Development of work breakdown structure standard for safety planning on stadium construction work based on risk

Amelia Anggraini, Yusuf Latief
Faculty of Engineering, Universitas Indonesia, 16424 Depok, Indonesia
E-mail: amelia.anggraini1997@gmail.com

Abstract. Purpose: The purpose of this study is to reduce the level of work accidents in stadium construction by developing risk-based work breakdown structures. Methodology: The research methodology includes several stages, namely the literature study, analysis of data archives and previously related project and research, as well as through the validation of experts. Result: The results of this study are WBS standards, implementation methods, activities, resources, potential hazard risks and safety planning using risk-based WBS standards on stadium construction work, as a method in preventing, reducing, eliminating or even nullifying the chance of accident throughout the development of a construction work. Applications/Originality/Value: This research will hopefully provide benefits to the construction world by presenting work accidents prevention methods by incorporating risk elements into each level of project work in the Work Breakdown Structure which will be used as input in the making of a safety plan.

1. Introduction
Sports stadiums are thought to have been known since the times of Ancient Balkan state and Rome. The conception of sports stadium development has been growing rapidly within the past few decades. This can be caused by the increasing demand for various sports-related activities and entertainment-related events within the sports stadium. Now, stadiums are seen as not only an icon of a city, but also a benchmark of how much a community and its infrastructure have developed. According to UEFA, the design of a football stadium have to obey several requirements such as: to become a people-friendly building that serves safety and comfort; provide for the wider community, including football and non-football events; and provide the most current technologies as facilities available for the public, resulting in a better experience [1].

Stadium construction is one of many developments in Indonesia’s construction industry. The construction industry is one that contributes a fairly large amount of workplace accidents. Workplace safety is a vital part of efficiency and productivity [2]. Employees and field staff are project assets that must be protected so it can work well without creating incidents. Work safety measures are desperately required, for the staff and corporations and their production. The staff have to follow protective laws, during this case, the OSH program, since the OSH program is closely associated with employee safety. A comprehensive OSH program and cognizance of project staffs are important reducing the occurrence of accidents [3].

In Indonesia alone, the level of work accidents is quite high where for every 100,000 workers 20 workers are victims of fatal consequences. It is known that in 2015, according to Acting
Director-General of Manpower Development and Supervision of the Ministry of Manpower Maruli Apul Hasoloan, there were 110,285 occupational accidents. This number decreases in 2016 to 101,367 cases or 8% with 2,375 fatalities with claims up to 792 billion rupiahs [4]. This is also strengthened by data belonging to the Employment Social Security Agency (BPJS) of Employment which states that in 2017 the number of work accidents was reported to reach 123,041 cases with 2,282 fatalities with claims of 971 billion rupiahs and throughout 2018 there were claims of Work Accident Insurance claims (JKK), which is 173,105 cases or equivalent to the claim value of Rp. 1.2 trillion [5,6].

Many factors can be the cause of workplace accidents, where there are factors that are separate elements and some of them are factors that cause elements together. Work accidents are one of the big problems in a company and cause the most losses. According to statistics, 85% of the causes of accidents come from dangerous actions (unsafe acts) and 15% of them come from dangerous conditions (unsafe conditions) [7].

Work accidents that occur on a project may be reduced if the activities of the project are outlined properly where each job is placed at a level that concurs the WBS standards. The WBS that has been created is used throughout the project part with the known basic coverage. One common approach utilized by the project team to form WBS is that the use of previous WBS comes with many changes. However, though every project is unique, it will largely be standardized to permit the supply of a stronger estimate base for project management [8]. WBS encompasses a major role during a project, therefore the creation of WBS is an obligation in project management both within the planning and implementation phases. however, in practice in Indonesia, there are still several projects that do not use WBS or seldom create WBS in a formal form [9].

Every level in the WBS brings an additional level of complexity. All activities, when sorted according to the standard WBS, allows easier identification and mitigation of potential risks, thus making it necessary to develop a standard Work Breakdown Structure [10]. In each activity that has been classified within the WBS standard, it’s easier to spot potential risks and therefore the contractor will produce a risk mitigation form from existing risk sources. This creates the necessity to develop Work Breakdown Structural standards for risk-based safety plans in order to produce results usable as a guide for construction. The objectives of this study are as follows: Developing the work breakdown structure of the stadium building. Identifying sources of risk that may pose a potential hazard to stadium construction work. Developing a safety plan using risk-based standardized Work Breakdown Structure.

