Development of Risk-Based Standardized WBS (Work Breakdown Structure) for Quality Planning of Road Construction Project

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Abstract

Provision of roads provides access for rural and marine communities to health, education, employment and other necessary social services. A road construction project with the WBS (Work Breakdown Structure) as a result of poor planning can affect the quality of the project. WBS is very important in the management planning process by turning it into phases, and work packages. Risk-based WBS standardization is one that can be a reference in road construction projects to achieve project quality. The most dominant risk variables were chosen using questionnaires and analyzed using SPSS (Package Statistics for Social Sciences) then added to the WBS arrangement in order to obtain results that were accurate results.

Keywords
Quality, Risk, WBS, Road Construction

1. Introduction

Establishing a work breakdown structure known as the Work Breakdown Structure (WBS) is taken as a fundamental task by professionals and researchers in project management (Echeverry et al., 1991). The WBS can then be established to align the appropriate workflow, material flow, and cash flows for detailed planning in the construction schedule (Echeverry et al., 1991). The WBS (Work Breakdown Structure) is the starting point of a project planning, implementation and control (Globerson, 1994). It can be argued that WBS has an important role in project quality, making WBS an obligation in project planning (Burghate, Burghate, & Burghate, 2015). The efficient work breakdown structure (WBS) has proven to be very important in the project management planning process by turning it into stages, and work packages (Burghate, Burghate, & Burghate, 2015). In sequence, it can positively impact other project management processes, such as activity definition, project schedule, risk analysis and response, control tools or project organization (Burghate, Burghate, & Burghate, 2015).

In the project, regardless of how well they plan and carry out their work, project component failures can occur, often due to poor WBS (Burghate, Burghate, & Burghate, 2015). A poor WBS construction can lead to adverse projects such as messy work, frequent scope, budget overruns, deadlines and problematic procurement (Burghate, Burghate, & Burghate, 2015). The standardization of WBS in Indonesia is an important thing that can be a reference in the construction of sustainable road construction in order to obtain the quality of a project (Irdemoosa, Dindarloo, & Sharifzadeh, 2015). Just few research has been published on the methodology or tools that can develop WBS to be appropriate for a project, and limited to certain construction areas such as apartment building construction and boiler manufacturing (Irdemoosa, Dindarloo, & Sharifzadeh, 2015).

Based on several studies such as Wong and Norman (1997), Mahamid (2013), Manavazhi and Adhikari (2002) and Cheng (2014) describe performance measures such as quality, cost and timing of road projects, governed by various factors. The researchers identified many causes that affect the performance of a road project. The lack of material planning observed becomes one of the main causes of cost and time overruns in road construction projects. Dawood and Castro (2009) added to gain efficiency gains, building projects on time and within budget, more innovative tools and techniques are needed to help project managers plan and manage road development projects. A study by Heggie (2004), says that developed countries spend about 1.2% -2.5% of their gross domestic product for road construction projects. Amoatey and Ankrah (2016) added the need for sustainable road maintenance is very important, especially with regard to road safety and economic development. While the timing of the implementation of maintenance activities is very important, because it can significantly affect the overall network life cycle costs. (Amoatey & Ankrah, 2016). The Battaineh (1999) study also evaluated project progress reports from 164 buildings and 28 highways built during the 1996-1999 period in Jordan. The study found that the delay was the average ratio of the actual completion time to the planned contract duration of 160% for the road construction project and 120% for the building project (Mahamid, 2011). Project managers need methods or tools that can help learn, compare, and strategize project implementation (Dawood & Castro, 2009). Therefore, the need for research on the development of WBS standards for the quality planning of risk-based road construction projects.

