The development of safety plan to improve OHS (occupational health and safety) performance for construction of irrigation channel based on WBS (work breakdown structure)

Ayasha Tamara¹,², Yusuf Latief³, and Rossy Armyn Machfudiyanto¹

¹ Department of Civil Engineering, Engineering Faculty, Universitas Indonesia, 16424 Kampus UI, Depok, West Java, Indonesia

ayasha.tamara13@gmail.com, latief73@eng.ui.ac.id, rossyarmyn@gmail.com

Abstract. Construction has now become an industry with the highest risk of work accidents. The risk of workplace accidents in construction can be caused by several factors, such as the work method, workplace, environment, human factors and poor safety management system. One of the examples of safety management system that can reduce the level of work accidents in construction is safety plan. The purpose of this research is to identify the potential hazards of the work components in construction of channel irrigation WBS (work breakdown structure) that have been standardized, and to develop a safety plan based on the risks identified in the construction of channel irrigation WBS in order to improve occupational health and safety performance for channel irrigation construction. The research methods used were archive analysis with questionnaire and case studies. The results of this study reported potentially hazardous risk sources on channel irrigation construction projects, therefore preventive actions and corrective actions are to be made later for the development of a safety plan as a form of preventing the risk of workplace accidents to improve OHS performance for construction of channel irrigation.

1. Introduction

Irrigation channels are infrastructure that distributes water originating from a dam to agricultural properties owned by people. With the existence of this irrigation channel, the need of water for the farmers' fields will be guaranteed. Irrigation channels and drainage channels in an irrigation network usually consist of primary canals, secondary channels, tertiary canals and quarter channels [9].

With the increasing construction of irrigation channels that constantly being pushed forward, it is highly likely that an irrigation channels project must be constructed with a difficult design in a difficult place as well. In addition, natural factors and the needed tools can also be a risk factor for workplace accidents in irrigation channels projects. The phenomenon of the work accidents causes can also be seen from managerial factors, including the absence of work safety policies at the company level and at the project level [13][14]. The weak management of occupational safety will be the main cause of workplace accidents in irrigation channels projects. Therefore, an action is needed to minimize the risk of workplace accidents, namely the need for the government to develop work safety regulations and procedures and to be strictly enforced [3]. Safety plan is a very important element of project management. This is because the Safety plan covers all health and safety conditions in the workplace. The safety plan does not only reduce opportunities for project delays and risk of workplace...
accidents, but also increases the potential for success and confidence of team members [8]. Safety plan must be implemented in the planning process of the project as early as possible and then carried out during the construction stage of the irrigation channel. In the proposal stage of the safety plan, it is necessary to define detailed work activities therefore each work risk can be known, for which standardized Work Breakdown Structure (WBS) functions are needed in the safety plan. Standardized WBS can prevent the risk of workplace accidents because each activity contained in the WBS is identified and analyzed against potential hazards. Development of safety plan based on standardized WBS is one of the construction work accident prevention measures. Together with the implementation of a developed and based safety plan, it is expected that effectiveness can be achieved, therefore OHS performance of the project can be improved.

2. Research Objectives
The objectives of this study are:
1. To identify the sources of high potentially hazardous risks in the work components of the Irrigation Channel Project WBS that affect OHS performance.
2. To develop safety plan based on identified risks in Irrigation Channels WBS to improve OHS/Safety Performance in Irrigation Channel construction projects.

3. Literature Review

3.1. Channel Irrigation Work Breakdown Structure (WBS)
According to the 6th edition of PMBOK, WBS is a hierarchical decomposition of the entire scope of work that the project team must apply to achieve project objectives and create the necessary work results. Each level of the WBS shows an increasingly detailed definition of project work Decomposition is a technique used to divide in more detail as the WBS is the basis for project planning and control [8].

Irrigation channel WBS that has been standardized consists of 4 levels, namely, Project Name; Irrigation Channel Project at WBS level 1. While at WBS level 2 there are 7 Work Section namely; Preparatory Work, Soil Works, Layering Work, Drafting Works, Water Discharge Control, and other complementary works. Subsequently, WBS level 3 has Sub Work Section, which is a component of the work section that is defined in more detail. Finally, WBS Level 4 includes the work package for each component of the type of work on the irrigation channel project. Whereas between level 4 and 5 there are alternative methods, then WBS level 5, which consists of activities from work packages, and WBS level 6 includes resources (tools, materials, workers).

