Cost Integrated Safety Management for Accident Risk Control in Cement Manufacturing Process

Afrigh Fajar Rosyidiin, Patdono Suwignjo and Moses Laksono Singgih
Department of Industrial and Systems Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
afrighfajar7@gmail.com, patdono@ie.its.ac.id, moseslsinggih@ie.its.ac.id

Abstract

Cement Production Company (CPC, a nickname) is a company engaged in the production and distribution of cement. CPC has a long series of production processes, has various potential hazards and impacts the environment, health, and safety. Therefore, research is needed to improve workplace safety. Based on interviews with workers at CPC, the raw mill and kiln areas are areas with a lot of potential hazards. Raw mill and kiln are areas with a sound intensity that exceeds the threshold value of 85dB. In addition, the process in both areas requires high temperatures of up to 1500 °C. This study uses the Hazard Identification, Risk Assessment and Risk Control (HIRARC) approach. This approach aims to identify hazards that may occur in the workplace, provide a risk assessment and classification according to safety or acceptable impacts on the environment and provide suggestions for improvement. Compared to the proposed improvements to get the best alternative with Pugh's method and carried out the work accident cost analysis using the Benefit-Cost Analysis (BCA) method to determine the amount of profit received by the company after being compared with the losses due to work accidents. The expected result of this research is a risk control by proposing the best work accident prevention mechanism based on quality and cost.

Keywords
Occupational Health and Safety, HIRARC, Pugh's Method, Benefit-Cost Analysis (BCA), Accident Prevention.

1. Introduction
Occupational Health and Safety are important for the company, because the impact of accidents and occupational diseases does not only harm employees, but also the company both directly and indirectly. Health and safety is an effort to maintain and improve the highest degree of physical, mental and social well-being for workers in all positions (Haworth and Hughes 2012). The aspect of work accidents in industry is that 88% of industrial accidents are caused by unsafe actions, 10% of accidents are caused by unsafe conditions and 2% of accidents are caused by other factors (Hosseinian and Torghabeh 2012).

Cement Production Company (CPC) is a company located in Indonesia engaged in the production and distribution of cement. CPC is a company that pays attention to safety and always makes a continuous improvement in the field of safety by creating innovative programs to increase employee and contractor awareness of the importance of work safety. Based on researcher interviews with the workers at CPC, the raw mill and kiln area is an area that has many sources of potential hazards. Raw mill is the first stage of material grinding for cement production. While the kiln is the most important equipment in the cement manufacturing process, namely as a place of contact between hot gas and kiln feed material so that the compounds that make up cement are formed.

Dust exposure also causes a decrease in a lungs function and an increase in the prevalence of chronic obstructive pulmonary disease and cancer (Koh et al. 2011). Inside the kiln there is a combustion process with a temperature of 1500 °C, if the protective layer has poor resistance it can cause an explosion or fire. From this potential, it can cause many losses, including human casualties, injuries, environmental damage, psychological impacts and financial losses (Ewais and Bayoumi 2018). Raw mill and Kiln are areas with a sound intensity exceeding the threshold value of 85dB. If a person is exposed to the noise that exceeds the threshold value every day, it can cause a hearing loss to a permanent deafness (Wardani et al. 2020).

The purpose of this study is to improve work safety by selecting the best work accident prevention mechanism based on quality and cost factors. The stages to achieve the goal are knowing the potential hazards contained in the object of research, Providing risk assessment and risk level mapping, Risk control by providing improvement proposals for risks that have high and very high levels, Selection of the best alternative and cost analysis of the best alternative to find out improvements is feasible and provides benefits for the company or not. This study uses the integration of HIRARC, PUGH and BCA methods which can be applied to companies. The combination of several methods from various disciplines is expected to be able to solve safety related problems in the company.

2. Literature Review

Literature review is a reference in the form of writings that are relevant to the research to be carried out. Using most of the references from international journals. The literature review contains a description of the theory of a research result, findings, and also materials in research activities. All of this can then be used as a theoretical basis when conducting a research or compiling a scientific papers.

2.1 Hazid Methodology

Hazid's methodology is a systematic analysis that is critically analyzed by a team in which operations and processes are assessed in order to be able to find out the potential danger of a maloperation or malfunction of one piece of equipment and its overall consequences (Rivera Domínguez et al. 2021). This method serves to identify potential hazards that may occur in the workplace and their consequences. Identification of specific hazards with several aspects, namely sources, environmental, physical and mental overload, surrounding, natural and locative, storage and administrative. Hazard identification will be carried out in several areas within the company's location. Critical and systematic analysis will be able to find out the potential hazards and the consequences of the hazards on the operations and production processes.