The development of WBS standards on construction projects has been done previously in several studies such as WBS for land work (Li & Lu, 2016), WBS for underground projects (Irdemoosa, Dindarloo, & Sharifzadeh, 2015), WBS and its implementation in 3D or software (Wain (2013); Hans (2013); Moine (2013)) and WBS on real estate projects (Lei-Su, 2012). . In addition, WBS linkages in project planning calculations are discussed in the research of cost estimation methods based on WBS (Sequeira & Lopes, 2015); Khera et all (2013); Sequeira & Lopes (2015)), WBS in improving project performance (Ponticelli, O'Brien, & Leite, 2015), WBS against schedule (Polonski, 2015), and WBS on planning changes (Lai S.-T., 2014). The development of WBS standards for construction projects is not yet available, especially for road construction projects. WBS standardization especially in Indonesia is important and can be a reference in sustainable road construction development in order to obtain the quality of a project (Irdemoosa, Dindarloo, & Sharifzadeh, 2015). Little research has been published on methodologies or tools that can develop WBS to be appropriate for a project, and very limited to certain construction areas such as apartment building construction and boiler manufacturing (Irdemoosa, Dindarloo, & Sharifzadeh, 2015).

2. Literature Review

2.1 Work Breakdown Structure (WBS)

WBS is established with the objective of aligning the appropriate workflow, material flow, and cash flows for detailed planning in construction schedules (Echeverry et al., 1991). The WBS (Work Breakdown Structure) is the starting point of a project planning, implementation and control (Globerson, 1994). The complexity of the project can be broken down by using basic tools and transforming into a hierarchical level of components and more detailed work to be more manageable (Leemann, 2002). A chart or WBS diagram according to Roswidiyastuti (2009), is a concrete form describing a project with the top-down method approach shown in the project structure and how the project is broken down into the downward decomposition form, which is divided into:

- Summary (phase)
  By setting the objectives and objectives of the project, each phase regulates the major deliverables to the overall phase of the project plan.
- Task level (details)
  Generally can produce job products (Australian Catholic National, 2008)

There are 2 (two) WBS formats that can be used, namely table format and graph format (Rianty, WBS Standard Development (Work Breakdown Structure) for Quality Planning of High Risk Based Building Architecture Works, 2016). The first form of WBS can be described as a table numbered in primary and secondary levels. In graphic form, WBS is created in the form of drawing so that it compiles and produces tree diagrams. The table format describes the regular and organized WBS tables, making it the right choice for organizations that choose this format, the form describes a text-like hierarchical structure (Zecheru & Olaru, 2016).

For a leveling system, at level 1 it contains only the final project and objective and the product. At this level should identify directly on the elements of the budget classification structure and the company report. The WBS structure is

from a life-cycle perspective where each of the highest levels overall in the WBS corresponds to the major phase of the project's life cycle. For example definition, design, testing, and procurement. Then level 2 Contains a major product segment or subsection that is defined at the WBS destination and WBS process starting from identifying and defining all the deliverables required to generate completeness for each phase of the project. It starts with high level outcomes and must be achieved by creating a user interface. Level 3 outlines all deliverables into higher activity. Contains a component definition of a subsystem or subsystem of a major segment level two. Think about what it does to complete the deliverables by knowing the user's wishes, performing a prototype user interface and testing the user interface to use. Level 4 is the decomposition of the next activity into the smallest part and the lowest level. And level 5 is broken down to the next level (level n) to get the desired level breakdown.

2.2 Risk Identification for Quality Performance

Risk is an uncertain event, has negative and positive impacts and effects on the project objectives and targets (Project Management Institute, 2013). According to Australia Standard Risk Management (1999), risk management is an iterative process consisting of well-defined measures and if executed in sequence, will support better decision-making. Quality planning deals with the quality conditions required for each work package (Nicholas, 2004). Therefore, according to Rianty (2017) to be able to identify the risk that is by categorizing WBS starting from work package, method or design, activity, material resources, tools, and labor as risk category or event of risk that can influence the purpose, that is performance quality of road construction projects.

According to Suanda (2016), project quality is a project element that is seen and felt by all parties in the project, both internal and external. The quality of a good project is closely related to the brand image of the organization. This characteristic can make the quality parameters to be managed as best as possible in project management. Managing project quality is a focus-on management process rather than a result. This is because the quality of the good results is only generated by the process of managing the good quality since the beginning of the project.