2. Literature Review
This section will discuss about the literature review which is used as a basis for the theory used in this research.

2.1. Work breakdown structure
Work Breakdown Structure (WBS) is defined as a hierarchal decomposition of work that has to be conducted by the project team to realize project targets and produce the specified deliverables [11]. The deliverable in question is a unique product, result, or capability to show the services that have to be created to finish the method, phase, or project. This is typically used narrowly concerning external deliverables, that are subject to approval by the project sponsor or client. [12] also defines deliverables as any measurable, tangible, verifiable results or items that must be produced to complete a project or project part. WBS may also be defined as a system to divide a project into manageable work packages or components. The WBS creates a general framework for identifying the scope, costs, allocation of responsibilities, communication, risk assessment, direction and management of the project [13].
When done, the Work Breakdown Structure is put to Modification Control and controlled for the anticipated and imminent modifications that will affect the scope of work in compliance with the Change Management framework developed for the task [14].

The approach followed by the project team in terms of developing WBS ranged from reusing previous WBS with many changes to progressive breakdown of the work required for the project, to the event of deliverables supported WBS with a spotlight on the fundamental practicality of the ultimate product.

**Figure 1:** The Research Flow Diagram
2.2. Risk management

Risk is an uncertainty of events or conditions which if they occur will have a positive or negative impact on the project. Risks stem from uncertainties that arise in the project. Risks that have been identified and analyzed will then be used to plan risk responses [15]. Project risk management is defined as a systematic method of distinguishing, analyzing, responding to and controlling project risks. The management of risks is conducted to extend the likelihood of positive risk impacts and to cut back the likelihood of negative risk impacts in order to optimize project success [13].

Figure 2: Matrix of Causes and Effects of Dominant Risks

Risk in projects is usually taken as a negative term. However, within the construction industry, managing risks that arise requires for it to be enforced in a structured way, utilizing risk management knowledge to minimize the occurrence of risks [16]. In risk management, risk assessment influences to determine the possible consequences of exposure to potential hazards, because, with the risk assessment, workplace accidents are very likely to be prevented or even eliminated. Therefore, to be able to identify risks, WBS categorization needs to be started from the work package, methods / design, activities, material resources, equipment, and labor and the environment as a category of risk events that can affect safety performance objectives.

An organization is allowed to apply risk control methods in whatever form as long as these methods can identify, evaluate and have risk priorities and can control risks using a long-term
or short-term approach. One way that can be used is to use Work Breakdown Structure (WBS) as stipulated in Minister For Public Works and Human Settlements Regulation No. 28 of 2016 Part 4: Job Unit Price Analysis (AHSP) Cipta Karya [17].

2.3. The concept of occupational safety and health performance
According to [18] the Regulation of the Minister of Manpower of the Republic of Indonesia Number 44 of 2015 concerning Procedures for Accident Reporting and Inspection that what is meant by work accidents are accidents that occur in work relationships including accidents that occur on the way from home to work or vice versa and diseases caused by the environment work. In line with the regulation [19] also argued that a work accident is an event that is undesirable and often unexpected or unpredictable which can cause losses in terms of time, property or casualties that occur in an industrial process or related to it.

Accidents occurring in construction sites may result in heavy injuries. Examples of this are workers falling from heights or suffering from electrocution. The reason behind work accidents are staff negligence and undisciplined attitudes within the project site. Accident prevention have to be put into practice so that the staff and management officers can have an increased awareness in preventing and developing workplace hazard management for construction [5]. Further investigation of the hazards that usually occur can lead to the creation of safety plans for a construction project.

Safety plan is a set up of documents that contains safety directions that facilitate firms to avoid potential hazards and prove the best approach to mitigate dangerous conditions. The coaching of this document is vital throughout the project designing, design and implementation stages in order to minimize the risks of accidents and might improve worker safety.

