additions to Managerial Item**, is an item of activity to execute a project or a risk response related to governance. Example: PA 1 (Preventive action 1) is ensures that Mutual Check (MC-0) is performed, soil characteristics test (sondir test) at the commencement of work. Can be additional managerial items as well as additional items on WBS Preparation for project and engineering team.
2. **Additions to Another WBS**. The risk response may be activities or work items that are added to other WBS elements, i.e. work packages or WBS level 4 in addition to the work in question which is still in WBS precast bridge structural work, as well as in addition to WBS precast bridge structures such as additions to WBS preparatory work/preliminary. Example: based on RBSxWBS matrix (No. 50) Risk on the installation/erection precast using double crane method which generate response material resources: Steel plates as equipment platforms. Can be an additional resource on erection precast work with double crane method. As a result of loose soil conditions.
3. **Additional to Related WBS Elements**. Risk response can be an addition to the WBS elements concerned, this is related to company or organizational policies regarding how far to control the work. Example: based on RBSxWBS matrix (No. 30) Risk on fabrication and installation work on formwork. Generate work response temporary support and platform which become additional work activity/resource on formwork installation work, commonly used for work formwork installation work on the sea or river.
4. **Additional to the Work Specification Requirements**. The risk response can be an addition to the job requirements, which can be incorporated into contract standards, Work Instructions or Work specification requirement. Example: based on RBSxWBS matrix (No. 22) Risk on the stone/bronjong foundation work. Generating a material checking response prior every entering the project site may be an additional requirement in the RKS (general project specification) or contract (if the work is subdivided) or Work Instructions (if executed alone).
5. **Affects to WBS Coefficients**. Risk response can also affect coefficients within the WBS Resource structure. The coefficient on the material is related to waste material and material composition, the coefficient on the tool is related to the capacity of the tool, and the coefficient on the labor is related to the productivity of the worker. Example: based on RBSxWBS matrix (No.29) Risk of rebar waste material resulting response in additional mechanical iron connection (coupler). It will be minimizing the waste of rebar material with the addition of mechanical connection, the coefficient of WBS for rebar material is affected because the volume usage is not as much as usual (coefficient can be reduced).

The pattern recognition analysis resulting 22 Preventive Actions and 21 Corrective Actions as risk responses. These responses will be added in the WBS on the sub work section or additional work activity. Risk response is a risk mitigation measure that is added in compiling WBS at levels 4, 5, and 6 of work packages, activities and resources as an improvement and development in this study.

Table 4. Risk Response Category Mapping for Preventive Action

NO	PREVENTIVE ACTION	CATEGORY					RECOMMENDATION
		1	2	3	4	5	
PA1 **…**	Mutual Check (MC-0) is not performed at the commencement of the project as the initial volume reference	●	●				Managerial / WBS Preliminary: Project & engineering team
PA22	Actual land condition data of project do not given or not complete	●	●				Managerial / WBS Preliminary: Document & Administration

Table 5. Risk Response Category Mapping for Corrective Action

NO	CORRECTIVE ACTION	CATEGORY					RECOMMENDATION
		1	2	3	4	5	
CA1 **…**	Incorporate Mutual Check (MC-0) activities as standard procedure for preparation work		●	●			Managerial / WBS Preliminary: Re-site survey of project location
CA21	Making the collection information about procurement and negotiation process to get the appropriate material price planning		●	●			Managerial / WBS Preliminary: project and engineering team

There are 14 dominant risk variables for the RBS input, and there are upper structure, lower structure and soil works, as the dominant sub work section resulting from Pareto analysis for the WBS input of RBSxWBS matrix. The results are 14 risk responses.

Table 6. Risk Response Category Mapping for Precast Bridge Works (RBSxWBS Matrix)