2.2 Risk Matrix

Risk Matrix is a semi-quantitative assessment tool used to categorize and prioritize event risks and to decide whether a particular risk is acceptable based on historical statistical data (Ikwan et al. 2021). The use of a risk matrix in mapping risk levels is to determine and calculate between severity and probability (Luo et al. 2018). Table 1 is a risk matrix graph that has a function as a tool for risk levels mapping.

Table 1. Risk Matrix Graph

Probability ↑							
	A	Frequent	Low	Medium	High	Very High	Very High
	B	Probable	Very Low	Low	Medium	High	Very High
	C	Occasional	Very Low	Low	Medium	High	High
	D	Remote	Very Low	Low	Low	Medium	High
	E	Improbable	Very Low	Very Low	Low	Medium	Medium
			1	2	3	4	5
			Negligible	Minor	Moderate	Major	Catastrophic
			Impact Severity →				

2.3 Fishbone Diagram

Fishbone diagram is a diagram that shows the relationship between cause and effect. From this cause-and-effect diagram it will be known the factors that causing the problem. This method was developed by Kaoru Ishikawa in 1968. The application of fishbone in risk analysis is to find out the cause of the occurrence of risk to provide convenience in the next stage which has a function for risk control (Tortorella et al. 2020). This diagram is composed of a structure similar to a fishbone and there are parts inside. The Fish Head section is a problem or a topic that will be analyzed or found out the cause of the problem. The topic will be influenced by the causes which will be written in the fishbone section. In the fishbone section, write down any categories that can affect the topic written on the fish's head. Usually, the determination of this category uses the 5M 1E method, namely Man, Method, Material, Machine, Measure, Environment.

2.4 Hierarchy of Control

Hierarchy of Control is a sequence in the prevention and control of risks that may arise which consists of several levels in sequence (Uzun et al. 2018). This method provides convenience in providing improvement proposals because of the level of control that functions to adjust the improvements to be given for the risks to be controlled. The level of improvement is based on 5 hierarchy of control, elimination, substitution, planning, administration and personal protective equipment (OHSAS:18001 2007).

2.5 PUGH Matrix

Pugh's method is a matrix diagram that is used to compare a number of alternatives to find which alternative will be the best to meets predetermined criteria. This matrix is used to compare the number of available alternatives with predetermined criteria and can be used in a decision-making situations that have a large number of criteria. The purpose of using the Pugh's Matrix is to provide a simple approach to consider a several factors in making a decisions regarding the selection of improvement alternatives (Joshi et al. 2019). Table 2 is a PUGH Matrix worksheet for selecting the best alternative.

Table 2. Worksheet PUGH Matrix

	Alternative A	Alternative B	Alternative C	Alternative D	Alternative AB	Alternative AC
Criteria 1	S	+	S	+	-	+
Criteria 2	S	-	S	+	-	+
Criteria 3	S	S	S	+	-	-
Criteria 4	S	-	+	+	+	S
Criteria 5	S	-	+	+	+	S
Criteria 6	S	-	S	-	-	S
Criteria 7	S	+	S	-	S	-
Criteria 8	S	+	S	-	S	+
Criteria 9	S	-	S	-	+	+
Criteria 10	S	S	-	S	-	-
Total +	0	3	2	5	3	4
Total S	10	2	7	1	2	3
Total -	0	5	1	4	4	3
Total Score	0	-2	1	1	-1	1
Rank	4	6	1	2	5	3

The Pugh matrix consists of a several alternatives that will be selected with the necessary criteria in choosing an alternative that meets the desired criteria. The Pugh matrix is also used in qualitative alternative optimization by combining the concepts of two alternatives that will form a hybrid alternative or a combined alternative. The selection of the best alternative is done by evaluating where alternative A is chosen as the standard or the baseline. This baseline will be scored as “S” against the provided criteria. The concept of alternative assessment is carried out using the following assessments:

- If it is better than the standard, it is given a positive sign “+” on the appropriate criteria.
- If it is worse than the standard, it is given a negative sign “-” on the appropriate criteria.
- If it is the same as the standard, it is marked with “S” on the appropriate criteria.

For a positive assessment it has a weight of 1, for a negative assessment it has a weight of -1, and for the same assessment as the baseline it is given a weight of 0. Then the total weight is calculated for each alternative. The alternative with the highest weight is the best alternative.

2.6 Benefit Cost Analysis

Benefit cost analysis (BCA) is a method used to evaluate management using a comparison of the costs incurred against the benefits (Ebers and Thomsen 2021). Benefit cost analysis can also be defined as a method for conducting economic evaluation which is used as a comparison to the efficiency of several inversions. Benefit cost analysis (BCA) has been widely used in research to evaluate economic resources to be used efficiently. The purpose of using the Benefit cost analysis method is knowing the amount of profit or loss on a project with a cost analysis that compares the benefits and costs as a consideration for the feasibility of an improvement (Boardman 2018). The application of this method is used to develop a business by considering the costs of developing investment by paying attention to the ratio of

profits to costs incurred (Brent 2006). Equation 1, 2, 3 is a calculation of present value (PV) based on Benefits, Costs and Benefi Cost Analysis (BCA) can be formulated as follows:

$$PV\ (C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t} \quad (1)$$

$$PV\ (B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t} \quad (2)$$

$$BCA = \frac{PV\ Benefit=B}{PV\ Cost=C} \quad (3)$$

An alternative is considered worthy of being used as a reference in the fulfillment of risk control solutions that have a BCA value of more than 1. In addition, it will also provide benefits for the company.