Occupational safety and health, or commonly referred to as OSH, are all activities to guarantee and protect the safety and health of workers through the prevention of work-related injuries and occupational diseases [10]. In the Minister For Public Works and Human Settlements projects, the safety plan is known as the RK3K (Contract Safety Plan). RK3K is a complete plan for the construction of an Occupational Health and Safety Management System (SMK3) for Public Works and is an integral part of the construction work contract document made by the owner and approved by the contractor, to further serve as a means of interaction between the owner and contractor in the implementation of public works construction SMK3 [10].

3. Methodology
This study uses a qualitative approach to obtain the standardized WBS for the stadium building construction. A survey and in-depth interview were conducted through a structured questionnaire given to professionals in the contractor industry who have had a minimum of ten years’ expertise in stadium construction. Explanations associated with the flow of this analysis may be more clearly seen in Figure 1.

3.1. Research variable
The variables for this research are derived from the results of analyzing WBS work package archives obtained from five similar stadium construction project data. There are nine clusters of work, forty-one types of work, and two hundred thirty-nine work packages. Based on the validation of several OSH experts, ninety-seven variables have been found to affect the performance of OSH. The variables found are further defined in Table 1.

| WBS Level Category | Risk Variables That Influence Project Performance |
|--------------------|--------------------------------------------------|
| WBS Lv. 4 Work Package | X1 Changes in design and scope of work |
X2 Subcontractor productivity is not achieved
X3 Acceleration (crashing does not pay attention to safety procedures)
X4 Job package changes (new job)
X5 Insufficient geological and geotechnical information and data
X6 The planned method is not based on field conditions
X7 Safety plan is not following the planned method
X8 Errors in planning implementation methods
X9 Error calculating work volume
X10 No scheduling of work
X11 Installation is not according to specifications or drawing plan
X12 Construction method error
X13 Error in workmanship
X14 Sequence of risk-based unplanned work
X15 Some activities are not planned during project planning
X16 Installation is not according to specifications or drawing plan
X17 Error in workmanship
X18 Error in planning for defining project activities in full
X19 Fall from height
X20 Hit, because of falling / moving objects etc.
X21 Hit, contact with sharp objects / hard objects
X22 Aspiration/absorption of harmful substances into the body, through respiration/skin
X23 Slip
X24 Electric current is affected
X25 Movement exceeds ability (sprained)
X26 Eyes sprinkled
X27 Caught in and between objects (pinched, buried, sinking, etc.)
X28 Exposed (temperature, barometric pressure, vibration, radiation, sound, light, etc.)
X29 Fire
X30 Skin diseases resulting from exposure to hazardous materials
X31 Accident during heavy equipment mobilization
X32 Burns to the skin
X33 Ready mix from concrete pump spills / splashes on workers
X34 Leftover material that cannot be controlled (many)
X35 Material testing did not comply with the planned procedure
X36 Material theft occurred at the project site
X37 The material specifications used are not appropriate
X38 Lack of control of project waste / material waste
X39 Lack of control over the use of hazardous materials
X40 Scarcity of materials according to specifications
X41 Late material delivery
X42 Changes in the condition of material resources to the project location
X43 Waste of material usage in the field
X44 Material quality does not meet specifications
X45 Error calculation of material requirements
X46 Does not take into account material availability at the time of project implementation
X47 No material scheduling
X48 Material loss (theft)
X49 The volume of material sent is not suitable
X50 There is no quality control for tool use
X51 Low tool capacity
X52 Does not do equipment scheduling
X53 Error in estimation of tool productivity
X54 Equipment that is not suitable for working conditions
X55 Low quality equipment
X56 The equipment used does not match the planned implementation method
X57 Equipment specifications are not according to plan
X58 Error estimating tool productivity
X59 Errors in calculation of equipment requirements
X60 Does not take into account the availability of equipment at the time of project implementation
X61 Does not do tool scheduling
X62 The equipment does not match the working conditions
X63 Low quality equipment
X64 Overload Vertical Transport Equipment
X65 Formwork / skafolding fell and hit workers / facilities
X66 Formwork collapse
X67 Rammed into nearby workers / facilities
X68 Exposed to dump truck maneuvers
X69 Workers with a sling crane
X70 The drill tool collapsed and tilted
X71 There is no training for workers
X72 The educational background of workers is low
X73 The use of labor does not match expertise
X74 No scheduling of workforce
Data collection is done by using a form survey to grasp the perceptions of experts on risk factors. After the probabilities and its effects are determined, a risk score may be calculated using the subsequent formula as written in Eq. (1)

\[ R = P \times I \]  

(1)

Where \( R \): Risk factors, \( P \): Probability and \( I \): Impact. The probability and impact matrix, also called the risk level matrix, illustrates how risk ranking for risk factors is as in Table 2.

