A conceptual framework of cost of safety model in infrastructure project based on work breakdown structure (WBS) to improve safety policy in Indonesia

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Abstract. The high accidents rate in infrastructure projects in Indonesia in the last 1 (one) year due to lack implementation of the Occupational Health and Safety Management System in its entire project. One of the key indicators that influence it is the safety cost allocation. Currently, there is no structured guidelines to prepare cost of safety that is in accordance with the conditions of infrastructure projects in Indonesia. The purpose of this study is to address this gap by conceptualizing cost of construction safety as a more structured model for construction safety improvement. A conceptual framework which is not only integrate construction project management theory and regulation in Indonesia, but also consider project scope, project duration, project location, hazard analysis, and safety program, is proposed. This conceptual paper contributes to the emerging literature on safety cost and produce a systematic model of safety costs by involving appropriate risk control, and considering applicable regulations.

1. Introduction
The Indonesian government for the 2015-2019 period focused on infrastructure development, i.e. road, toll road, port, and airport constructions in necessary areas. This is required, considering that the condition of infrastructure in Indonesia is still far from ideal, and has even been depreciating in the last two decades. Study from Bloomberg Mckinsey in 2013, in kemenkeu.go.id [1] stated that compared to other countries in the world which had an average of around 70% of GDP invested in infrastructure stock, that of Indonesia was only 38% which decreased from 49% in 1995. According to the 2015-2016 Global Competitiveness Report compiled by the World Economic Forum (WEF)[2], Indonesia ranks 80th out of 137 countries in terms of infrastructure quality especially roads, which is a down grade from 72nd in the previous year [3]. President Joko Widodo stated that the acceleration of infrastructure development is needed to create higher economic growth, both in the medium and long term.

However, the infrastructure development program was not implemented smoothly, and as a result, there were recurring construction accidents on national scale construction projects from the end of 2017 to the beginning of 2018. Recorded from August 2017 to December 2018, there were thirty-five accidents on construction projects and still increasing in number. This led to the Ministry of Public Works and Settlements Indonesia (MPW) to suspend construction work temporarily in February 2018, especially on projects involving elevated construction. Consequently, the
suspension led to the loss of as much as billions of rupiahs per day. Besides economic losses, construction accidents also cause casualties such as death. Also, what we least realize is that recurring construction accidents can result in public anxiety in both the construction workers and the public. When communities around these projects are anxious, they can reject development, and as a result hampering infrastructure development of the country as a whole which is a priority at this time.

The Construction Safety Committee identified general findings that contractors do not prioritize construction safety, namely the implementation of a construction safety and health system has not been optimally implemented. This is also supported by the evaluation results related to the Orderly Implementation of Construction Services conducted by the Directorate General of Construction of the MPWS which stated that the implementation of construction SHS in MPW was only 27.43% in 2016 and 34% in 2017. One of the key factors that emerged in the evaluation as causes of this low implementation was related to the cost of Occupational Safety and Health (OSH).

The procedure for calculating the cost of implementing construction safety is not strictly regulated in the laws and regulations. In PW Minister Regulation No. 05 of 2014 about the Occupational Safety and Health Management System in the construction sector, it is stated that OHS cost is part of the total cost which includes: safety plan preparation; safety socialization and promotion; work protective equipment; personal protective equipment; insurance and licensing; safety personnel; health facilities; signs; and other things related to safety risk control.

However, in Minister Regulation No. 31 of 2015, Amendments to the Third Minister of PW Regulation Number 07/PRT/M/2011 about Standards and Guidelines for the Procurement of Construction Works and Consultancy Services, safety costs are included in the overhead costs. The two regulations only regulate OSH costs administratively in the preparation of government budgets, but not for the procedures concerning the preparation of OHS costs, starting from hazard control. Against this backdrop, the purpose of this paper is to conceptualise the cost of construction safety as a more detailed and structured model, that results in accurate calculations.

2. Cost of safety
The construction sector has the highest risk of accidents compared to others [4]. According to the MPW, the number of construction accidents in the past year in Indonesia has increased. In Malaysia, accidents in the construction industry reached 3 times greater than other industries [5]. One of the key factors of an increase in the number of these accidents in Indonesia is the cost of safety (COS). Some researchers have divided the COS into several parts, and they include [6] [7] (fig.1):

- An insurance cost is that which must be paid by the employer to the insurance company to bear the costs incurred in the event of an accident or illness due to work on workers. This amount depends on the job category of workers.
- Prevention costs are costs calculated by the employer to meet the applicable safety regulations during the course of completing their work.
- Accident costs are those required when a work accident occurs, with the amount depending on the severity. Elias [7] divided the cost of accident into 2 (two) direct and indirect costs of accident.
- Recovery cost is that which must be incurred by the employer to workers affected by work-related accidents, after the second day of treatment to recover and be able to resume work. This is regulated by the Spanish social security system.
Figure 1. Cost of Safety [6] [7]

