

Reducing Environmental and Health Risks in Construction Projects Through Hazard Identification and Risk Assessment

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Abstract. This study looks into the implementation of the HIRARC approach in five Indonesian construction companies in order to reduce risks to workers' health and the environment. Companies face increased pressure to maintain productivity as technology and manufacturing advance, which often results in a higher likelihood of worker injuries if they are not in compliance with OSHA regulations. To assess the effectiveness of the HIRARC technique, the study examines the companies' occupational health and safety, hazard identification, risk assessment, and risk control practices. Accidents continue to occur despite the companies' implementation of the approach, indicating the need for further development. As a result, the study recommends that OSHA management and construction workers receive HIRARC training and certification to reduce accidents and protect worker health and the environment. Implementing hazard identification and risk assessment methodologies can also assist construction firms in reducing environmental and public health risks, thereby promoting sustainable development. Overall, these findings emphasize the significance of implementing effective occupational health and safety practices in order to create a safer and healthier workplace.

1 Introduction

Construction service activities significantly contribute to the development and economic growth of all countries, including Indonesia. In the era of the free market and the advancement of technology, companies are forced to remain productive to compete with others. However, it is notable that the higher the company's production level, the higher the number of work accidents will be. A work accident is unplanned, uncontrolled, and unpredictable, which can interfere with the company's productivity. Therefore, every company must have preventive measures for such issues to keep track of their productivity goal and achieve the management goal of zero accidents.

Every company must implement Occupational Safety and Health (OSH) to ensure their workers' safety. Implementing OSH in every workplace is mandatory according to [1, 2] concerning work safety. However, the application of OSH in the industrial sector has not shown the expected results, which is indicated by the high number of work accidents. As noted by the International Labour Organization (ILO), it is estimated that around 2 million workers have breathed their last because of work accidents and occupational disease between 2010 and 2016 [3]. Moreover, according to [4], there are five causes of work accidents, including man factors, tools or machines, raw materials, and environmental factors. In addition, [5] research states that work accidents are mainly caused by unsafe

behaviour or man factor. Therefore, preventive measures regarding such issues must be planned, carried out, and monitored by implementing the correct OSH measures.

As a result of its efficacy as an OSHA measure for hazard identification, risk assessment, and risk control, the HIRARC method has been widely adopted by businesses all over the world, including in Indonesia. The HIRARC method has also been implemented at the five construction companies that are the subject of this study: PT Wijaya Karya (Persero) Tbk., PT Astanita Sukses Apindo, PT Glory Industrial Semarang II, PT Riau Andalan Pulp and Paper (RAPP), and PT Charoen Phokpand Indonesia. This was done in an effort to prevent and reduce the number of accidents that occurred on the job. [6, 7, 8, 4, 9] are the five scientific sources that the research draws from in order to investigate the implementation of HIRARC in various companies that manufacture a variety of different products. On the other hand, these sources have some drawbacks, such as the fact that they do not supply a detailed explanation of the risk analysis stage undertaken by each company nor of the workers' participation in the process of risk control.

The National Safety Council has highlighted the fact that human error is the leading cause of accidents that occur in the workplace. As a result, it is essential for businesses to place a high priority on the safety of their workforce by providing OSHA management and construction workers with HIRARC training and

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certification [10]. Companies are able to prevent and reduce risks to the environment and human health, ensure workplace safety, and promote sustainable development when they adopt hazard identification and risk assessment methods such as HIRARC.

2 Methodology

This study used a systemic literature review in order to collect the data needed. As stated by [11], a systematic literature review (SLR) is a method that is done by determining, identifying, and assessing the chosen sources critically in order to provide an explanation of the formulated question. Therefore, a well-planned search strategy for the defined question is needed.