3. Methods

This section describes the steps used to conduct research. This research method aims to be a reference in conducting research so that research can run systematically, the objectives are achieved and in accordance with the previously determined time. Figure 1 is the research process and the method used to solve the problem.

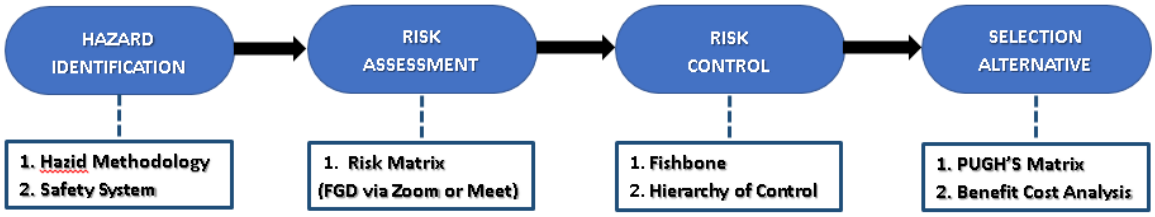

Figure 1. The Research Process

3.1 Hazard Identification

Hazard Identification is to identify the potential hazards that exist in the work environment and their consequences. In addition to knowing the existing work safety system on the object of research. The method used for this stage is HAZID Methodology, this method serves to identify hazards that may occur in the workplace. Identification of specific hazards with several aspects, namely sources, environmental, physical and mental overload, surrounding, natural and locative, storage and administrative. The hazard identification process also pays attention to the existing safety system, so the safety system must also be identified. Identification of Safety System to find out the safeguards, mitigation and controls applied in the current workplace. This step is useful to find out how optimal the safety system in the workplace is to identify potential hazards. This data is also used for the process of working on the hazid method.

3.2 Risk Assessment

In this process, risk level assessment and mapping will be carried out according to the impact received by the work environment. Risk assessment uses risk matrix tools and the steps taken are to assess the severity and probability of the identified risks. Risk assessment based on Expert Judgment through Forum Group Discussion via zoom meeting. FGD is a discussion process that involves an experts for a problem solving by considering the available resources in group discussions or brainstorming. Determination of a risk level mapping is the multiplication between severity and probability. The results of the risk assessment that have a high and a very high risk levels will be given.

3.3 Risk Control

The results of the risk assessment are used to determine recommendations for improvements to be made. Risk control will produce the output in the form of a risk mitigation. In this study, the recommended risk levels were only high and very high. Prior to the recommendations for improvement, the causes of a potential hazards will be analyzed using the Fishbone approach, to find out the causes of potential hazards in order to provide convenience in the next stage which has a function for repair. The method used for improvement is the Hierarchy of Control. Based on the results of the previous stages will be analyzed and given improvements based on the 5 control hierarchies, namely elimination, substitution, planning, administration and personal protective equipment.

3.4 Selection Alternatif

At this stage, the best alternative will be selected by comparing several recommended alternatives with the criteria needed to carry out risk control. The selection of this alternative is done using the PUGH method. After selecting the best alternative, a cost analysis will be carried out using the Benefit Cost Analysis (BCA) method. The determination of the benefit value is obtained from the costs incurred if the risk occurs, reducing operational costs and increasing company income after being given control. Meanwhile, for determining the value of costs are all costs incurred for risk control. After obtaining the value of benefits and costs, it will be determined whether the repair is worth continuing or not.

4. Data Collection

Researchers get the data for research from two sources, namely interviews with the company workers and data records from the company in the last five years. The data was taken from the production data, assessment of the work environment, safety systems, nearmis, work accidents and a maintenance costs. All data that has been obtained is not allowed to be disclosed by the company. To make good a research, researchers also using the previous studies references that have similarities in the theme or object of research.

5. Results and Discussion

This section is the result of research in the raw mill and kiln area. This research is an integration method of the HIRARC, PUGH and BCA.