There have been several studies conducted on safety costs, and most have focused on the costs of preventing construction accidents. COS is influenced by several factors including: Project scope [4], [5]; Project duration [4]; Man-hour values [5]; Recovery cost [6]; Project budget [8]; Project phase [8], [9]; Project progress [9]; Material operating budget [9]; Number of accidents [4], [9]; Number of workers [9]; Number of subcons [9]; Type of labour contract [9]; Prevention cost [4], [5], [6], [8], [9], [10], [11]; Accident cost [6], [9], [10]; Safety performance [10].

One of the fundamental problems that led to the low implementation of construction safety management systems in Indonesia was the absence of safety cost calculation standards. According to Lopez [9], the COS in construction projects was influenced by several factors, namely: the scope and duration of the project, the number of work accidents, the safety component, and the costs when an accident occurs. The optimal amount of OHS costs is 1% of the total project [4], or equal to 1.92% of the total project cost, according to Gurcanli [5] by considering the work component and the hours of labour.

With the mathematical formulation method, according to Pellicer [6], the prevention costs for construction projects add up to around 1.54% of the total project costs. Abdul Hamid stated that the cost of compliance with health and safety management system among contractor in construction industry varies from minimum 0.15% to 1.08% with average of 0.41%, while Son found that efficient safety control cost should be 1.2 - 1.3% of total contract costs (table I).

Pellicer’s calculation also states that safety costs add up to 5% of the project’s value by calculating insurance costs and costs when a construction accident occurs. According to Toutouchian [8], in studies conducted on oil and gas projects, the estimated cost of safety was different at every stage of the project. The influencing variables are: the total budget, project stages and prevention costs (first aid kit, etc.). Lu [10] stated that, a low level of construction safety would result in a high accident rate in the projects. The influential factors are prevention and accident costs, as well as safety performance assessment. Lopez [9] concluded that the number of occurred accidents was directly proportional to the number of workers, subcons and the amount of safety costs, but inversely proportional to the cost of prevention.

It was stated in PMBOK construction extension that the most commonly used construction...
techniques for estimation are analogous, parametric, bottom-up, three-point estimation, and Monte Carlo simulation. The more accurate the estimates means the more detailed information about the project, and the more consuming time and resources to develop.

3. Work Breakdown Structure
Making a WBS is a process that describes work and project results of individual components in the form of a top-down list. It also means hierarchically describing the components to be built, as well as the work associated with them. Each WBS represents a more detailed work item. It is a system that divides a project into manageable work packages, components, or WBS elements in order to provide a common framework for scheduling scope, costs, allocation of responsibilities, communication, risk assessment, monitoring and control.

According to PMBOK construction extension [14], each construction project, regardless of size and complexity, continues to face a variety of uncertain situations due to the common factors within the construction industry. Hazard risk can be identified using several approaches, one of which is by following a work breakdown structure.

4. Public Works and Human Settlements Infrastructures
The Ministry of PW has duties and functions as regulators as well as owners in the national infrastructure development of Indonesia. According to Minister of Public Works Regulation No. 8 of 2018 about the 2015-2019 MPW Strategic Plan [15], there are various types of infrastructures built by the MPW in 3 (three) organizational units with the largest budget as the object of this study, there are dam, bridge, road, and flat.
5. Conceptual Framework Discussion
The proposed conceptual framework of the cost of construction safety in this research begins with determining the type of MPW infrastructure that will be examined as a study boundary. The types of MPW infrastructure that will be used as objects of this research are roads, bridges, dams and flats. In general, this research is divided into 4 major stages which are carried out sequentially (figure 2), and they include:

5.1. Preparation of work components / Work Breakdown Structure (WBS).
After determining the type of infrastructure to be studied, the next step is to develop WBS on buildings, roads, bridges and dams which include the preparation of WBS diagrams, dictionaries and checklists. This arrangement is carried out by referring to:

Figure 2. Conceptual Framework of Cost of Construction Safety
5.1.1. Ministry of Public Works regulation No 28 Year 2016 about analysis work unit price.
In appendix part 4, Analysis of Work Unit Prices (AHSP) in the field of Cipta Karya, it is stated that compiling an analysis of the price of work units in constructing buildings begins by describing the scope of work, and this is called the Work Breakdown Structure (WBS). Likewise in this research, in accordance with the Ministerial regulation, the preparation of safety costs begins with compiling the WBS.

