Prediction Model Safety Performance Model on The Dam Construction Project Based Bayesian Networks

M N Asrar and T J W Adi
Departement of Civil Engineering, Faculty of Civil, Planning, and Geo Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
Corresponding author: muhammadnabilasrar@gmail.com

Abstract. Low understanding of Safety Performance on Dam Construction Project due to ignoring risk factors in the implementation of the construction process. Work accidents that occur in construction projects can put workers at standstill and result in low Safety Performance. Therefore by improving Safety Performance in construction projects can increase the competitiveness of contractors in the Dam Construction Industry. Therefore, it is necessary to determine the identification of relevant variables to measure Performance Safety in construction projects based on the level of risk of work accidents so that, it can achieve modern Performance Safety Management in the Dam Construction Project. This research aims to measure Safety Performance using a probabilistic approach that is able to accommodate uncertainty in the Bayesian Networks based on Dam Construction Project. By creating a Safety Performance prediction model on the Dam Construction Project. We will be able to know the safety and health performance of the work on the Dam Construction Project.

1. Introduction
The construction industry has a certain and unique characteristic where it has limits, such as the time associated with project implementation, the effect of costs on project budgets, quality and specification levels, safety, and health especially for project workers as well as surrounding community [1]. The construction industry is still labor-intensive, in the work environment is considered still relying on human resources so that, it involves many parties during the process. [2]. Therefore the safety and security of workers are important factors that must be adhered to. In accordance with applicable safety regulations. Due to its dynamic nature and complex construction industry that it is inseparable from incidents of work accidents to The most important element to the success of construction companies located in safety management, productivity, quality, health and environment other that marketing and finance [3]. Occupational safety and health are important issues in the construction sector. Therefore, it can risks the productivity and financial losses arising from poor health and safety policies [4].

Low profit in strategic sector in construction due to poor occupational safety and health policy. [5].These factors led to low construction industry performance caused the lack of supervisory management at the implementation stage in inadequate construction projects. Therefore Safety Performance was an important factor to support the successful performance of construction projects. Low safety at construction projects has resulted in the impact on the quality of workers and delays in construction work [6]. Work accidents in construction projects can caused workers to quit and result in low performance, resulting in budgets being diverted for budget accident costs, decreased productivity can caused project losses [7]. In dact, the number of work accidents that occur on construction sites is quite alarming, because it does not apply safety rules while working [8].
Dams are generally used as a place to hold water during certain periods to meet water needs in the event of a dry season. The purpose of building dam construction projects can be caused for irrigation, hydro power, flood control, wildlife and sediment control. In addition to the benefits provided in the work of various dam construction projects have a very high level of risk during the construction project [9]. Work on dam construction projects has a very high complexity as well as risks during the project [10]. Therefore, the way to increase the project’s chances of success is to improve Safety Performance by proactively managed, in the context of partial data formulation in knowledge and understanding with a more effective approach can be done by Bayesian Network method [11]. Bayesian network can be a tool in decision making system related to work accidents prevention and safety control during work [12]. This paper aims to design a prediction model of Safety Performance in dam construction projects to measure performance K3 due to the uncertainty of risk to dam construction workers at the time of implementation and take the precautions quickly and accurately. So that is is useful to improve Safety Performance.

2. Literature Review
The theory underlying this research discuss the concept of Safety Performance in dam construction projects and previous research using the Bayesian Network model to measure occupational safety and health performance in the field.

2.1 Safety Performance
Safety Performance is an important factor for the safety management as well as the success of a project due to the high rate of work accident in construction project. Therefore, a quantitative safety performance prediction model is required using a probability approach to measure the performance of construction projects [13].

2.2 Dam Construction Project
Dam infrastructure development has a very important role because of the management of water resources and has very important benefits such as irrigation, hydro power plants, industrial water supply, flood control management, disaster mitigation due to drought, fish cultivation and recreation [14]. Dam construction work has a considerable level of cost both financially and from human resources incorporated in the planning, design and implementation phase of the construction process [15].

2.3. Risk Factors of Dam Construction Project
In the process of dam construction has risk factors that occur namely internal and external factors, 1) the onsite weather occurs due to methodology and hydrology such as landslide, flooding, at the dam project site. 2) Earthquakes, explosions due to unbalanced existing conditions on the upstream and downstream sides of dam construction. 3) Social events such as land acquisition disputes in residential settlements. While internal risks occur during the process: 1) Dam design planning 2) constants and contractors must communicate with each other. In this case the construction work of dams 3) operations in reservoir construction 4) increase the need for community-based drinking water [16].