5.1 Result of Hazard Identification

Identification of potential hazards is carried out using the Hazid Identification method by taking into account the system that has been carried out. Identification of potential hazards is carried out using categories based on the source of the hazard, namely Electrical, Mechanical, Physical, Chemical, Biological, Ergonomic, Psychosocial, Surrounding hazard, Natural phenomena, Locative. The results of the identification of hazards in the raw mill area contained 25 potential hazards and 39 risks. While in the kiln area, there are 25 potential hazards and 40 risks. In the raw mill and kiln area, 29 safety systems have been implemented to improve safety and reduce accidents. The safety systems implemented vary among permits, instruments, signs, fire prevention and suppression etc.

5.2 Result of Risk Assessment

Risk assessment in this study is based on Expert Judgment through the Forum Group Discussion. FGD is a discussion process that involves an experts for problem solving by considering the available resources in group discussions or brainstorming. Assessors as well as Expert judgment in this research are the employees of PT. CPC who has a working period of 8-10 years and is responsible for the raw mill and kiln area. The risk assessment was carried out via Zoom Meeting on December 4, 2021 at 7-10 p.m. The Discussion went smoothly and active. Table 3 below is the result of the risk assessment in the raw mill and kiln area.

Table 3. Result of Risk Assessmnet

Area	Risk Level				
	Very Low	Low	Medium	High	Very High
Raw Mill	16	10	12	1	0
Kiln	14	8	14	2	2
Total	30	18	26	3	2

For risks that get a high and a very high levels, A preventive controls will be given to prevent the risks from occurring in the workplace. Based on table 3 there are 3 risks at a high level and a very high level there are 2 risks. But there are 2 risks that are the same so there are only 4 risks that will be recommended for improvement.

5.3 Result of Risk Control

At this stage there are 4 risks which recommendations for improvement will be given. Before giving a recommendations for improvement, first it will be analyzed using the fishbone method. This analysis is to make it easier to provide a recommendations for improvement because the cause of the risk will be known. Figures 2, 3, 4 and 5 are the results of the analysis using the Fishbone method for the risks to be controlled.

1. Hazard : Combustion Emmision,
   Risk : Greenhouse Effect

Level : Very High

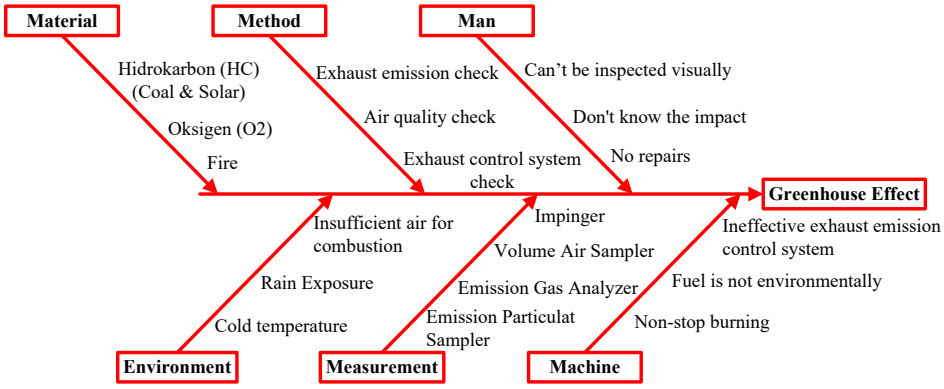

Figure 2. Fishbone Analysis of the Greenhouse Effect.

Fishbone Analysis Conclusion

Greenhouse effect is a risk from the Figure 2. The exhaust gas from the combustion in the rotary kiln contains carbon called a greenhouse gas. Continous ombustion in the kiln still uses fuels that are not environmentally friendly. In addition, there is a possibility that the emission control system is not very effective, inspection and measurement is not very effective either. Incomplete combustion in the kiln can also contribute to a greenhouse gases, incomplete combustion is also affected by the insufficient air for combustion, exposure to the rain and a cold temperatures.

2. Hazard : Clinker Dust
   Risk : Pneumoconiosis, Eye irritation, Skin irritation and Cancer
   Level : Very High

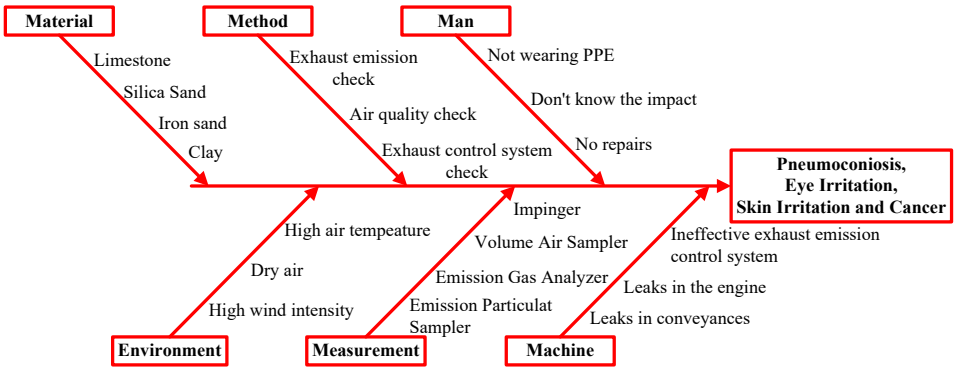

Figure 3. Fishbone Analysis of Pneumoconiosis, Eye irritation, Skin irritation and Cancer.