**Table 2:** Probability and Impact Matrix

| Probability   | Threats     |
|---------------|-------------|
|               |            | Always | Often | Sometimes | Rarely | Never |
|               |            | 0.90   | 0.70  | 0.50      | 0.30   | 0.10  |
|               |            | 0.05   | 0.04  | 0.03      | 0.02   | 0.01  |
|               |            | 0.09   | 0.07  | 0.05      | 0.03   | 0.01  |
|               |            | 0.18   | 0.14  | 0.10      | 0.06   | 0.02  |
|               |            | 0.36   | 0.28  | 0.20      | 0.12   | 0.04  |
|               |            | 0.72   | 0.56  | 0.40      | 0.24   | 0.08  |

| Impact       |            | 0.05   | 0.20  | 0.40      | 0.80   |

The next stage is mapping the causes and effects of the results of gathering expert opinions related to the dominant risks found. From the opinion of experts, it is found that there are
Figure 3: Mapping Analysis of Causes and Impacts on Risk X23
25 (twenty-five) causes of risk which will then be used to map risks and preventive measures, 9 (nine) risk impacts will be obtained which will then be used to map risks and corrective actions, 23 (twenty-three) preventive actions against risks which will then be used for mapping of risks and causes, and 15 (fifteen) corrective actions will be obtained which will then be used for mapping of risks and impacts. The next step is to analyze the causes and impacts that will be described in the form of a matrix to find the root causes and impacts of each of the highest risks to the safety performance of the stadium construction project as Figure 2 follows.

Based on the matrix in Figure 2, it can be seen that the same impact can be caused by several causes, and vice versa from one cause can cause several impacts. For example, on Impact 7 (D7) (a collapse out of control) can occur because it is caused by P3, P13 and P26. Furthermore, from the matrix of causes and impacts of this dominant risk, it can be mapped to the risk of preventive actions and corrective actions as in Figure 3.

From Figure 3, it can be explained that the risk of X23 (Exposed to electric current) is one of the highest risks. These risks have several causes, namely P1, P6, P7, P9, P10, P11, P14, P20, P21, P22, and P25 where P1 is anticipated with TP1 (Preventive Action 1), P6 with TP4, P7 with TP5, P9 with TP7, P10 with TP15, P11 with TP20, P14 with TP9, P20 with TP17, P21 with TP8 and TP18, P22 with TP8 and TP19, and P25 with TP21. The risks also have impacts D1, D3, D4, D5 and D8 where D1 is dealt with TK2 (Corrective Action 2) and TK4 (Corrective Action 4), D3 with TK5 and TK9, D4 with TK6, D5 with TK9 and D8 with TK12 and TK13.

4. Result and discussion
Based on the research conducted, the following are the results obtained. To answer RQ 1, a standard WBS has been made for stadium construction works such as in Figure 4 below. Figure 2 below shows one of the 9 (nine) job clusters of the stadium construction. Level one is the project name; level two shows the clusters of work consisting of preparatory work, structure, architecture, external work, interior, mechanical, electrical, arena and accessibility facilities; level three shows the work types; level four shows the work packages; level five shows activities and level six shows the resources, namely the materials, tools and labor.

Figure 4: WBS Standard for Stadium Construction
To answer RQ 2, there are sources of risk that are potentially dangerous and influence OSH performance in stadium construction. These potentially hazardous risks are acquired by conducting literature studies. The results are then verified, processed and later given to professionals. These professionals will then be asked whether or not they agree with the risk factors. The professionals are also asked to provide input relating to every of the risk factors associated with impact assessment and their causes. These potential risks are then grouped according to the level in the WBS starting from the work package, alternative methods / designs, activities and also resources. Here are the dominant risks found at Table 3.