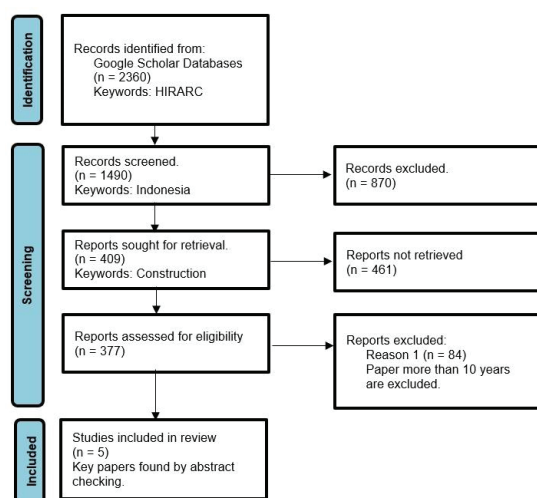


Fig. 1. Systematic Literature Review Methods

The systematic literature in this study was performed by means of accessing the Google Scholar database (<https://scholar.google.com/>). Google Scholar was chosen because it is one of the substantial databases to look for scientific sources such as journals, conference papers, theses, books, and many more. Moreover, Google Scholar allows the author to make use of a single and costless online resource which then can increase the author's ability to look for sources of a specific topic.

As depicted from Figure 1, when the keyword "HIRARC" was entered, there were 2,360 results shown. The results were then further limited by means of entering the second keyword "Indonesia" and the website showed 1,490 related results. The search then was narrowed down to keyword "Construction" which resulted in 409 records. From 409 records, research from more than 10 years and studies from identical company are excluded. Therefore, the author only chose five different sources which analyze five different companies that manufacture different products.

3 Results & Discussion

The HIRARC method has been implemented by several companies in Indonesia, including the five companies below:

Table 1. Summary of HIRARC Method Implemented by Construction Companies in Indonesia

Journal, Author, Year	Summary
Application of the HIRARC (Hazard Identification, Risk Assessment and Risk Control) method to the East Jakarta WIKA Tower project of PT Wijaya Karya (Persero) Tbk, [6]	HIRARC is one way to identify potential hazards in all types of work. The steps start with identifying hazards, then assessing risks and implementing controls. HIRARC is part of the structured Management System of Wijaya Karya (Persero) Tbk in the SHE Plan procedure. The WIKA-PEMPM-03.03 revision 02 procedure and HIRARC method risk assessment differ (Amd. 04). HIRARC was applied to the East Jakarta WIKA Tower Project without flow risk assessment. The HIRARC form with no column of applicable laws and regulations and the failure to communicate risk assessment results to workers and management representatives are non-compliance. Creating a good workflow, monitoring and communicating risk assessment results, following up on HIRARC audit results, reviewing SHE Plan procedures, and routine foreman supervision can improve risk assessment procedures.
Occupational Health and Safety Evaluation with the HIRARC Method at PT Charoen Pokphand Indonesia [4]	PT. Charoen Pokphand Indonesia consists of 4 areas: feed mill area, raw material area, silo area, and finished goods area. The company was in the preparatory stage of SMK3 certification using HIRARC. PT Charoen Pokphand Indonesia's HIRARC health and safety assessment revealed several dangerous activities. Activities had extremely high, high, and normal risk ratings. The silo area had 8.82% (extremely high), 14.71% (high), and 47.06% hazardous activities (average). Hazardous activities were 14% (extremely high), 35% (high), and 39% in the raw material warehouse (average). The company suggested sanctions, checklists, maintenance, device replacement, method changes, and training to address these issues. These measures are expected to reduce the extremely high risk rate in the silo area by 8.82% and the high and average risk rates by 23.53%. The raw material warehouse expects a 15.79% reduction in extremely high risk and 21.05% in high and average risk.
HIRARC Implementation as an Effort to Prevent Work	The number of work accidents in the production process at PT Glory Industrial Semarang II in 2014 as many as 350 cases. In 2015, it is