3. Methodology

Table 1. Research Metodhology

RESEARCH QUESTION	**RQ 1**	**RQ 2**	**RQ 3**	**RQ 4**	**RQ 5**	**RQ 6**
	How is WBS for the Current Road Works?	What are the implementation methods of each road work package?	What are the activities of each method of implementing each work path package?	What are the required resources of each activity based on the method of implementing each road work package?	What are the risk factors that come from the resources that affect the performance of each work package?	How to develop risk-based WBS used to plan quality?
Variable X	WBS road construction project	Method of implementation	Job activities	Job resources	Job risk factors	WBS standards are risk-based for road works
Variable Y	Quality of Road Construction Project					
Research Strategy	Archive Analysis	Archive Analysis	Archive Analysis	Archive Analysis	Archive Analysis, Survey	Case Study
Instrument	Questionnaire	Questionnaire	Questionnaire	Questionnaire	Questionnaire	Questionnaire
Data Analysis	Delphi Analysis	Delphi Analysis	Delphi Analysis	Delphi Analysis	Delphi Analysis, Pilot Survey,	Delphi Analysis,Pareto Analysis

	Respondent Questionnaire, Risk Analysis

After RQ 1 to RQ 4 is answered, to answer RQ 5 validation of the results of the preparation of criteria related to the quality of the road construction project as well as identify the risks of the activities that affect the quality performance of the project by conducting interviews and in-depth discussions with experts. The purpose of doing this stage is to choose which variables are most appropriate and effective, by adding or reducing the variables put forward to the expert. At this stage the expert will respond to the construct and content on the questionnaire so that later the questionnaire can be understood by the respondent. Then the pilot survey conducted to determine whether the questionnaire made difficult to understand respondents.

Respondent questionnaires were used to obtain the dominant and most influential risk events on the quality performance of road construction projects. Data obtained respondents are processed using SPSS version 24 to test the validity and realiabilitas. Then after obtaining a dominant risk event, the risk variables are re-analyzed to produce a risk response in the form of preventive action, impact, and corrective action. In RQ6, the risk response is integrated with the dominant work of Pareto analysis.

4. Results and Discussion

Data collection as a reference of WBS (Work Breakdown Structure) in this study based on the specifications of the Bina Marga (Directorate General of Highways) and BPJT (Toll Road Regulatory Agency) as the main reference in the preparation in Indonesia. The compilation of the WBS can produce 4 (four) levels with 9 (nine) divisions. The arrangement is then re-analyzed with BQ (Bill of Quantity) based on 27 successful projects to be detailed for level 6 at the smallest level or resource. For levels 1 to 4 are the WBS composition of road construction projects to date, while levels 5 and 6 are additional levels as a contractor or project manager reference in project planning to the smallest level, ie resources.

Table 2. Comparison of Specifications

WBS Development	BPJT	Bina Marga
Division 1 - Preparatory Work	Includes division: 1 (General), 2 (Cleaning the Workplace), 3 (Demolition), and 15 (Transfer and Protection of Existing Equipment)	Includes division: 1 (General)
Division 2 - Drainage	Includes division: 6 (Drainage)	Includes division: 2 (Drainage)
Division 3 - Land Work	Includes division: 4 (Land Works), 5 (Cut of Structure), and 7 (Preparation of Ground)	Includes division: 3 (Land Work)
Division 4 - Widening of Pavement and Roadside		Includes division: 4 (Widening of Pavement and Shoulders)
Division 5 - Bulking Hardening and Concrete Pavement Pavement	Includes division: 8 (Aggregate Base)	Includes division: 5 (Bulking Hardening and Concrete Pavement Pavement)
Division 6 - Asphalt Pavement	Includes division: 9 (Pavement)	Includes division: 6 (Asphalt Pavement)
Division 7 - Structure (only for bridge project)	Includes division: 10 (Concrete Structures), and 11 (Structural Steel Works)	Includes division: 7 (Structure)
Division 8 - Toll Service Facility	Includes division: 13 (Lighting, Traffic Light, and Electrical Work), 14 (Plaza Tol), and 16 (Office and Toll Facilities)	
Division 9 - Refund Conditions and Minor Works	Includes division: 12 (Other Jobs), and 17 (Daily Jobs)	Includes division: 8 (Refund of Conditions and Minor Works),

	9 (Daily Jobs), and 10 (Routine Maintenance Works)

Risk events on initial expert validation of 5 expert people resulted in 45 variables. The variables are then distributed to 30 respondents, and re-validation by the final expert as many as 5 people to produce a dominant variable judging by the frequency (F) and impact (I).