3.2. Occupational Health and Safety
Occupational Health and Safety (OHS) is a program system created for workers and employers as an effort to prevent (preventive) the emergence of workplace accidents and diseases due to work relations in the work environment by identifying factors that have the potential to cause workplace accidents and diseases due to work and anticipatory actions related to work, and anticipatory actions if such matters occur [10]. Subsequently, workplace accidents are unexpected and unwanted events that disrupt the process of an organized activity [12]. Workplace accidents can be caused by two categories of causes: unsafe human acts and unsafe condition [2].

3.2.1. Safety Performance. The strength and success of any construction company lies in the effective management of safety, productivity, quality, health and the environment, in addition to marketing and finance [15], therefore safety performance in a project is a measurement of the success of a project, similar to time, quality and cost [4]. Safety performance is an indicator of how organizations or companies have an awareness of high-risk issues or susceptible to work errors, which can lead to reduction of accidents. Safety performance has six attributes, namely the level of work safety awareness of all stakeholders, measurable safety costs, safety documentation or accident records
as a measure of performance evaluation, safety and productivity in improving project performance, self-discipline management and Reactive Measure Performance [5].

3.3. Safety Plan Concept

3.3.1. Definition of Safety Plan. Safety Plan is a practical safety plan that can help companies avoid potential hazards and can control them in the best way such these hazardous conditions occur [6]. Safety Plan is known as RK3K. RK3K according to Permen PU Number 5/2014 is a complete document of the plan for the implementation of the Public Works Construction OHS system management (SMK3) and is a unit with the contract document of a construction work, which is made by the Service Provider and approved by the Service User. The benefits of the Safety Plan are to be a form of prevention, reduce or even prevent accidents construction projects, increase morale and productivity, reduce occupational illnesses and accidents, reduce workers 'compensation costs and gain workers' commitment to achieve OHS goals [7].

3.3.2. Safety Plan Format. The safety plan used in this study refers to the format from Minister of Public Works 05 / PRT / M / 2014, where in the existing format each risk event is identified based on job description, but not based on WBS. In the RK3K format, the implementation of construction works follows Minister of Public Works 05 / PRT / M / 2014, in which there are several factors that have to be included in the RK3K, as follows: (A) OHS Policy, (B) OHS Organization, (C) OHS Planning; C.1.Hazard Identification, Risk Assessment, Priority Scale, OHS Risk Control, PIC., C.2.Compliance with laws and regulations and other requirements, C.3. OHS Objectives and Programs, (D) OHS Operational Control, (E) Examination and Evaluation of OHS Performance, (F) OHS Performance Review

4. Methodology
The stages to achieve the research objectives in this study are described in a research phase flow diagram as seen on the Figure below:

5. Result and Discussion

5.1. To Answer RQ 1
To answer Research Question 1, risks were identified where risks can be caused by Alternative Method / Design, Work Packages, Activities, Resources (material, labor, and equipment) and environmental factors. Subsequently, a study with the literature study stage was conducted to then obtain potential risks which were then validated by experts. Then, as many as 286 risk factors that influence the OHS Performance of Irrigation Channel Construction Works were determined, where there are 23 dominant factors in each stage of the project activity. Out of the 23 dominant risk factors in Irrigation Channel Construction Work, there are several risk variables repeated in several work
activities, therefore 11 risk factors are dominant in Irrigation Channel Construction Works if viewed only from the risk.