Accidents in Garment Production Processes [8]	decreased by 60.5% to 138 cases, and in 2016 workplace accidents occurred in the production process of PT Glory Industrial Semarang II increased 38.4% from the previous year to 224 cases. This study found that PT. Glory Industrial Semarang II applied 88 of 97 HIRARC (Hazard Identification Risk Assessment and Risk Control) applications in its production process. The author concludes that regulations must implement HIRARC.
Efforts to Reduce Work Accident Risk Rate Based on Clause 431 OHSAS 18001:2007 Using the HIRARC Method at PT Astanita Sukses Apindo [7]	Hazard identification yields PT Astanita Sukses Apindo must control 87 hazards—74 from factory activities and 13 from head office activities. At head office, acceptable is 5 to 8, priority 3 is 4 to 2, substantial is 1 to 8, priority 1 is 2 to 0, and very high is 12 to 0. Hierarchical control method implementation caused this reduction. 5 methods reduce risk. Elimination, substitution, engineering, administration, and PPE.
Analysis of the Application of Occupational Safety and Health (K3) in the Hot Tapping Steam Pipe Line Work (Case Study of the Asia Pacific Rayon Department of PT RAPP) [9]	Through a variety of hazard analysis techniques, including Job Safety Analysis (JSA) and Hazard Identification and Risk Assessment Determination Control, PT RAPP is able to recognize unsafe work practices and conditions (HIRADC). With these techniques, potential risks connected to each job step are identified, and control measures are developed. Another strategy, known as hazops, concentrates on the workplace, living quarters, equipment use, and production with the goal of identifying potential accidents and pinpointing the causes of work-related deviations. Unlike JSA and HIRADC, Hazops approaches hazard analysis in an unexpected way.

hazards, analyzing potential risks, risk assessment, risk control, monitoring, and evaluation. The steps above have been encompassed in the HIRARC method.

Based on the source, it was apparent that implementing the HIRARC method to the WIKA Tower project did not comply with the risk assessment process flow. It was shown that the HIRARC form for the WIKA Tower project did not in line with the fixed points. There were no applicable law and regulation columns within the paper. Moreover, The company needed to communicate the risk assessment result to the workers and the representative management. Such conduct is indeed violating the SHE Plan and OHSAS 18001:2007 procedures. The author also noted that implementing HIRARC, PT WIKA was inattentive in analyzing the risk assessment.

There were still so many unidentified hazards, such as, for example, the distribution of cast cement to iron reinforcement, bolt anchor installation, and curing rafts. However, all of the possible hazards have been identified in their area of drying, formwork installation, rebar work, embedding work, mixing with the molten, release of formwork, and mixing of batching plants.

Moreover, the author also found another non-compliance of PT WIKA in which the company needed to carry out risk control properly. It was doubled because workers' risk control participation still required improvement. Such a case then triggered the number of work accidents that continue to increase. Therefore, the author suggests that it is preferable that PT WIKA make a virtuous workflow, monitor and communicate the risk assessment result, follow up on the HIRARC audit result, review the SHE's plan procedure, and always have regular monitoring with the foreman. As for the conclusion, it can be noted that from PT WIKA's HIRARC, there were three controls they can use in project work: engineering control, administrative control, and PPE.

The source that investigates journal PT WIKA Tower East Jakarta is exemplary because it has been equipped with improvements or suggestions for a better Risk Assessment and Risk Control. However, the author has yet to be able to explain how engineering and administrative control should be carried out in the future.

3.1 PT Wijaya Karya (Persero) Tbk

PT Wijaya Karya (Persero) Tbk. is an Indonesian State-Owned Enterprise (BUMN) engaged in construction. Based on the work safety aspect, the number of work accidents at PT Wijaya Karya (Persero) Tbk was 12 times in all of the 2014 projects. The projects include some Steam Power Plant (PLTU) projects such as Tanjung Batu PLTU, Cilacap PLTU, Ketapang PLTU, Diesel Generator (PLTD) project at Ambon, and WIKA Tower Project. Among the tasks above, the WIKA Tower contributes the most, with seven accidents (PT Wijaya Karya (Persero) Tbk, 2014). Therefore, a risk management activity is urgently needed to reduce or eliminate the hazards that bring about work accidents. Risk management includes various steps: identifying

3.2 PT Astanita Sukses Apindo

PT Astanita Sukses Apindo is a company engaged in the manufacturing industry. The company produces fire engine units with various types and different specifications. However, the manufacturing locations have a high risk to put their workers in accidents or occupational diseases. That is because the factory was untidy with dangling cables on the streets, many sharp workpieces, chemical exposure, and also the workers not using personal protective equipment (PPE).

The hazard identification activity started by identifying the activities that have the possibility to risk the workers and then identifying the source of the possible hazards. Based on hazard identification, the potential risk that has the ability to carry potential risk for the workers can be taken into account. The author

noted that based on the identification result, there were 87 potential hazards of work accidents and occupational diseases. 74 potential risks were from production activities while the other 13 were from administrative activities.