Table 3. Risk Rangking

	Risk Variables That Affect Project Quality Performance	MEAN F	MEAN I	RISK SCORE	RISK LEVEL	RISK RANK
X12	Changes in the condition of the material source to the project site	0.41	0.54	0.14	High	5
X13	Material quality does not match job planning specifications	0.44	0.47	0.11	Moderate	20
X16	Bad tool condition	0.55	0.49	0.16	High	3
X19	The productivity of the planned equipment is not as needed	0.48	0.43	0.10	Moderate	29
X27	False perception in reading of shop drawing	0.49	0.53	0.18	High	1
X37	The quality of the workforce is not as planned	0.50	0.51	0.14	High	6
X45	Natural disasters	0.37	0.58	0.14	High	4

Table 4. Risk Response

Category	Risk Variables	Cause	Preventive Action	Impact	Corrective Action
Resources: Materials	X12 Changes in the condition of the material source to the project site	Storage systems in storage are too old and not sufficient	Storage planning in the storage area, and material mobilization need attention.	The quality of road construction materials does not match the planned specifications	Perform a job mix formula tailored to the available material
	X13 Material quality does not match job planning specifications	There is no check or quality plan in the purchase or supply of materials for example in doing jobmix formula	Quality plan needs to be well planned and must be implemented		The existence of quality control along with surveillance reports to be in the material condition data periodically
Resources: Equipment	X16 Bad tool condition	Maintenance or maintenance along with poor spare part management	A test or equipment test is required before purchasing or leasing	Asphalt product or other material is not maximal	Using replacement tools or other spare parts are available and can meet the project quality targets
	X19 The productivity of the planned equipment is not as needed		Need to be maintained equipment and spare parts		
Resources: Labor	X27 False perception in reading of shop drawing	Lack of training and qualification of workers	There is clear planning on the quality of the project with the results of the work	Road construction projects are not in line with other designs and plans	The existence of control and evaluation of human resources according to the scope and its changes

Category	Risk Variables	Cause	Preventive Action	Impact	Corrective Action
	X37 The quality of the workforce is not as planned	The existence of design changes or the scope of work so that labor needs to be conditioned	Conduct regular training planning, and select a competent workforce.	The quality of work by workers is not maximal	It is necessary to set a schedule for re-working hours and the scope of work is re-analyzed if the number of workers is less
Environment	X45 Natural disasters	Changes in Earth's structure and climate	Planning contract clauses about the occurrence of disasters or climate change in case of rework.	Material or other work that has been done is disrupted quality	Review re-scheduled work according to climate or weather forecast by a trusted climatic body

After WBS has been validated, Pareto Analysis shall be conducted. According to Suanda (2016), Pareto is one way of knowing the vital source that causes most of the project quality issues. The BQ data selected for pareto analysis is the Toll Road 6, due to the complete BQ and the toll road project. Based on the Pareto analysis of the 6-segment toll road project, the most significant job on the project cost is the asphalt pavement. Asphalt pavement becomes very important to observe its quality performance in order to avoid cost overrun or late schedule. Therefore, asphalt pavement is used as a basis in developing WBS with corrective and preventive measures that have been sorted.