This study determined the risk priority using scaling based on the probability and impact matrix of PMBOK 5th Edition, thus the values and ranks and level of risk can be known. The risk level analysis was then carried out to discover the known rank and level of risk. Analysis of risk and ranking levels were analyzed using the AHP (Analytic Hierarchy Process) method, thus the rank and level of the risk factors were identified. The dominant or highest risk was based on the category H (high) with the highest value, category M (moderate) risk with moderate value, and category L (low) for risk with the lowest value. Risk value was obtained by means of FR = F x I, where F is the frequency and I is the Impact. [1]. The frequency of risk taken was assessed using the New Zealand Standard Risk Management in 2004 where there are 5 rating scales [11], as listed on the Table below:

### Table 1. Frequency Scale Indicator (F)

| Scale | Criteria | Indicators | Frequency of Accident Occurrence |
|-------|----------|------------|----------------------------------|
| 1     | Very low | Very unlikely to occur | Accidents occur once in 5 years |
| 2     | Low      | Likely to occur | Accidents occur within a span of 2-5 years |
| 3     | Moderate | Pretty likely to occur | Accidents occur within a span of 1-2 years |
| 4     | High     | May Occur | Accidents occur within a span of 2-10 months |
| 5     | Very High| Very possible to occur | Accidents occur once a month |

### Table 2. Impact Scale Limit (D)

| Scale | Severity/ Loss/Impact Indicator |
|-------|---------------------------------|
| 1     | The impact that is caused is very small for humans, Where the worker does not experience injuries. Workers experience minor injuries but can be treated with first aid treatment / clinic but can continue work. |
| 2     | Workers experience minor to severe injuries and require more complete medical treatment (hospital or health center) and cause a maximum working day of 2x24 hours to disappear |
| 3     | Worker suffered serious injuries and needed medical treatment at the hospital and caused the workday to disappear at least 2x24 hours. |
| 4     | The impact is very big that workers experience permanent or partial disability (functions / organs) or even die |

The following is the weighting of impact and frequency for risk factor variables based on PMBOK 5th Edition:

### Table 3. Weighting Frequency and Impact and Matrix Reading Result

| Value | Criteria | Weight F | Criteria | Weight D | Probability and Risk Impact Matrix Reading Result |
|-------|----------|----------|----------|----------|--------------------------------------------------|
| 1     | Very Low | 0.1      | No effect | 0.05     | 0.001 - 0.005 Low Risk |
| 2     | Low      | 0.3      | Less influential | 0.1 | 0.06 - 0.17 Moderate Risk |
| 3     | Moderate | 0.5      | Pretty influential | 0.2 | 0.18 - 0.72 High Risk |
| 4     | High     | 0.7      | Influential | 0.4 | |
| 5     | Very High| 0.9      | Very Influential | 0.08 | |
After the calculation was performed, the highest risk was obtained as follows:

| Work Package                          | Activity                                                                 | Risk                                                                 | Risk Score | Rank |
|---------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------|------------|------|
| Mobilization and Demobilization       | Equipment Mobilization and Demobilization                                 | Workers are exposed to heavy equipment when lifting / dropping equipment | 0.213      | 4    |
|                                       | Personel Mobilization and Demobilization                                 | Collides between vehicle                                              | 0.18       | 23   |
| Drainage of Water                     | Pump operation                                                           | Electrocuted/electrical shock by electric current from pump operation | 0.213      | 5    |
| Material transport and/or excavation results for horizontal and, vertical distance | Loading material / excavation results using heavy equipment              | Got hit by dump truck maneuvers                                        | 0.196      | 10   |
|                                       |                                                                          | Got hit by swing excavator                                             | 0.191      | 15   |
|                                       |                                                                          | Got hit by dump truck maneuvers                                        | 0.189      | 17   |
|                                       |                                                                          | Got hit by Bulldozer                                                   | 0.194      | 13   |
|                                       |                                                                          | Collides between vehicle                                               | 0.194      | 12   |
|                                       |                                                                          | Slipped vehicle (excavated soils fell)                                 | 0.199      | 8    |
|                                       |                                                                          | Heavy equipment crashing into workers / facilities (dump truck and bulldozer) | 0.2         | 7    |
| Disposal mobilization of material / excavation results of vertical horizontal distance |                                                                 | Heavy equipment brake fail to function (crashing into workers / facilities) | 0.193      | 14   |
| Brick and Stone laying with PC-PP Mortar types M, S, N, O | Brick laying | Falls from height                                                      | 0.214      | 3    |
| Flow metering device Types Peilskaal | Flow metering device installation                                       | Electrocuted/electrical shock by electric current                      | 0.249      | 1    |
|                                       | Peilskaal Installation                                                   | Electrocuted/electrical shock by electric current                      | 0.215      | 2    |
| Concrete work in Columns, Beams and Plates | Reinforced concrete column ( Casting in situ)                           | Slipped when climbing the column                                       | 0.197      | 9    |
|                                       | Conventional Mixed Concrete                                             | Falls from height                                                      | 0.189      | 18   |
|                                       | Ready mix Concrete                                                      | The concrete pump pipe were clogged, then broken and exposed to workers Concrete bucket overload and fell down from TC due to a broken sling that spilled to workers under the plant | 0.188      | 19   |
| Water Gate Works and Installation of Iron Frame | Canal Lining (Plastering) Concrete plastering                            | Landslide                                                            | 0.19       | 16   |
|                                       | Wood plastering installation                                             | Buried by landslides                                                   | 0.187      | 21   |
|                                       | Installation of Iron Frame                                               | Electrocuted/electrical shock                                          | 0.195      | 11   |
5.2. To Answer RQ 2