One of the potential hazards is electrocution risk, which can cause the workers to faint or even worse, dead [12], [13]. Therefore, there are three categories of risk value for the electrocuted risk. The risk value is determined as follows:

1. Consequences

Consequences are given a value of 1 because fainting still can be given first aid, such as elevating the legs so that blood flow returns to the brain. Moreover, first aid can also be done by loosening tight clothing. After the worker can regain consciousness, if necessary, the worker can be transferred to the nearest hospital to receive further aid.

2. Exposure

Exposure was given a score of 3 because work with a high potential for electrocution in electrical parts is not carried out daily.

3. Probability

Probability is assigned a value of 1 because the probability is very small. The result of the risk assessment showed that the factory or production activities had 74 potential risks that were divided into 2 acceptable risks, 14 priority risks, 37 substantial risks, 9 priority risks, and 12 very high risks. Meanwhile, in the head office activities, there were 13 potential risks that were further divided into 5 acceptable risks, 4 priority risks, 1 substantial risk, 2 priority risks, and 1 very high risk.

After the identification process, risk control was then performed on the potential risk that can trigger work accidents or occupational diseases. The risk control was done by taking into account the risk value in order to determine the priorities and decide how to control each of the possible risks. Take for example the potential risk of hearing loss that is caused by the exposure to noise in workshop administrative activities at the factory had a risk value of 15, initially. However, after the risk control was performed by changing the room design, the risk value was lowered to 5. Some changes were made in the construction of the new administrative office such as replacing the holding door that functioned as a barrier between the production room and also the workshop administration.

After performing risk control, the number of potential risks both in the factory and head office activities was reduced. The reduction of the potential risk can be seen in the table below:

3.3 PT Glory Industrial Semarang II

PT. Glory Industrial II is a subsidiary of the Makalot Group company in Taiwan and was founded in 2005 in the Tanjung Emas Port area of Semarang. As an international company, Makalot continues to create new business models and jump out of the frame of traditional clothing manufacturers, and have a pivotal role in the global garment industry value chain. By establishing an advanced ERP system and global manufacturing

network throughout the Philippines, Indonesia, Vietnam, Cambodia, China, and Sri Lanka. As a great company that has many workers, PT Glory Industrial Semarang II surely has identified, assessed, and controlled the potential hazards and risks in the form of HIRARC, especially in the production process.

The author noted that the control application contained in the HIRARC document in the production process had 97 control applications, of which 29 were in the warehouse section, 29 were in cutting, 18 were in sewing, 8 were in ironing, and 13 were in finishing. Moreover, the source also confirmed that PT. Glory Industrial Semarang II has carried out Hazard Identification, Risk Assessment, and Risk Control (HIRARC) annually, yet a number of work accidents still occur.

After identifying the possible hazards, the author found that there were 62 potential risks in the production process at PT. Glory Industrial Semarang II. Such a huge number includes 12 potential risks in the warehouse process, 19 potential risks in the cutting process, 13 potential risks in the sewing process, 7 potential risks in the ironing process, and 11 in the finishing process. Moreover, after the risk has been identified, it was then further assessed by employing a priority scale that is divided into three, namely high (3), moderate (2), and low risk (1). High risk has a value of more than 51, moderate risk has a value between 26 to 50, and low risk has a value below 25. The risk assessment that was conducted by the author in the source found that there were 46 low risks, 11 medium risks, and 5 high risks.

An example of the implementation of the HIRARC method in the company can be seen in the warehouse process. In the lifting activity of the warehouse process, there are three risk controls written in the document. However, two risk controls were not performed, namely the conveyor and the absence of the conveyor due to the limitation that was made by the owner of the industrial area. The absence of the conveyor has the potential risk to cause muscle disorder or sprain, which has a priority scale of 3 which means that the potential risk is at a low-risk level.

As in the sewing process, the company had performed risk control by means of maintaining the machine. The maintenance was done by controlling and having regular checking of the sewing equipment. Before the tool is ready to be used, it will be checked by the sewing mechanic in order to make sure that it is safe to be used. The sewing equipment itself has the potential risk to injure the workers and has a priority scale of 3, meaning that it has a low risk.