Table 5. Risk Category

CODE	RISK RESPONSE	CATEGORY					
		1	2	3	4	5	
	PREVENTIVE ACTION						
TP1	Storage planning in the storage area, and material mobilization need attention.	√					*Category* *1. Additional management (to manage projects based on the governance or system of a project organization)* *2. Other WBS additions (other than asphalt pavement work)* *3. Additional WBS related (asphalt pavement work)* *4.Additional job requirements (contained in work instructions or contracts with the aim of controlling the work through the established policy)* *5. Affects WBS coefficients (related to waste material, material composition, tool*
TP2	Quality plan needs to be well planned and must be implemented						
TP3	A test or equipment test is required before purchasing or leasing		√				
TP4	Need to be maintained equipment and spare parts		√				
TP5	There is clear planning on the quality of the project with the results of the work	√					
TP6	Conduct regular training planning, and select a competent workforce.	√			√	√	
TP7	Planning contract clauses about the occurrence of disasters or climate change in case of rework.	√			√		
	CORRECTIVE ACTION						
TK1	Perform a job mix formula tailored to the available material			√		√	
TK2	The existence of quality control along with surveillance reports to be in the material condition data periodically	√					
TK3	Using replacement tools or other spare parts are available and can meet the project quality targets					√	
TK4	The existence of control and evaluation of human resources according to the scope and its changes	√					

CODE	RISK RESPONSE	CATEGORY					
		1	2	3	4	5	
TK5	It is necessary to set a schedule for re-working hours and the scope of work is re-analyzed if the number of workers is less	√					*capacity, and worker productivity)*
TK6	Review re-scheduled work according to climate or weather forecast by a trusted climatic body			√			

5. Conclusion and Recomendation

The development of WBS based on risk in the previous table uses the variables with category 2 (Other WBS additions) ie TP3, TP4 and Category 3 (Additional WBS related) code TK1 because the result is entered into category 2. For TP3 and TP4 after validated by experts, form a variable in the development of WBS into "Tool Productivity Control" located in the cluster of work perseiapan, at level 4. While TK1 form variable "Job Mix Testing" for the clump asphalt pavement work on level 5. Due to space limitations, here is the mapping:

Table 6. WBS of Road Construction Project

WBS LEVEL 1		WBS LEVEL 2		WBS LEVEL 3		WBS LEVEL 4	
CODE	**PROJECT NAME**	**CODE**	**SCOPE OF WORK**	**CODE**	**TYPE OF WORK**	**CODE**	**WORK PACKAGE**
	Road Construction Project	1	Preparatory Work	1.1	Mobilization & Demobilization	1.1.1	Mobilization Program
						1.1.2	Demobilization Program
				1.2	Field Office and Facilities	1.2.1	Office of Service Provider and Facilities
						1.2.2	Service Workshop and Warehouse
						1.2.3	Offices and Accommodations for the Directors
				1.3	Management and Traffic Safety	1.3.1	Management Plan and Traffic Safety
						1.3.2	Description of Temporary Minimum Road Equipment
						1.3.3	Temporary Road or Bridge Works
						1.3.4	Maintenance for Traffic Safety
				1.4	Field Technical Review	1.4.1	Field Survey Work for Design Review
						1.4.2	Routine Implementation Survey Work
						1.4.3	Determinantion of Measurement Point
						1.4.4	Field Engineering Expert
				1.5	Environmental Security	1.5.1	Environmental Management Efforts
				1.6	Relocate Existing Utility	1.6.1	Utility Relocation Work and Existing Services
				1.7	Occupational Health and Safety	1.7.1	K3 Construction Management System