5.2.1. Causes and Effects of Risk and Risk Response. To answer the Research Question 2, the potential risks were identified in Irrigation Channel WBS work activity. After the potential sources of risk are known to have an effect on OHS performance based on literature studies that have been validated by experts, the causes, impacts, risk values, and preventive and corrective actions were found which was then made to a safety plan. The following is a list of causes, impacts, as well as preventive and corrective actions for each risk.

Table 5. Causes of Risk Affecting OHS Performance Indicators (Work Accidents)

| Code | Causes |
|------|--------|
| P1   | Human errors such as worker negligence, fatigue, and unhealthy conditions of workers |
| P2   | Workers do not use personal protective equipment (PPE) properly or do not use PPE at all |
| P3   | Did not attend Safety Morning Talk (SMT) or Safety Briefing before carrying out activities |
| P4   | Lack of OSH signs such as Safety First (SF) |
| P5   | Do not do House Keeping or 5R (Compact, Neat, Clean, Care, Diligent) |
| P6   | There is no Work Instruction, safety plan, and police line |
| P7   | There are no work methods or work methods are not on target |
| P8   | Did not implement Safety Patrol before the activity is carried out |
| P9   | Heavy equipment operators are incompetent |
| P10  | Heavy equipment were not in the right position |
| P11  | Excessive material stock so that it becomes unstable and can cause material to collapse |
| P12  | The condition of the heavy equipment that is not good and does not meet the standards |
| P13  | The work area is not protected by OSH signs |
| P14  | Unstable material placement |
| P15  | Unstable platform / work area structure |
| P16  | Absence of tool inspection work instructions before operation |
| P17  | Workers do not check the work area first |
| P18  | Workers are not equipped with work safety equipment |
| P19  | Lack of quality control of materials and heavy equipment |
| P20  | Untidy work area; materials and tools are not in the right place (scattered materials and tools) |
| P21  | Workers are too close to heavy equipment when lifting / dropping equipment/materials |

Table 6. Effects of Risk Affecting OHS Performance Indicators (Work Accidents)

| Code | Effect |
|------|--------|
| D1   | An accident occurred which resulted in workers being injured or died |
| D2   | Construction Failure |
| D3   | Project activities become unproductive therefore work becomes late or delayed |
| D4   | Damage to project facilities |
| D5   | Dealing with security forces (police) |

After the causes and the impacts were known, an analysis was carried out regarding the impacts and causes to find the root of the problem and the causes of the dominant risk which is illustrated by the following matrix:
Table 7. Matrix of Causes and Impacts of Highest Risk

| Causes | Impacts |
|--------|---------|
| P1     | D1      |
| P2     | D2      |
| P3     | D3      |
| P4     | D4      |
| P5     | D5      |

Based on the causes and the impacts analysis, it was concluded that there were preventive and corrective actions that can be taken. Preventive action is a proactive evaluation process to prevent potential risks that will become a problem in the future. Corrective action is a precaution taken to prevent recurrence.