Fishbone Analysis Conclusion

Clinker dust containing Cr6+ that can cause a pneumoconiosis, eye irritation, skin irritation and cancer. Clinker dust contains a limestone, silica sand, iron sand and clay. The workers are exposed to the dust because they do not wear The PPE and doesn't know the dangers of the clinker dust. In addition, there is a possibility that the emission control system is less effective, inspection and measurement are not effective either. The Spread of a Clinker dust is possibly due to an ineffective exhaust gas system, engine leakage and lifting equipment. The distribution of clinker dust is very fast due to high wind intensity, dry air and higher air temperature.

3. Hazard : Heat Temperature
   Risk : Dehydration, Fainting, Skin pain and Death
   Level : High

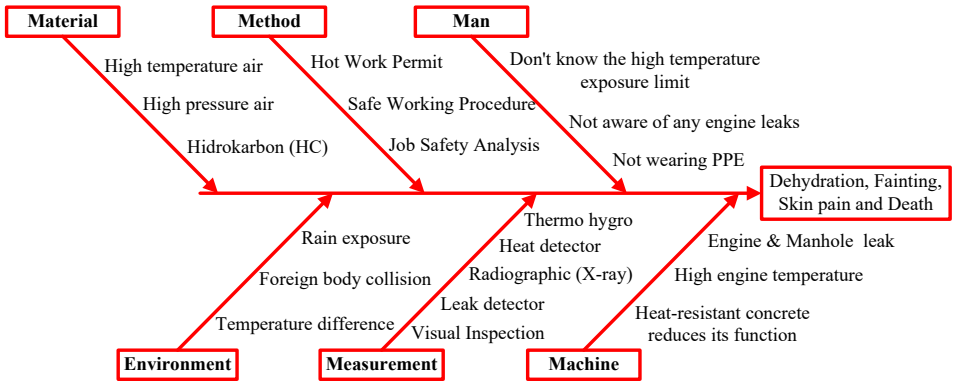

Figure 4. Fishbone Analysis of Dehydration, Fainting, Skin pain and Death.

Fishbone Analysis Conclusion

Dehydration, fainting, skin pain are a risks from the heat in the kiln. The reason the heat temperatures are exceeding the safety threshold value is because of the engine leaks, manhole leaks, high engine temperatures and the damaged heat-resistant bricks. The workers are exposed to the heat because they doesn't wear the PPE, doesn't know the limits of exposure to heat temperatures and doesn't know about the leakage. Hot Work Permit, Safe working permit and Job safety analysis are also ignored by the worker. Leaks in equipment or manholes could be a collision from a foreign objects, exposure to the rain and a temperature differences.

4. Hazard : Rainwater
   Risk : Reduced functionality of equipment
   Level : High

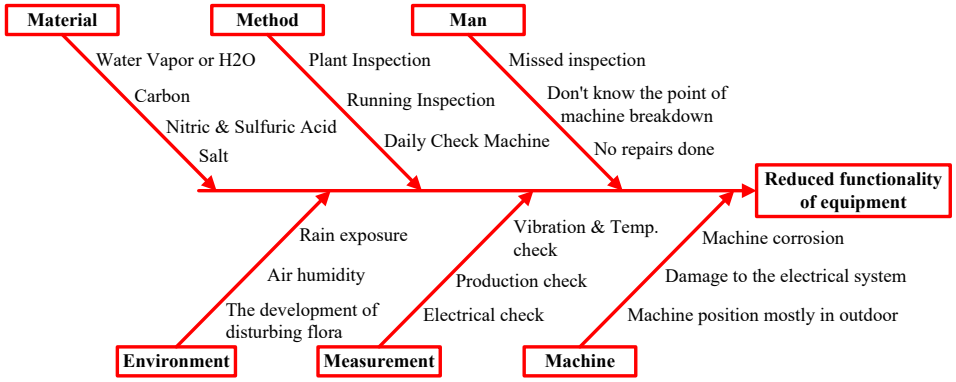

Figure 5. Fishbone Analysis of Reduced functionality of equipment.

Fishbone Analysis Conclusion

The Fishbone diagram in Figure 5 shows that the right side is a topic or a problem, namely the reduced function of equipment due to the rain. The rain can cause a damage or reduce the engine function because it contains a carbon, acid and salt. In addition, a rain can also cause corrosion because the engine position is mostly in the outdoors and electrical damage due to humidity. Many disturbing flora is developed Due to the high intensity of the rain. Inspections may have been carried out but something was missed and the maintenance worker did not know which point the machine is damaged so it was not fully repaired.