NO	RBS	WBS	RISK RESPONSE	CATEGORY					RECOMMENDATIO N
				1	2	3	4	5	
1	X5, X8, X19	Work activity of piling wok (precast pile, steel pile)	Operational monitoring of stake in the field (making daily evaluation form)	●		●			Managerial / Activity Items on Piling Works
2	X2, X11	Work package of piling work (precast pile, steel pile)	Used the type of unit price work contract especially for piling work			●		●	Work package of piling work / coefficient of unit price analysis
3	X7, X25	Work activity of jointing pile (precast pile, steel pile)	Acceptance criteria of jointing pile (create mock up)			●	●		Work activity of piling work
4	X19	Work activity of bored pile work	Checking the availability of drilling equipment spare parts as requirement			●			Work activity of bored pile work
5	X2, X11	Work Package of Rock foundation	Rechecking the volume of rock material on site after delivery from quarry			●			Work activity of rock foundation work
6	X6	Work activity Fabrication and installation of formwork pile cap/abutment	Additional temporary support and catwalk for formwork installation			●		●	Work activity of formwork / coefficient of unit price analysis
7	X2, X6, X11	Work activity Abutment / column / pier head	The use of rebar-mechanical joints for dense firing conditions and can reduce rebar waste materials			●		●	Work activity of rebar installation / coefficient of unit price analysis
8	X8	Work activity of PC Strand installation on girder (pre-tension and post-tension)	Test PC strand material (tensile test) before pre-tension and post-tension				●		Specification terms of PC strand installation activity
9	X8	Work activity of Girder Stressing (pre-tension and post-tension)	Rechecking chamber after stressing work				●		Specification term of Stressing girder activity
10	X10	Work activity of delivery girder material from workshop to site	Special escorts to avoid incidents / accidents				●		Specification term of delivery girder activity
11	X6, X8	Work package of erection girder use double crane method	Preliminary of soil investigation and addition of steel plate as equipment base		●		●		Work package of erection double crane
12	X6, X18	Work package of erection girder use double crane, balance cantilever, temporary tower method of work	Certificates of eligible tools serve as contract prerequisites with vendors		●		●		Specification term of erection girder precast

NO	RBS	WBS	RISK RESPONSE	CATEGORY 1	2	3	4	5	RECOMMENDATION
13	X18	Work package of erection girder use double crane, balance cantilever, temporary tower method of work	Additional cost of contingency risk (traffic management, temporary safety tools)		•		•		Work package of erection girder
14	X7, 19	Work activity of erection girder use double crane, balance cantilever, temporary tower method of work	Operators have operating license (SIO) as a prerequisite				•		Specification term of erection girder precast

Here is the sample of standardized WBS which is enhanced by the risk response obtained for upper structure work.

Table 7. Risk-Based Standardized WBS for Upper Structure Work

*■ : Development

WBS L. 3	WBS L. 4	Alt. Method of work	WBS L. 5 Activity	WBS L. 6 Resources	*Requirement*
Upper Structure Work	Fabrication and installation of formwork abutment/column/ pier head	Concrete cast insitu	Rebar installation work	** Add Material: Mechanical joint rebar material*	
			** Additional steel temporary support & catwalk*		
			Fabrication and installation of formwork	** Add Material: Temporary steel support & catwalk*	
	Girder Stressing (pre-tension and post-tension)	Pre-tension and post-tension	Installation of PC Strand		** Tensile test material PC Strand*
			Stressing girder		** Checking the chamber after stressing*
	Erection of girder use Double crane method	Double crane	Preparation work of material, equipment and labor		** Checking the certificate operation of the equipment & SIO (license) for Operator*
			Positioning of crane for erection work	** Add Material: Temporary steel plate as base equipment*	

5. Conclusion

The result of standardized WBS of Precast Bridge Construction consists of 6 (six) levels i.e. 4 primary levels (project name, work section, sub work section, work package) and 2 complementary levels (work activity and resources). Alternative of work methods become the shape of work activity and resources breakdown.

The identification of risk variables from WBS precast bridge construction yield 31 risk variables with 7 risk categories and produce 13 highest risk variables which influence of project cost performance. The identification of risk responds yield 22 preventive action, 21 corrective action and 14 risks respond as the development recommendation of standardized WBS.

The development of standardized WBS grouped into 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. Risk-based standardized WBS of Precast Bridge Construction can be utilized for cost estimation, helping project executor identifies project works to the smallest items and setting cost objective for each item in greater accuracy as a tool to ensure every work has considered the requirements to respond cost-related risks.

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Biographies

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

Remi Fitriadi Kurnia is a student of graduate program at the Faculty of Engineering, University of Indonesia with specialization in the areas of Project Management. He holds a Bachelor degree in Civil Engineering from Bandung Institute of Technology. He has practical experience as professional civil engineer and more than ten years of project experiences at the one of construction State Own Enterprise in Indonesia.