Table 8. Preventive Action

| Code | Preventive Action |
|------|-------------------|
| TP1  | Complete worker PPE and work protective equipment |
| TP2  | Complete OHS signs in the project environment and place the sign in a strategic location |
| TP3  | Conduct OHS socialization such as routine and scheduled safety briefings before work begins |
| TP4  | Hold a OHS inspection to identify potential hazards |
| TP5  | Check the implementation of K3 that has been set on the project |
| TP6  | Conduct machine conditions inspection periodically before carrying out operations |
| TP7  | Hold Safety Morning Talk (SMT) before the activity begins |
| TP8  | Use appropriate heavy equipment operator and certified and competent personnel |
| TP9  | Check the work area of heavy equipment and compaction of the soil in the work area and place the steel plate before the heavy equipment enters the work area |
| TP10 | Protect material stocks and work areas using OHS signs |
| TP11 | Retaining wall installation for landslide prevention system |
| TP12 | Manage good project transportation management such as the availability of directions, signs and road dividers |
| TP13 | Car out good tool storage management |
| TP14 | Ensure that the work area is safe |
| TP15 | Check the condition of the cable so that it is not exposed to water / iron to prevent short circuit |
| TP16 | Carry out quality control and assurance of heavy equipment and materials used to meet specifications |
| TP17 | Employ workers who are experts and certified |
| TP18 | Ensure the physical condition of the worker is good |
| TP19 | Create a safety plan as a reference for the implementation of OHS standards and procedures during the project |
| TP20 | Keep a safe distance from the material being lowered from the truck |
| TP21 | Periodically measure environmental noise to ensure that environmental noise levels do not exceed the prescribed quality standards |
Preventive Action

TP24 Use personal protective equipment such as welding guards, welding gloves, chest apron and checking the feasibility of a welding machine before use
TP25 Conduct supervision planning on every work activity

Table 9. Corrective Action

| Code | Corrective Action |
|------|-------------------|
| TK1  | Supervise every work activity |
| TK2  | Replace workers who are not certified and incompetent |
| TK3  | Replace tools and materials in accordance with the specifications required |
| TK4  | Carry out project work activities according to the safety plan that has been made |
| TK5  | Identify workplace accidents that occur so that risks can be identified |
| TK6  | Manage first accident response if there is a work accident |
| TK7  | Evaluate actions taken in handling workplace accidents |
| TK8  | Conduct periodic audit of the OHS management system and carry out internal or external quality audit |
| TK9  | Review system failures used in the project |
| TK10 | Carry out OHS management system evaluation such as checking safety plan |
| TK11 | Conduct training in handling safety and work accidents in the event of an accident in the project |
| TK12 | Review material that has been used if there is a failure by conducting a material test |
| TK13 | Quarantine the area of work accidents for further investigation |
| TK14 | Report work accident events which will then be a project evaluation |
| TK15 | Save and handle victims and recovery activities |

5.2.2. Development of the Safety Plan. To develop a safety plan, the Safety plan used in this study refers to the format of Minister of Public Works 05 / PRT / M / 2014, where in the existing format each risk event is identified based on job descriptions, but not based on WBS.
Figure 3. Table C.1 Hazard Identification, Risk Assessment, Priority Scale, Safety Risk Control, Responsible Person format from government regulations PU 05 / PRT / M / 2014.

Table: HAZARDS IDENTIFICATION, RISK ASSESSMENT, PRIORITY SCALE, SAFETY RISK CONTROL AND RESPONSIBILITY

| No | JOB DESCRIPTION | HAZARD IDENTIFICATION | RISK ASSESSMENT | PRIORITY SCALE | SAFETY RISK CONTROL | PERSON IN CHARGE |
|----|-----------------|------------------------|-----------------|----------------|---------------------|-----------------|
|    |                 |                        | Frequency | Severity | Risk Level |
|    |                 |                        |           |          |           |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |

Figure 4. The results of the development table C.1 Hazard Identification, Risk Assessment, Priority Scale, Safety Risk Control, Responsible for the Highest Risk of Irrigation Channel.