Table 3: The High-Level Risks Found

| No. | Risk Variables That Influence Project Performance                                      | Level | Rank |
|-----|--------------------------------------------------------------------------------------|-------|------|
| 1   | X3 Acceleration (crashing does not pay attention to safety procedures)                 | High  | 14   |
| 2   | X6 The planned method is not based on field conditions                                | High  | 18   |
| 3   | X7 Safety plan is not following the planned method                                    | High  | 10   |
| 4   | X14 Sequence of risk-based unplanned work                                            | High  | 15   |
| 5   | X19 Fell from a height                                                                | High  | 12   |
| 6   | X20 Hit, because of objects that fall / move etc.                                     | High  | 16   |
| 7   | X21 Hit, tangent to sharp objects / hard objects                                      | High  | 19   |
| 8   | X22 Suction / absorption of harmful substances into the body, through breathing / skin| High  | 22   |
| 9   | X23 Slipping                                                                          | High  | 6    |
| 10  | X24 Exposed to electric current                                                       | High  | 11   |
| 11  | X26 Eyes sprinkled / sprayed                                                          | High  | 21   |
| 12  | X27 Caught on and between objects (pinched, buried, etc.)                            | High  | 9    |
| 13  | X31 Accidents during heavy equipment mobilization                                     | High  | 20   |
| 14  | X50 There is no quality control for tool use                                         | High  | 17   |
| 15  | X65 Scaffoldings fell and hit workers / facilities                                    | High  | 3    |
| 16  | X66 Formwork collapse                                                                 | High  | 1    |
| 17  | X67 Tools crashing workers / facilities around                                        | High  | 7    |
| 18  | X70 The drill tool collapsed and tilted                                              | High  | 4    |
| 19  | X85 Too much overtime                                                                  | High  | 2    |
| 20  | X88 There is no evaluation of the safety plan                                         | High  | 8    |
| 21  | X90 Weather conditions are not according to plan                                      | High  | 5    |
| 22  | X95 Landslide                                                                         | High  | 13   |

To answer RQ 3, after knowing what activities are carried out in the construction of the stadium, the next step is to make a list of potential risks and identify sources of potential risks that most influence the OSH. After obtaining this risk source, a Safety Plan is prepared using the WBS standard based on RK3K in the attachment to the Minister for Public Works and Human Settlements Regulation Number 05 / PRT / M / 2014. The results obtained in the form of safety planning recommendations are based on the format from the Minister for Public Works and Human Settlements 05 / PRT / M / 2014 with the addition of work packages as the second column, activities as the third column and risk control as the ninth column. The results are as follows in Figure 5.
5. Conclusion

Based on the results of the research and the analysis carried out, the conclusions are as follows: The standard for the WBS of stadium construction divided into seven levels, where Level one is Project Name, Level two is Cluster of Work, Level three is Type of Work, Level four is Work Package, in between level four and level five is (Alternative Methods / Design), Level five is Activity, and Level six is Resource. Standards of work for the WBS of stadium construction are set consistent to the level of classification based on the analysis of data / archives from the BOQ and RKS that have been validated by relevant professionals. The identification of potential sources of risk in stadium construction work have succeeded in identifying several potential risks in every stage of the stadium building construction process. Once the variables are obtained, the risk events also are equipped by risk responses for every variable in order avoid and mitigate potential hazards. The preliminaries for safety planning using risk-based of WBS standards is accomplished and developed based on the work safety planning for building construction work section of the safety planning document/RK3K Minister For Public Works and Human Settlements Regulation 05/PRT/M/2014. This will be used as an assessment of the material auction method or service providers. Moreover, this can also be used as guidance for contractors in preparing the implementation of project safety planning.

Acknowledgments

The authors would love to give thanks to the financial support provided by Universitas Indonesia through PIT 9 funding scheme under Grant number NKB - 0087/UN2.R3.1/HKP.05.00/2019 managed by the Directorate for Research and Public Service (DRPM) Universitas Indonesia.