WBS LEVEL 1		WBS LEVEL 2		WBS LEVEL 3		WBS LEVEL 4	
CODE	**PROJECT NAME**	**CODE**	**SCOPE OF WORK**	**CODE**	**TYPE OF WORK**	**CODE**	**WORK PACKAGE**
						1.7.2	K3 Field Office and Facilities
						1.7.3	Risk Management
				1.8	Soil Testing	1.8.1	Test Characteristics
				1.9	Quality Management	1.9.1	Project Quality Assurance & Quality Plan
						1.9.2	Quality Control of Materials & Products
						1.9.3	Testing for Completion
						1.9.4	Tool Productivity Control
		2	Drainage	2.1	Support Drainage (Out of Bridge Construction)	2.1.1	Sewers and Waterways
						2.1.2	Drainage of Stone & Mortar Pairs
						2.1.3	Concrete Precast Drainage
						2.1.4	Concrete Cast Insitu Drainage
						2.1.4	Porous Drainage
						2.1.5	Culvert Pipes and Culvert Boxes
		3	Land Work	3.1	Land clearing	3.1.1	Cleaning, Peeling And Cutting Trees
				3.2	Excavation	3.2.1	Excavation
						3.2.2	Stone Excavation
						3.2.3	Stone Excavation
						3.2.4	Pavement Paved Excavation
						3.2.5	Concrete Pavement Excavation
						3.2.6	Structure Excavation
				3.3	Pile	3.3.1	Dumps Back
						3.3.2	Heap From the Outside (Borrow Area)
				3.4	Land Improvement	3.4.1	Geotextile Works
						3.4.2	Vacuum Consolidation Method (VCM) Works
						3.4.3	Dynamic Compaction (DC)
		4	Widening of Pavement and Roadside	4.1	Widening Pavement Work	4.1.1	Widening of Asphalt Pavement Works
						4.1.2	Widening of Concrete Pavement Works
				4.2	Roadside Works	4.2.1	Widening Roadside Works
		5	Bulking Hardening and Concrete Pavement	5.1	Gilded Pavement	5.1.1	Aggregate Base

WBS LEVEL 1		WBS LEVEL 2		WBS LEVEL 3		WBS LEVEL 4	
CODE	**PROJECT NAME**	**CODE**	**SCOPE OF WORK**	**CODE**	**TYPE OF WORK**	**CODE**	**WORK PACKAGE**
						5.1.2	Gilded Pavilion Without Asphalt Cover
				5.2	Concrete Pavement	5.2.1	Soil Cement Base
						5.2.2	Aggregate Cement Foundation Base (CBT dan CTSB)
						5.2.3	Concrete Pavement Pavement
		6	Asphalt Pavement	6.1	Asphal Mixing Plant (AMP)	6.1.1	Basic Asphalt Layer (Prime coat/ Tack coat)
						6.1.1.4	Job Mix Testing
						6.1.2	Upper Asphalt
				6.2	Non Asphal Mixing Plant (Non-AMP)	6.2.1	Macadam Penetration Layer
						6.2.2	One Layer Asphalt Lab (Burtu)
						6.2.3	Two Layer Asphalt Labels (Burda)
		7	Toll Service Facility	7.1	Plaza Tol	7.1.1	Construction of Toll Gate
						7.1.2	Toll Gate Equipment
				7.2	Office and Toll Facilities	7.2.1	Field work
						8.2.2	Office Development
		8	Work of Minor Working Condition Refund	8.1	Refund of Minor Working Conditions	8.1.1	Return of Existing Pavement Condition
						8.1.2	Return of Shoulder Walk Conditions on Asphalt Pavement
						8.1.3	Return of Sewer Conditions, Water Channels, Galian, Stockpiles and Reforestation
						8.1.4	Traffic Equipment and Traffic Control
				8.2	Routine Maintenance Road & Bridge	8.2.1	Routine Pavement Maintenance, Shoulders, Drainage, Road and bridge equipment

This study resulted in the standard arrangement of WBS development of a risk-based road construction project to improve quality performance. WBS that has been categorized, then is determining the risk events that affect the quality performance. With the dominant work of pareto analysis, Asphalt Pavement Work is then used as a basic for WBS development that generates a risk response and can be developed into the WBS composition. If such a risk response is applied, incidents or undesirable things in achieving road project quality performance can be prevented or mitigated. The risk response is a guideline for project quality planning, job oversight to the smallest level and recommendations

for project managers in controlling other performance such as time and cost (Rianty, 2017). That way, the hypothesis proposed in this study has been proven. Future research is expected:

- This study analyzes the BQ of road construction projects in Indonesia, then it would be better to analyze the archive of road projects not only from BQ.
- This research only analyzed the archives and spread the questionnaire in Indonesia, then it can be spread widely not only in Indonesia.
- For future, similar studies of road construction projects improve other performance such as time and cost.
- WBS development This research is risk-based, for the future can be developed with other things, such as software.
- The WBS approach developed using the pareto method, then the next research can use another approach.

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