In the risk control, one risk can be given one or more alternative of improvements in accordance with the Hierarchy Control. Because in the next stage, the best alternative will be selected using the PUGH and BCA methods. Table 4 below is a risk of the 4 risks that have a high and a very high levels.

Table 4. Result of Risk Control.

Business name:	Diagnosis:	Date:
Cement	**Area**	**December 14, 2021**
Location:	Number of workers	Economic activity:
Raw Mill and Kiln	**8**	**Cement Production**

No	Hazard	Risk	Risk Control	
1	Combustion Emission	Greenhouse Effect	**Elimination**	-
			Substitution	1. Use of fuel co-processing by replacing coal with municipal or industrial waste. 2. Kiln Engine Repair.
			Eng. Control	3. Development of Carbon Capture, Utilization, and Storage (CCUS). 4. Construction of Waste Heat Recovery Power Generation (WHRPG).
			Adm.	Safety Sign, General Work Permit, JSA, SWP.
			PPE	Wearpack, Helmet, Mask, Glasses, Gloves.
2	Clinker Dust	Pneumoconiosis, Eye irritation, Skin irritation, and Cancer	**Elimination**	-
			Substitution	1. Improved performance of Electrostatic Precipitator (ESP) Kiln. 2. Improvements to Kilns and Conveyances. 3. Replacement of clinker with fly ash from power plant waste.
			Eng. Control	-
			Adm.	Safety Sign, General Work Permit, JSA, SWP.
			PPE	Wearpack, Helmet, Mask, Glasses, Gloves.
3	Heat Temperature	Dehydration, Fainting, Skin pain and Death	**Elimination**	-
			Substitution	1. Replacement of refractory brick in the kiln.
			Eng. Control	2. Providing Thermal Insulation with Liquid Ceramic Coating on the outside of the kiln. 3. Giving Misty Fan to the outside of the kiln.
			Adm.	Safety Sign, GWP, Hot Work Permit, JSA, SWP.
			PPE	Wearpack, Helmet, Mask, Glasses, Gloves.
4	Rainwater	Reduced functionality of the equipment	**Elimination**	-
			Substitution	1. Equipment repair that has reduced functionality.
			Eng. Control	2. Installation of a dehumidifier in the control room. 3. Coating process on the areas that are exposed to the rain water.
			Adm.	Safety Sign, GWP, Plant Inspection Record, JSA, SWP.
			PPE	Wearpack, Helmet, Mask, Glasses, Gloves.

From the results of the proposed improvements above. Risk control by elimination cannot be given because the source of danger is a major component in the cement production process. So what is done is to control risk by the next sequence, namely substitution. In the proposed improvement above, risk control by substitution can be carried out. Substitution is a risk control method that focuses on replacing a tool or machine or item that has a hazard with one that does not have a hazard. Besides that, there are also suggestions for improvement by engineering control and the next level of the hierarchy.

5.4 Result of Selection Alternative

At this stage, the selection of alternative improvements will be made by comparing with the predetermined criteria. This alternative selection is done using the PUGH method. The best alternative will be selected and recommended to the company to improve safety hierarchy of control to be applied in the workplace or machine (Elimination, Substitution, Engineering Control). For administrative control and PPE has been applied by the company. Table 5 is the result of choosing an alternative using the PUGH method.

Table 5. Selection alternative result with PUGH's Matrix.

No	Hazard	Risk	Level	Best Alternative
1	Combustion Emission	Greenhouse Effect	very high	Use of fuel co-processing by replacing coal with municipal or industrial waste
2	Clinker Dust	Pneumoconiosis, Eye irritation, Skin irritation, and Cancer	very high	Replacement of clinker with fly ash from power plant waste
3	Heat Temperature	Dehydration, Fainting, Skin pain and Death	high	Providing Thermal Insulation with Liquid Ceramic Coating on the outside of the kiln
4	Rainwater	Reduced functionality of the equipment	high	Coating process on areas exposed to rainwater

The best alternative was chosen because it has the highest value from other alternatives through 7 assessment criteria. The following are 7 assessment criteria for selecting the best alternative, namely Cost, Machine Productivity, Worker Safety, Worker Comfort, Environmental Security, Maintenance and Repair, Robustness. In terms of quality and function, the selected alternative has the ability to reduce or prevent risk. But in terms of costs, it is not known, so a cost analysis will be carried out to find out whether or not the proposed improvement is implemented in the company.