5.1.2. PMBOK Construction Extension
In construction projects, scope planning, scope definition and WBS are the first steps in determining the framework. This is stated in one body of knowledge known as project scope management.

5.2. Safety and environment hazard risk analysis
Furthermore, to discover the hazard control measures put in place to prevent accidents during the construction process, an analysis of safety and environmental risk hazards have been prepared. The results of this analysis include risk control, which begins with hazard identification, risk assessment, and establishing risk control for hazards related to work activities in accordance with the WBS that had been previously prepared. This analysis is carried out by considering the project location especially to identify hazards with projects in certain locations. In conducting this analysis, there are references, among others:

5.2.1. Government Regulation No. 50 Year 2012 about Safety System. In appendix II points 2.1.1 and 2.1.3 this regulation states that identification of potential hazards and risk assessment must be considered when formulating a safety plan. If risk control efforts are required, it is determined through the level of control.

5.2.2. Ministry of Public Works regulation No. 05 Year 2014 about construction safety system. In article 16, in this regulation, it is stated that in every construction project, service users must identify potential hazards. On the other hand, article 19 point b states that the service provider must submit a safety plan in the bidding document.

5.2.3. PMBOK Construction Extension. Project Risk Management, one of the bodies of knowledge, states that one of the potential risks in a construction project is safety and security. To identify hazard risk means to perform Hazard Identification, Risk Assessment, and Determining Control (HIRADC). The four strategies of mitigating negative risks are avoid, transfer, mitigate, and accept.

5.3. Safety target and program
After hazard controls are set, the safety targets and programs will be prepared to ensure the safety of the project. This safety program will then calculate its resource requirements. The preparation of objectives and safety programs refers to:

5.3.1. Government Regulation No. 50 Year 2012 about Safety System. In appendix II point 2.1.4 it is stated that measurable goals and objectives are required in developing a safety strategic plan in controlling risk.

5.3.2. Ministry of Public Works regulation No. 05 Year 2014 about construction safety system. Section 20 stated that the cost of OHSMS Construction implementation is allocated with the general cost.

5.3.3. Ministry of Public Works regulation No 66 Year 2015 about cost of construction safety system. In point E, the details of the implementation of construction OHSMS are expressed
in the preparation of the analysis of the work unit price (AHSP) in the MPW field, in accordance with item G.

5.3.4. *PMBOK Construction Extension.* One of the bodies of knowledge, Health Project Safety Security and Environment Management, states that there are several methods of maintaining workplace health, to ensure safety at work, to guarantee security within the workplace, and to preserve the work environment.

5.4. *Last step is to develop cost of safety model*

The preparation of these costs is based on existing activities in the safety program using the bottom-up (detailed) estimating method, namely, the method of estimating costs that are influenced by the size and complexity of individual activities, work packages, and work components.

According to Popescu in Zhang [16], one of the aspects that influence the cost of a construction project is its location. Some locations have different price indexes which affect the cost of materials, labour, and equipment. This was also stated by Pietlock in Zhang, saying that there is a location factor used in calculating the price of the same project at a different location. In Indonesia, there was a construction cost index (IKK) issued by Badan Pusat Statistik (BPS) since 2003. According to BPS [17], “IKK is used as a proxy of geographical adversity of a region, where the more difficult the geographical location, the higher price level in the area.” Five provinces in Indonesia with the highest construction cost indexes are Papua, West Papua, Riau Islands, Maluku, and then Bali.

In preparing the construction safety cost model, the location factors are also considered in accordance with the construction cost index issued by BPS. In addition, this model also considers:

5.4.1. *Ministry of Public Works regulation No. 28 Year 2016 about analysis work unit price on section public work.* In the appendix, it is stated that in the structure of the work unit price analysis, safety costs are included in the general costs, to be exact, in indirect costs. In appendix table 16, safety cost items include general safety, special safety, and unit price safety.

5.4.2. *PMBOK Construction Extension.* A body of knowledge, project cost management states that the prerequisites for bottom-up estimation are clear and detailed scopes including documents such as WBS, which are issued for drawings and construction specifications. Detailed estimation techniques produce transparent estimates and structures for more accurate and reliable projects.

6. Conclusion

This four step detailed and structured conceptual framework results cost of safety in accurate calculations and improve safety performance in construction projects. By integrating construction project management theory and regulation in Indonesia, and also considers project scope, duration, and location, as well as hazard analysis, and safety programs, this conceptual framework can be used as structured guidelines in place to prepare the cost of safety in accordance with the present conditions of infrastructure projects in Indonesia.

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