Meanwhile, in the ironing process, the company did not perform 1 risk control activity out of 8 activities. The risk control that was not performed was cleaning the iron table. The ironing process itself has a potential risk of prolonged standing and muscle disorders which has a priority scale of 2, meaning that it has medium risk. In addition, the risk control by performing socialization of the K3 policy, which has the same priority scale, has been applied to the electricity area which has a danger of electrocution. The socialization was done by having K3 experts for all of the departments.

In the finishing process, there are also some risk control measures that were not performed in the company. The risk control that was not performed was waste disposal. The finishing process itself has the potential risk to cause muscle disorders and sprains, which has a priority scale of 3, which means that it has a low-risk level. Another risk control measure that was not performed is the use of trolleys. In the real field, the use of trolleys was replaced with small carts, although standardized tools are safer. Moreover, the company has noted that training is a process in which the workers can gather knowledge and learn basic skills in performing their job description. This conception is in line with the fact that knowledge affects the company's performance.

Besides training, monitoring activities were also carried out. During the monitoring, it was found that most of the workers did not use Personal Protective Equipment (PPE) while working. That is because the company did not provide appropriate PPE such as insulating footwear with applicable standards or regulations. The OSHA standard has clearly noted that the working footwear has to be made from aluminum, steel, fiber, or plastic that is non-slippery and can protect the worker's feet from heat and sharp objects to prevent potential work accidents.

3.4 PT Charoen Phokpand Indonesia

PT. Charoen Pokphand Indonesia is an animal food company located at Jalan Surabaya-Mojokerto KM 26, Krian. At the time when the source was written, the company was preparing for SMK3 certification. Therefore, the company wants to evaluate the OHS system with HIRARC, one of the supporting documents for SMK3 certification. Within the paper, the author argues that HIRARC has the goal to detect possible hazards in each work activity so that they can be controlled immediately to prevent and minimize workplace accidents.

In the Hazard Identification stage, two hazards were found in the PT. Charoen Pokphand. The first possible hazard is when the worker did not check the presence of other workers in the silo when operating the sweeper machine. In addition, the second possible hazard was from the fogging device that is hard sounding. After the hazards have been identified, the risk assessment was performed, and it was found that the fogging device has a risk value of 4 based on the AZ/NZS 4360:2004 and a likelihood value of 3. The value of 4 in the risk value is based on the severity of the potential risk in which the fogging device can cause hearing loss that can be considered a severe injury. Meanwhile, the value of 3 was given on the likelihood because based on the interviews, the author of the paper has come to a conclusion that sterilization activities are done regularly every week, and therefore workers are exposed to the hard sounding every week as they did not wear the provided earmuffs.

One of the risk controls measures that were done by PT Charoen Phokpand Indonesia were by having an OSH seminar in order to remind and make the workers aware of the importance of OSH. Another risk control measure that was pursued by the company was by

enacting regulations and enforcing fines or warning letters to any workers who did not perform their job according to the Standard Operating Procedure (SOP).

3.5 PT Riau Andalan Pulp and Paper (RAPP)

PT Riau Andalan Pulp and Paper or usually known as PT RAPP is a company based in Riau and produces fiber, pulp, and paper on a global scale. The company produces pulp with high-quality dry sheets. The production itself involves chemical products and modern machines such as extended Superbatch cooking, oxygen delignification, and Elemental Chlorine Free. With such a high quality, the pulp and paper from the RAPP company are exported to China, Singapore, Australia, Korea, and various European countries such as Russia, and Turkey, as well as countries in the Americas such as the USA, Mexico, and Brazil.

As the workers of the company have high exposure to chemicals and other hazards, therefore, the company has implemented the HIRARC method in risk management in order to prevent work accidents. With global exposure, it goes without saying that the work accidents in PT RAPP will lower the reputation of the company and cause mistrust among the consumer parties.