To determine the feasibility of the proposed improvement in terms of cost. The chosen alternative will be cost analysis using Benefit Cost Analysis (BCA) to determine the ratio between the benefits obtained and the costs incurred. BCA calculations use the following assumptions:

- MARR(s) = 5%
- N = 5 years

MARR used in this calculation is derived from the average value of Indonesia inflation from January 2019 to December 2021. The N value (number of compounding periods) used is 5 years, namely preventive costs for the next 5 years using historical accident data 5 years earlier. Table 6 is the result of a cost analysis using the BCA Method to determine the feasibility of the recommended repairs.

Table 6. Benefit Cost Analysis of recommended repairs

Benefit	Cost	PV Benefit	PV Cost	BCA
1. Combustion Emission				
$ 2,866,149	$ 796,061	$ 2,620,545	$ 623,734	**4.2**
2. Clinker Dust				
$ 4,498,348	$ 3,737,530	$ 4,112,875	$ 3,417,253	**1.2**
3. Heat Temperature				
$ 36,657	$ 30,191	$ 33,515	$ 27,604	**1.21**
4. Rainwater				
$ 188,390	$ 65,380	$ 172,247	$ 51,227	**3.36**

The thing that is quite complicated is the cost benefit analysis or the calculation of the benefits obtained if the alternative is applied. Because apart from tangible costs, there are also intangible costs that are difficult to measure. Then the method used to formulate the estimated profit obtained is the costs incurred if the risk occurs, Reduction of operational costs and the addition of company income after being given control. For the costs incurred are obtained from the cost of materials, installation and maintenance. From the calculation results above, it is found that the calculation of the costs incurred and the benefits resulting from all proposed improvements has a value of more than 1 (> 1), so that risk control can be applied in the company because it provides benefits for the company.

6. Conclusion

Conclusions from the research on cement production companies are Identification of potential hazards is carried out using the Hazid methodology by taking into account the safety system that has been identified. Identification of potential hazards is carried out using categories based on the source of danger, namely Electrical, Mechanical, Physical, Chemical, Biological, Ergonomic, Psychosocial, Surrounding danger, Natural phenomena, Locative.The results of hazard identification in the raw mill area contained 25 potential hazards and 39 risks. In the kiln area, this identification has 25 potential hazards and 40 risks. The area has 29 safety systems that already been implemented to

improve safety and reduce accidents. Various safety systems are applied, including permits, instruments, signs, fire prevention and control, etc.

The results of the hazard identification are used to conduct a risk assessment to determine the level of risk from the known potential hazards. At the risk assessment stage, the researcher uses a risk matrix to determine the assessment. The results of the risk assessment that have been carried out shows that in the raw mill area there are risk levels of hazard, namely 16 very low, 10 low, 12 medium, 1 high and 0 very high. As for the kiln area, there are risk levels of hazard, namely 14 very low, 8 low, 14 medium, 2 high and 2 very high.

Risk control is given to the risks that get a high and a very high levels to prevent the risks from occurring in the workplace. Based on the conclusions above, there are 3 high risks and 2 very high levels, but there are 2 equal risks, so there are 4 risks that are recommended for improvement. Prior to the recommendation for improvement, it will be analyzed using the Fishbone Method to determine the cause of the risk. For the risk control, this study uses a risk control hierarchy, namely Elimination, Substitution, Engineering control, Administration, PPE.

Using the Pugh Method, it is done to compare the number of available alternatives with predetermined criteria for making a decision using 7 criteria there are Cost, Machine Productivity, Worker Safety, Worker Comfort, Environmental Security, Maintenance and Repair, Robustness. After determining the best alternative, a cost analysis will be carried out using Benefit Cost Analysis. The following are the results of selecting the best alternative and cost analysis:

- Hazards of Combustion Emissions with risk control The use of Co-processing as a substitute for coal as a substitute for municipal or industrial waste, has a value of BCA = 4.2 which means it is feasible to implement and provides benefits for the company.
- Hazards of Clinker Dust with a risk control Replacement of the clinker with fly ash from the power plant waste, has a value of BCA = 1.2 which means it is feasible to apply and provides benefits for the company.
- Hazards of Heat Temperature with a risk control of Provision of Thermal Insulation with Liquid Ceramic Coating on the outside of the kiln, has a value of BCA = 1.21 which means it is feasible to apply and provides benefits for the company.
- Hazards of Rainwater with a risk control of coating process in areas that are exposed to the rainwater has a BCA value of 3.36 which means it is feasible to apply and provides benefits for the company.

