Analysis of safety cost structure in infrastructure project of precast of precast concrete bridge based on Work Breakdown Structure (WBS)

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Abstract. The Indonesian construction industry has increased due to the policy of infrastructure projects acceleration. Construction is a dangerous industry that often takes casualties. In recent years there have been many accidents in the precast bridge projects, which have caused moral and material losses, projects were stopped and delayed. Separate budgets that are not specifically prepared in implementing the Occupational Safety and Health Management System (OHSMS) is one of the causes of the poor implementation of OHSMS and create high rates of accidents. Thus, the financing of OHSMS was taken from the project budget, which led to a reduction in the profits. The aims of the study are determining the work breakdown structure (WBS) in precast bridge project, identifying hazards and risks, developing safety plans, identifying safety costs components and calculating of safety cost. This research is a survey research with respondents of experts in construction safety, descriptive analysis is used to determine variables. A case study approach is also used to calculate safety costs. The results of this study are the precast bridges standardized WBS, safety plan to each hazards and activity, finding the safety costs components based on WBS, and the percentage of total safety cost Kundur Bridge is 3.21%.

1. Introduction
The Indonesian construction industry has increased due to policy of infrastructure projects accelerations. The most project that are being worked are road and bridges. Nowadays, precast concrete is one of most often used in constructing bridge. Precast have many advantages to support project in order to achieve the goal of the project. The advantages are buildable, saving cost and time [1]. In managing project scope, using WBS is important things to do [2]. WBS is a sistem which make project into smaller components in order to make it easier to manage [3] [4]. The purpose of the WBS are planning and design tool, a structural design tool, and project status report tool [2]. In WBS, activity is complementary level for planning and managing projects to achieve project performance. Choosing the right construction method for constructing precast concrete bridge is one of important thing also, such as double cranes method for girder erection which is easy to implement but very dangerous. So that the implementation of safety construction become the main thing that must be managed properly.

Construction is one most dangerous industry [5] [6] and also the business [7]. In recent 2 years, there were more than 14 work accidents in construction projects and cause fatality in all around Indonesia [8]. So, safety is challenge for construction industry all around the world [9] including Indonesia. A difficult and complex construction project is one of factor causing many accidents [10]. The impact of
construction accidents not only affecting the workers but also can affect to project time, project cost, medical, and other negative impact [11].

Project safety performance measurement based on the results of WBS identification [12]. A good project safety performance can be achieved with good OHSMS. Safety plan is needed to plan a good OHSMS. Safety plan is important document which contain plan for implementing safety OHSMS in project to support companies in avoiding potensial hazards and can manage properly [13]. In developing a OHSMS, risk analysis is a basis for forming good safety planning [10-16]. In the Permen PU No. 05/2014, safety planning consists of potensial hazards identification, risk assessment, risk control, safety objectives and programmers, person in charge, and also safety cost [17].

Safety cost is very important but separate budgets that are not specifically prepared in implementing the Occupational Safety and Health Management System (OHSMS) is one of the causes of the poor implementation of OHSMS and create high rates of accidents. But many construction players still think that safety is and additional cost and reduce profits. So, each decision is not considered on the safety basis but economics [18]. In order to prevent that, Indonesian government through the ministry of public works and public housing issued a letter (SE PUPR) No. 11/2019 which regulating safety cost. In the letter mentioned there are 9 aspects, i.e. Personal Protective Equipment’s, Safety Plan, Socialization, Promotion and Training, Working Protective Equipment’s, Workers Insurance, Environmental Permissions and Licensing, Safety Officer Personnel’s, Medical Facilities, Infrastructures and Medical Devices, Safety Signs, Consultation with Experts Related to Construction Safety, Others [19]. In other regulation (Permen PUPR) No. 28/2016 safety cost grouped by 3 aspects, i.e general cost, specific cost and security cost [20].

It is very important to analysis safety cost for precast concrete bridge project. The aims of the study are determining the work breakdown structure (WBS) in precast bridge project, identifying hazards and risks, developing safety plans, identifying safety costs components and calculating of safety cost. This study limited to the upper structure precast concrete bridge with erection girder using double cranes method.

2. Methodology
This study conducted a survey research with qualitative approach to answer the research question. There are 5 steps that must be passed in this study to achieve each goal in this study. First step is to develop standardized WBS, with 2 variables work packages and activities, questionnaire is used to collect the data from the construction expert. Second step is to identify potensial hazards and determine risk control, questionnaire is used to collect data from construction and safety construction experts. Next step is to develop safety plan which contains two variables, safety objectives and safety programs, questionnaire is used to collect data from the experts. After that, we continue to identify the safety costs structures which contains general safety cost, specific safety cost and security safety cost, questionnaire is also used to get answer from the construction safety experts. The final step is to calculate the safety cost. One of bridge project is becoming a sample calculation. There are 7 total variables which will be studied in this research, consisting of 6 variables X (Work Package, Activity, Potensial Hazard, Risk Control, Safety Objective, Safety Program) and 1 variable Y (Safety Costs). The sampling technique used is nonprobability sampling [21] by asking for expert judgment [4]. The selected experts must meet the minimum requirements of working experience at least 10 years, bachelor degree, expert and experience in bridge construction and safety construction. The questionnaire with Guttmann scale is used to collect experts opinions “yes” or “no” [21]. The data’s that have been collected will be processed and analyzed descriptively.