Table: HAZARDS IDENTIFICATION, RISK ASSESSMENT, PRIORITY SCALE, SAFETY RISK CONTROL AND RESPONSIBILITY

| No | WBS LEVEL 4 | WBS LEVEL 5 | HAZARD IDENTIFICATION | RISK ASSESSMENT | PRIORITY SCALE | SAFETY RISK CONTROL | PERSON IN CHARGE |
|----|-------------|-------------|------------------------|-----------------|----------------|---------------------|-----------------|
|    | Work Package | Activity | Frequency | Severity | Risk Level |
|    |             |           |           |          |           |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |

According to the format of Minister of Public Works 05 / PRT / M / 2014, discussions were held for the development of a WBS-based safety plan. Where on the WBS-based safety plan, risk events will be described according to levels 4 and 5 of the WBS, namely activities and resources. This will streamline the process for contractors and other stakeholders to determine risk and evaluate the project due to the detailed explanation. In this research, risk identification based on WBS was carried out at the level of activity and resources. The table above is an example of a safety plan document at the Bina Marga Construction Works Department of Public Works which refers to the Minister of Public Works Regulation Number 05 / PRT / M 2014 dated 22 April 2014.
6. Conclusion
Based on the results of potential hazard sources identification in the irrigation channel construction work, it was found that there were 23 dominant risk variables that could affect the OHS performance. Subsequently, WBS-based safety plan development can be done from the highest risk using RK3K 05 / PRT / M/2014 document which aims to ensure that each work item can be identified properly and nothing is missed, therefore that the goal of safety targets is satisfactory. Thus, with the development of a WBS-based safety plan on irrigation channel work, it can streamline the process for contractors and other stakeholders to determine risk and evaluate the project due to the detailed explanation.

References
[1] Duffield C and Trigunarsyah B 1999 Project Management Conception to Completion (Australia: Engineering Education Australia)
[2] Endroyo B 1989 Keselamatan Kerja Untuk Teknik Bangunan (Semarang: IKIP Semarang Press)
[3] Gavious A, Mizrahi S, Shani Y and Minchuk Y 2009 The Costs of Industrial Accidents for The Organization: Developing Methods and Tools for Evaluation And Cost-Benefit Analysis of Investment In Safety J. Loss Prevent Proc. 22 434-438
[4] Hasan A. and Jha K. 2013 Safety incentive and penalty provisions in Indian construction projects and their impact on safety performance Int. J. Inj. Control Sa. 20(1) 3-12
[5] Machfudiyanto R A, Latief, Y , Suraji A and Soeharso S Y 2018 Improvement of Policies and Institutional in Developing Safety Culture in The Construction Industry to Improve The Maturity Level, Safety Performance, and Project Performance in Indonesia Int. J. Civ. Eng. Tech (IJCIET) 9 1022-1032.
[6] Midiatama 2015 Pembuatan Dokumen Safety Plan (Midiatama Academy: Midiatama.co.id)
[7] Pemerintah Republik Indonesia 2014 Peraturan Pemerintah PU No. 05/PRT/M/2014
[8] Project Management Institute 2017 A Guide to The Project Management of Body of Knowledge 6th Edition (Newton Square: Project Management Institute, Inc.)
[9] Sidharta S 1997 Irigasi dan Bangunan Air (Jakarta: Gunadarma)
[10] Silalahi B 1995 Manajemen Keselamatan dan Kesehatan Kerja (Jakarta: Bina Rupa Aksara)
[11] Standards Australia International Limited & Standards New Zealand 2004. Risk management : AS/NZS 4360:2004 3rd Edition. (Wellington: Standards Australia International and Standards New Zealand)
[12] Sulaksmono M 1997 Manajemen Keselamatan Kerja (Surabaya : Penerbit Pustaka)
[13] Suraji A, Roy D A, and J Peckitt S 2001 Development of Causal Model of Construction Accident Causation. J. Constr. Eng. Manage-Asce. 127(4) 127
[14] Tam C, Zeng S and Deng Z 2004 Identifying Elements of Poor Construction Safety Management in China Safety Science. 42(7) 569-586
[15] Venkataraman N 2008 Safety Performance Factor Int. J. Occup. Saf. Ergo. 14(3) 327-331

Acknowledgments
The Authors would like to thank the financial support provided by Universitas Indonesia through PITTA B funding scheme under Grant number NKB - 0803/UN2.R3.1/HKP.05.00/2019 managed by the Directorate for Research and Public Services (DRPM) Universitas Indonesia.