References

[1] Agency, M. S. S. O. (2016). The number of work accidents in Indonesia is still high. Jakarta: Manpower Social Security Organizing Agency Retrieved from https://www.bpjsketenagakerjaan.go.id/berita/5769/Jumlah-kecelakaan-kerja-di-Indonesia-emasih-tinggi.html

[2] Al, H., Abdan, K., Al-Nuaimi, A., Normariah, A., & Yahya, A. (2014). Safety and health risk assessment at Oman building construction projects. Int. J. Res. Eng. Technol., 3, 571-578.
[3] Blyth, K. (2004). Developing a framework for a standardized works programme for building projects. Construction Innovation, 4(4), 193-210. doi:10.1108/14714170410815097

[4] Brotherton, S. A., Fried, R. T., & Norman, E. S. (2008). Applying the work breakdown structure to the project management lifecycle. Paper presented at the PMI® Global Congress 2008, North America, Denver, CO. Newtown Square.

[5] Goh, K. C., Goh, H. H., Omar, M. F., Toh, T. C., & Mohd Zin, A. A. (2016). Accidents Preventive Practice for High-Rise Construction. MATEC Web of Conferences, 47. Retrieved from https://doi.org/10.1051/matecconf/20164704004

[6] Landage, A. (2016). Risk Management in Construction Industry. International Journal of Engineering Research, 5, 153-155. doi:10.17950/ijer/v5i1/035

[7] Lei, S. (2012, 2012/11). WBS-based Risk Identification for the Whole Process of Real Estate Project and Countermeasures. Paper presented at the 2012 National Conference on Information Technology and Computer Science.

[8] Mangkuto, R. A., Rachman, A. P., Aulia, A. G., Asri, A. D., & Rohmah, M. (2018). Assessment of pitch flooding light and glare condition in the Main Stadium of Gelora Bung Karno, Indonesia. Measurement, 117, 186-199. doi:https://doi.org/10.1016/j.measurement.2017.12.016

[9] Mohd Kamar, I., Lop, N. S., Mat Salleh, N., Manter, S., & Suhaimi, H. A. (2014). Contractor’s Awareness on Occupational Safety and Health (OSH) Management Systems in Construction Industry. ESi Web of Conferences, 3, 01019. doi:10.1051/esiconf/20140301019

[10] PMBOK. (2017). Project Management Body of Knowledge Sixth Edition (6th ed.). Pennsylvania: Project Management Institute.

[11] PMI. (2006). Practice Standard for Work Breakdown Structures Second Edition (2nd ed.). Pennsylvania: Project Management Institute.

[12] Ramli, S. (2010). Sistem Manajemen Keselamatan & Kesehatan Kerja OHSAS 18001. Jakarta: Dian Rakyat.

[13] Suanda, B. (2016). Advance & Effective Project Management. Jakarta: PT. PP Construction.

[14] Tarwaka. (2008). Manajemen dan Implementasi K3 di Tempat Kerja. Surakarta: Harapan Pers.

[15] Tonder, J. C. v., & Bekker, M. C. (2002). Analysis of a Methodology to Obtain a Work Breakdown Structure Built Up From Interdependent Key Project Deliverable Packages. Paper presented at the African Rhythm Project Management Conference, Johannesburg, South Africa.

[16] Widianto, S. (2019). Work Accident 2018 Reaches 173,105 Cases. Pikiran Rakyat. Retrieved from https://www.pikiran-rakyat.com/nasional/2019/01/15/kecelakaan-kerja-2018-mencapai-173105-kasus

[17] N. Van Vinh, P. Thi Kieu, T. Huu Bang. Evaluation of Response Modification Factor of Multiple Story Steel Buildings, IJETER, vol. 8, no.4, pp 1342 – 1348, April 2020.

[18] S.U. Irina, M. U. Karhan, H. T. Aminat, R. D. Aishat, K. U. Magomed, The Construction Technology of Preschool Institutions: Eco-Friendly and Fire-Resistant Materials, IJETER, vol. 8, no.4, pp 1227 – 1231, April 2020.

[19] A. T. Maria, Quality Estimation of Soil Body during Construction of Foundations with Curved Contact Surface using Harrington’s Desirability Function, IJETER, vol. 8, no.3, pp. 721 – 725, March 2020.