3. Results and discussions
In this section, the results of the data analysis will be discussed.
3.1. Development of a standardized WBS for precast concrete bridge

Project was divided to smaller WBS components to make it easier to manage [22]. The standardized WBS form the previous research which done [23]. The standardized WBS is validated by 5 experts. And the results of data analysis can be seen in Figure 1. Below shows the standardized WBS of Precast Concrete Bridge. There are 6 levels which founded form data analysis, Project Name, Work Section, Sub Work Section, Work Package, Work Activity and Resources. But this research only focuses on the upper structure works with double cranes method of girder erection. There are 37 main activities in upper structure works that must be managed. But for the girder erection with double cranes method work package, there are 5 main activities should be manage, such as preparation of materials, workers, and equipment’s, placement of cranes at two different side of bridge, girder erection, and girder placement on the bearing pad. These 5 activities will be the basis for further analysis.

Figure 1. Standardized work breakdown structure for precast concrete bridge.

3.2. Hazard identification and risk control base on WBS

After developing standardized WBS, the next steps are identifying potential hazards, assessing risk and finding risk control. Hazards identification is carried out from activity at level 5 standardized WBS precast concrete bridge. Then, risk assessment is done for knowing the risk rating and risk level. After that, the risk control are determined to reduce the risk rating and risk level. Table 1 show an example of hazard identification, risk assessment and also determine risk control in girder erection activity with double cranes method.

| WBS Level 5 Activities | Potential Hazard | Probability | Impact | Risk Rating | Risk Level | Risk Control |
|------------------------|------------------|-------------|--------|-------------|------------|--------------|
| Girder Erection fall down | Girder fall down | 3 | 5 | 15 | Middle | 1. Rigging Check 2. Creating, socializing, and evaluation SOP |
Girder erection activities has dangerous potential hazards, that is girder fall down with risk rating 15 and risk level middle. The respons risk to control and reduce the risk are rigging check and creating, socializing and evaluation of standard operational procedure. Those controls are administrative controls in the risk control hierarchy [24].

3.3. Development of safety plan and safety cost components identification base on WBS
After identifying potential risk, assessing risk and determining controls, the next steps are making and developing safety plan base on Permen PU No. 05/2014 and determining safety cost base on SE PUPR No. 11/2019 and also PUPR No. 28/2016. In developing safety plan, safety objectives and programmers should adjust to the risk controls. Specific safety objectives consist of description, and measurement and safety programmers consist of duration, achievement indicator, monitoring and person in charge [17]. Figure 2 below show safety plans which consist of safety objectives and programmers.

Safety cost component is identifying base on activity, hazards, risks, and safety plans. For girder erection activity in WBS, and potential hazards is girder fall down, the safety cost component is grouped in to specific cost, and the components are inspection and audit programs, documents, induction, direction, meeting, training, banner, and information board. Figure 2 also show safety cost component base on safety plan developed.

Figure 2. Safety plan and safety cost components.

3.4. Safety cost calculation
The sample of the project is Kundur Bridge, Tanjung Karimun Regency, Riau. The bridge length is 660 meters and total duration is 12 months. There are 60 engineers and 500 workers finishing this project. The calculation follow the guideline and method in SE PUPR No. 11/2019. The percentage of total safety cost is 3.21%. This percentage is higher than the policy of construction state owned company in Indonesia max 2% for precast concrete bridge [25]. If compared with the building construction in Indonesia this percentage is in the range 2.10%-3.70% [26].

4. Conclusion
The conclusion of this study base on the results of data analysis are:

- There are 6 levels of standardized WBS of precast concrete bridge, i.e. Project Name, Work Section, Sub Work Section, Work Package, Work Activity and Resources. There are 37 main activities in upper structure works that must be managed. But for the girder erection with double cranes method work package, there are 5 main activities.
- Girder erection activity has dangerous potential hazards, that is girder fall down with risk rating 15 and risk level middle. The respons risk to control and reduce the risk are rigging check and creating, socializing and evaluation of standard operational procedure. Those controls are administrative controls in the risk control hierarchy.
- Safety cost component for girder erection activity is grouped into specific cost. And the components are inspection and audit programs, documents, induction, direction, meeting, training, banner, and information board.
- The percentage of total safety cost Kundur Bridge is 3.21% is higher than the previous safety cost 0.65%. This percentage is higher than the policy of construction state owned company in Indonesia max 2% for precast concrete bridge.

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