During the hazard identification, the paper noted that there are possible risks in some activities, including the hot tapping steam pipeline activity, hot tapping machine installation, and changing tubes. As for the hot-tapping steam pipeline activity, the risk includes fire and high temperatures. Despite such a risk, the workers did not put on their Personal Protective Equipment (PPE) and the company did not provide training for the worker on the hot tapping steam pipeline activity. Meanwhile, the hazards that were found in the process of the hot tapping machines installation include explosions, leaking pipes, bursting of sharp objects, electric shock, and environmental issues. As for the changing tube activity, the hazards are in the form of leaking pipes, explosions, fires, and electric shocks.

Noticing such hazards, PT RAPP performed several risk controls by means of elimination, substitution, engineering control, administration, and enforcing the use of PPE. The elimination measure was done by eliminating the source of hazards in order to minimize the potential risk. The elimination measure allowed the company to adopt a much better work system that is safer, such as removing the oil in the work area which has the risk to make the workers slip.

Meanwhile, the substitution measure was done by substituting dangerous tools, materials, system, or procedures that are safer or has less hazardous potential. An example of a substitution measure is when the workers are forced to work in a hurry, the system has to be substituted with a working system that is not hustle, allowing the workers to focus and reduce the possible risk of work accidents.

The engineering control measure was carried out by modifying tools or machines which have the goal to control the hazards at the production activity, such as providing machine protectors. Machine protectors itself was made in order to provide distance between workers

and devices so as not to come into direct contact with existing hazards.

Lastly, administrative control was performed by enacting work procedures, work rules, and regulations, providing job training, determining work duration, and installing hazard signs. The implementation of the administrative control can be seen in the technical process which uses machines that emits noises of more than 85dB. In such a case, administrative control was performed by limiting working hours so that the workers are not exposed to the noise for such a long duration. As for additional risk control, the company also provides its workers with Personal Protective Equipment (PPE) such as gloves, masks, helmets, safety clothes, glasses, ear muffs, safety shoes, etc.

The journal source above is exemplary. That is because the source has encompassed the HIRARC analysis and its control measures in a concise and informative manner. Moreover, the journal also provides suggestions for the company to provide proper PPE and enact strict sanctions for workers that disobey the established rules.

4 Conclusion

From the sources focusing on the implementation of HIRARC in the industrial sector that has been reviewed, it is crystal clear that the companies have implemented the HIRARC method. The HIRARC method was conducted in risk management in order to achieve the OHS goal of “zero accidents.” However, the implementation of HIRARC is still not optimal because, in each company, there were still some points that did not take into account by the company and the workers. Therefore, some work accidents still happen, such as seven work accidents that happened in PT WIKA in 2014 only.

Based on the hazard identification of five different manufacturing companies, it can be concluded that there are still many possible hazards in each company. The possible risks such as being electrocuted, being pierced by sharp objects, muscle disorder, ankle sprain, and hearing loss is the most common risk to happen among five different companies. However some companies, such as PT WIKA, are still inattentive to the possible hazards in the work activity, making some possible hazards remains unidentified and uncontrolled. The unidentified hazards surely endanger the worker and also showed the company's carelessness.

As for the risk assessment, most of the companies assessed the possible risk by means of the AS/NZS 4360:2004 standard to calculate the risk value. However, companies such as PT WIKA did not inform the result of the risk assessment result to both employees and the representative management. Such a case surely made the company, especially the management, have a hard time controlling the possible risk that can put the workers in dangerous situations.

Meanwhile, at the risk control stage, nearly all of the sources mentioned that the workers' participation in the risk control is still low. This notion then confirmed the study conducted by the National Safety Council has

noted that the main cause of work accidents is man factor. Most of the workers did not put on their Personal Protective Equipment (PPE) or even worse, the company did not provide it. Moreover, the company did not properly monitor the workers and did not enact strict sanctions on the workers that did not follow the SOP. Such a case made the work accidents that are caused by man factor continue to take place.

The fact that the HIRARC method is not optimally implemented in each company has probably become one of the main reasons why there are still a huge number of work accidents. Therefore, it is advisable to enforce training and HIRARC certification for all OHS management in every company in Indonesia. Work accidents itself are a complex thing that involves the working hand of the internals and also the workers. It is important for the company management to practice and develop workers' professionalism by having a safe and effective working system. A safe working system includes providing proper PPE and ensuring the equipment and the process can be done in the safest way. The company should also monitor the workers and also their working activity regularly in order to ensure the safety and performance of the workers.

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