2.4 Bayesian Network
Bayesian Network is a Directed Acyclic Graph (DAG) model that represents distribution probability and randomly generated model variables. In the mathematical modeling stage, it can answer uncertainty probabilistically so that it can find the optimal structure of the data [17]. The Bayesian Network is a statically approach presented by Thomas Bayes that is effective at representing complex relation [18]. The Bayesian Network can be used for risk assessment and environmental applications by analyzing problems with the nonparametric approach of model structures and being impacted by relationships between variables that may be difficult to identify. So that probabilistic approach is used [19] with mathematical modelling in the figure 1 below is tail-to-tail. For a given condition of Z, the communication between X and Y is blocked, which is tail to tail condition independence. X and Y have common cause. The joint probability is therefore calculated as \( P(X, Y, Z) = P(Z) P(X|Z), P(Y|Z) \) [20].
2.5 Previous research related to Safety Performance using Bayesian Network Method

Previous research related to Safety Performance using Bayesian Network method with discussion of occupational safety and health. Even though it has different research objects but the discussion remains in the aspect of risks that can affects safety performance in construction projects, following the previous research table.

| No. | Authors | Method                                      | Result                                                                                                                                 |
|-----|---------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| 1.  | [21]    | Bayesian network, Sensitivity Analysis       | By using BBN method can model the condition to conduct an assessment as well as analyze the risk of falling at high altitude in the construction industry, in order to build safety protocols to be applied in the construction of high rise buildings because it provides probabilistic related risks. |
| 2.  | [12]    | Bayesian network, Sensitivity Analysis       | By modeling BBN this analytical technique is chosen to determine organizational factors and needs to be emphasized when promoting safe work behavior in construction projects, its analysis is used through the opinion of experts who are experienced in their fields. |
| 3.  | [22]    | Bayesian Network, Sensitivity Analysis       | BBN’s prediction model can analyze Safety knowledge and environment to support behavior analysis and improve safety knowledge attitudes will result in the highest proportion of safety behavior among employees in the workplace. |
| 4.  | [13]    | HFACS, Bayesian Network                      | The need holistically analyze the framework by analyzing risk factors that cause inaccurate safety assessments and can affect safety performance. So that it is necessary to form a prediction model Bayesian network and HFACS systematically against safety performance on construction projects. |
| 5.  | [23]    | HFACS, Bayesian Network                      | This study presents the HFACS Hybrid model on sustainable flight mergers with variety of human factors to the risk of work accidents by valid testing above. Modeling validated by the experts. |
| 6.  | [24]    | Bayesian Network, Probabilistic transmission | The factors that cause accidents in construction projects are due to unsafe behavior towards workers in the construction process, by selecting case studies in China exploring work accidents with probability transmission and modeled with the Bayesian network. |
3. Methodology
The method of the research used in this paper is conducted based on the background and objectives of this research has the following stages. The first stage is to develop the background and preparation of problems and research objectives. The second stage draws up the formulation of problems based on literature studies in order to get gap analysis of the research done. The third stage of literature study is carried out so that the research plan can be systematically arranged, namely: 1) Analyze and determine the relevant previous research 2) identify variables to measure Safety Performance on the dam construction project [13].

A preliminary survey conducted at the beginning of the research process to propose a probabilistic model suitable for measuring Safety Performance in dam construction. The fourth stage identifies variables used for this study that come from literature studies, pre surveys and expert judgment or it refer to people who are experts in the field of water building construction to be asked for opinion and input on the research conducted. The fifth stage created a model, 1) determines the variables that affect and measure safety performance on the dam construction project, through variable Identification, Variable relationships are used to see the affect of risk event, and Safety health management on Safety Performance. 2) Create a conditional probability table (CPT) to dynamically see the field conditions.

The sixth stage is validation of the created model, validation of the model diagram (the effect of the relationship between variables) by using subjective judgment. The seventh stage of the simulation shape sensitivity analysis to find out the indicators and variables that significantly affect the model then discuss the finalization of the model conclusions and recommendations for modeling suggestions made.

4. Result and Discussion
4.1 BBN Safety Performance Model
Model BBN Safety Performance on dam construction projects each node has a conditional probability table containing conditional probability distribution for each variable in a model and translated into Bayesian network. Variables used to measure safety performance from aspects of behavior, equipment and environment. Therefore, by knowing the source of risk as well as risk event is used to see the potential for work accidents that occur due to uncertainty of conditions in the dam construction process. Next, Bayesian model as in figure 1.

![Figure 2. The conceptual BN model for safety performance dam construction projects](image-url)
4.2. Model Validation
To test whether the model is relevant results in accordance with the conditions that occurred in the field by testing the model with a study case of water of dam construction projects namely Dam by conducting literature studies in order to determine relevant analysis, conducting a precursor survey that is experts in the field of construction services and experienced academics who are able to provide analysis of the model itself.

4.3 Study Case
In this study case, studies are used in construction projects water building (dam) in East Borneo province that has characteristics among others. The function of buildings to hold water in the rainy season when river water with a large amount of runoff and dam construction projects are also very prone to accidents due to labor done intensively in the construction process.

Results showed that using Bayesian networks approach is very suitable in conducting risk assessment of Safety performance in dam construction projects. By making a prediction model on dam construction projects provide recommendations to unravel the risk of work accidents. Because previous research only looked at it from a certain point of view. So it is not specific to the uniqueness of the risk problems of construction workers reviewed on dam projects.