References

Boardman, A. E., *Cost–benefit analysis : concepts and practice*, Fifth edition, Cambridge University Press, 2018.
Brent, R. J., *Applied Cost-Benefit Analysis*, Second Edition, Edward Elgar, 2006.
Ebers, A., and Thomsen, S. L., Benefit-Cost analysis of social media facilitated bystander programs. *Journal of Benefit-Cost Analysis*, vol. 12, no.2, pp. 367-393, 2021.
Ewais, E. M. M., and Bayoumi, I. M. I., Fabrication of MgO-CaZrO3 refractory composites from Egyptian dolomite as a clinker to rotary cement kiln lining, *Journa of Ceramics International*, vol. 44, no.8, pp. 9236–9246, 2018.
Haworth, N., and Hughes, S., *In Handbook of Institutional Approaches to International Business*, First Edition, The International Labour Organization, 2012.
Hosseinian, S. S., and Torghabeh, Z. J., Major Theories of Construction Accident Causation Models: a Literature Review. *International Journal of Advances in Engineering & Technology*, vol. 4, no. 2, pp. 2231–1963, 2012.
Ikwan, F., Sanders, D., and Hassan, M., Safety evaluation of leak in a storage tank using fault tree analysis and risk matrix analysis. *Journal of Loss Prevention in the Process Industries*, vol. 73, pp. 104597, 2021.
Joshi, A. K., Dandekar, I. A., Gaikwad, M. V, and Harge, C. G., Pugh Matrix and Kano Model-The Significant Techniques for Customer's Survey, *International Journal of Emerging Technology and Advanced Engineering*, vol. 9, no. 6, pp. 53–55, 2019.
Koh, D. H., Kim, T. W., Jang, S. H., and Ryu, H. W., Cancer mortality and incidence in cement industry workers in Korea. Safety and Health at Work, *Journal of Safety and Health at Work*, vol. 2, no.3, pp. 243–249, 2011.
Luo, T., Wu, C., and Duan, L., Fishbone diagram and risk matrix analysis method and its application in safety assessment of natural gas spherical tank, *Journal of Cleaner Production*, vol. *174*, pp. 296–304, 2018.
OHSAS:18001, *Occupational health and safety management systems — Guidelines for the implementation of Occupational Health*. Second Edition, OHSAS Project Group, 2007
Rivera Domínguez, C., Pozos Mares, J. I., and Zambrano Hernández, R. G., Hazard identification and analysis in work areas within the Manufacturing Sector through the HAZID methodology. *Journal of Process Safety and*

Environmental Protection, vol. *145*, pp. 23–38. 2021
Tortorella, G., Cómbita-Niño, J., Monsalvo-Buelvas, J., Vidal-Pacheco, L., and Herrera-Fontalvo, Z., Design of a methodology to incorporate lean manufacturing tools in risk management, to reduce work accidents at service companies. *Procedia Computer Science*, vol. 177, pp. 276–283, 2020.
Uzun, M., Bilir, S., Gurcanli, G. E., and Cebi, S., Hierarchy of Control Measures for Common Construction Activities: A Field Study. *5th international Project and Construction Management Conference (IPCMC2018),* North Cyprus, Turkey, November, 2018.
Wardani, R. W. K., Nurika, G., Lutfiya, I., and Nawawinetu, E. D., Noise and Subjective Complaints of Workers As Effort To Control the Occurrence of Noise Induced Permanent Threshold Shif (Nipts). *Journal of Vocational Health Studies*, vol. 3, no. 3, pp. 89-96, 2020.

Biographies

Afrigh Fajar Rosyidiin is a postgraduate student at the Industrial and Systems Engineering Department, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia. He received his Bachelor's degree from Safety and Health Engineering Department, Politeknik Perkapalan Negeri Surabaya (PPNS). His job experience was almost two years in the maintenance and operation of power in the plant industry health, safety, and environment department. His interest in research are risk analysis, quality, manufacturing safety, and productivity

Patdono Suwignjo is an associate professor at the Industrial and Systems Engineering Department, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia. He received an Engineer degree (1983) in Mechanical Engineering from ITS, a Master's degree (1991) was from the University of New South Wales, Australia, and his Doctoral degree (1999) is from the University of Strathclyde, Glasgow, UK. For many years he has been a consultant and advisor in several state-owned companies in Performance Measurement Systems, Strategic Management, Business Process Management, Risk Management, and Feasibility Study. From 2011 to 2020, he was appointed for several positions in The Minister of Education and Culture, i.e., as Senior Advisor; Secretary for the Directorate General of Higher Education; Director-General of Organizational Management for Knowledge, Technology, and Higher Education; and Ad interim Director General of Vocational Education. In June 2020, he retired from the government position and returned to campus.

Moses Laksono Singgih is a Full Professor at the Industrial and Systems Engineering Department, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia. He received his Bachelor's and Master's degree from Industrial Engineering Department, Institut Teknologi Bandung (ITB), Indonesia. He received Ph.D. from the University of Queensland, Australia. His research interests are productivity, quality, and manufacturing systems. Currently, he supervises postgraduate students with topics: a design for manufacturing and assembly (DFMA); quality management; lean six sigma; internet of things; sharing economy; circular economy, TRIZ, Kano Model, and product-service systems. He is a **Professional Member of the IEOM Society.** Please find his publications at www.moseslsinggih.org/publications