5. Conclusion
Bayesian networks method approach can be used to measure Safety Performance on dam construction projects against the risk of accidents to workers at the time of implementation and take precautions quickly and accurately. With the probabilistic Safety Performance model, Bayesian Network can assist project management personnel in resolving the risk of work accidents occurring in dam construction projects. Taking into account into the ability of project personnel to manage safety risks and improve Safety Performance in dam construction projects that are reflected in the implementation of good safety management performance tasks and ultimately develop a strong and positive safety climate.

References
[1] Asnudin and Andi 2008 Potensi Bisnis Usaha Jasa Konstruksi Di Indonesia SMARTek-Sipil Mesin Arsitektur Elektro 6(4) pp. 228-240.
[2] Ahankoob A and Charehzehi A 2012 Enhancement Of Safety Performance At Int Journal of Adv in Eng & Tech 5(1) 303-312.
[3] Venkataraman N 2008 Safety Perfomance Factor Int Journal of Occ Safety and Ergonomics 14(3) pp. 327-331.
[4] Gomes C M, Kneipp J M, Kruglianskas I, Barbieri da Rosa L A and Bichueti R S 2014 Management for sustainability in companies of the mining sector: an analysis of the main factors related with the business perfomance J. of Cleaner Production 84 pp. 84-93.
[5] Gerassis S, Martin J, Saavendra A and Taboada J 2017 Bayesian Decision Tool for the Analysis of Occupational Accidents in the Construction of Embankments J. of Const Eng and Man.
[6] Wong S S and Soo A L 2019 Factors Influencing Safety Performance In The Construction Industry Journal of Social Ciencies and Humanities 16(3) pp. 1-9.
[7] Alzahrani J I, Emsley M W 2013 The impact of contractors’ attributes on construction project success: A post construction evaluation Int J. of Project Man 31(2) pp. 313-322.
[8] Kanchana S, Sivaprakash P and Joseph S 2015 Studies on Labour Safety in Construction Sites The Sci World J. pp. 1-6.
[9] Asikoglu O L and Kale A O 2017 Occupational Health And Safety In Dam Construction Sites Intenational Journal of Modern Engineering Research 7(8) pp. 45-48.
[10] Haghshenas S S, Neshaei M A L, Pourkazem P and Haghshenas S S 2016 The Risk Assessment of Dam Construction Projects Using Fuzzy Topsis (Case Study: Alavian Earth Dam) Civ Eng Journal 2(4) pp. 158-167.

[11] Kammouh O, Gardoni P and Cimellaro G P 2020 Probabilistic framework to evaluate the resilience of engineering systems using Bayesian and dynamic Bayesian networks Reliability Eng & Syst Safety 198.

[12] Jitwasinkul B, Hadikusumo B H W and Memon A Q 2017 A Bayesian Belief Network model of organizational factors for improving safe work behaviors in Thai construction industry Safety Science 82 pp. 264-273.

[13] Xia N, Zou P X W, Liu X, Wang X and Zhu R 2018 A hybrid BN-HFACS model for predicting safety performance in construction projects Safety Science 101 pp. 332-343.

[14] Tortajada C 2015 Dams: An Essential Component of Development J. of Hydrologic Eng 20(1) pp. 1-9.

[15] Tortajada C 2000 Evaluation of Actual Impacts of the Atatu’rk Dam Int J. of Water Res Dev 16(4) pp. 453-464.

[16] Adamo N, Al-Ansari N, Laue J, Knutsson S and Sissakian V 2017 Risk Management Concepts in Dam Safety Evaluation: Mosul Dam as a Case Study J. of Civ Eng and Architecture 11(7) pp. 635-652.

[17] Benmouna Y, Benazzouz M, Chikh M and Mahmoudi S 2019 New Method for Bayesian Network Learning Int Journal of Pattern Recognition and Artificial Intelligence 33(2) pp. 1-23.

[18] Holmes D E and Jain C L 2008 An Introduction to Bayesian Networks and Their Contemporary Applications. In Innovations in Bayesian Networks, Germany: Studies in Computational Intelligence.

[19] Francis R A, Guikema S D and Henneman L 2014 Bayesian Belief Networks for predicting drinking water distribution system pipe breaks Reliability Eng and System Safety 130 pp. 1-11.

[20] lyu T, Song W and Du K 2019 Human Factors Analysis of Air Traffic Safety Based on HFACS-BN Model Applied Sciences 9 pp. 1-19.

[21] Nguyen L D, Tran D Q and Chandrawinata M P 2016 Predicting Safety Risk of Working at Heights Using Bayesian Networks Construction Engineering and Management 142(9) pp. 1-11.

[22] Mohammadfam I, Ghasemi F, Kalatpour O and Moghimbeigi A 2017 Constructing a Bayesian network model for improving safety behavior of employees at workplaces Applied Ergonomics 58 pp. 35-47.

[23] Zhou T, Zhang J and Baasansuren D 2018 A Hybrid HFACS-BN Model for Analysis of Mongolian Aviation Professionals’ Awerness of Human Factor Related to Aviation Safety Sustainability 10.

[24] Guo S, He J, Li J and Tang B 2020 Exploring the Impact of Unsafe Behaviors on Building Construction Accidents Using a Bayesian Network Environmental Research and Public Health 17(1).