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Fishbone Analysis of Human Error and Risk Control in High-Risk Construction Projects (Case Study: Biodiesel Project, South Kalimantan)

Dwi Iin Novianti*, Shine Pintor Siolemba Patiro, Rini Yayuk Priyati
Universitas Terbuka, Jakarta, Indonesia
Email: dwi_iin88@yahoo.co.id*, shinepintor@ecampus.ut.ac.id, rpriyati@ecampus.ut.ac.id

Abstract.
Workplace accidents continue to be a significant concern in the construction industry, particularly in high-risk activities such as working at height. This study aims to identify hazards and analyze the root causes of human error using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) and Fishbone Analysis approaches. The research uses a qualitative descriptive method, incorporating interviews, project photo/video observations, and document analysis to gather data. The findings reveal that the main contributing factors to human error include environmental conditions, human behavior, and work methods. Based on these findings, recommendations focus on enhancing supervision, implementing continuous safety training programs, ensuring the availability of ergonomic Personal Protective Equipment (PPE), and developing simple and effective work procedures. Fishbone Analysis proved to be an effective tool for identifying root causes and assisting in the development of a structured risk control strategy. The implications of this research emphasize the importance of a holistic approach to risk management, incorporating both technical and human factors to improve safety standards in construction projects.

Keywords: *Human error, Fishbone, HIRARC, accident, OSH*

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INTRODUCTION

Workplace accidents in the construction sector have shown a significant upward trend in recent years (Dai et al., 2022; Kim & Cho, 2016; Picchio & van Ours, 2017; Vargas-Garrido et al., 2021; Zago et al., 2018). Data from *BPJS Ketenagakerjaan* reveals a marked increase in workplace accidents, with cases rising from 370,747 in 2023 to 462,241 in 2024. One of the high-risk construction projects is the biodiesel project in South Kalimantan, managed by PT Wijaya Karya Rekayasa Konstruksi. This project involves high-risk activities such as working at heights, which are particularly prone to accidents caused by human error. Human error is often a major contributing factor to workplace accidents in construction, which directly impacts worker safety. Therefore, hazard identification, risk assessment, and root cause analysis of human error are critical in developing effective risk control strategies to mitigate these risks (Kumar et al., 2020; Lee et al., 2019; Sameera et al., 2021; Voon & Ariff, 2019; Yeow et al., 2020).

Data from *BPJS Ketenagakerjaan* indicates a rise from 370,747 cases in 2023 to 462,241 cases in 2024. The biodiesel construction project in South Kalimantan, managed by PT Wijaya Karya Rekayasa Konstruksi, involves high-risk activities such as working at heights, which are vulnerable to accidents caused by human error. This study focuses on hazard identification, risk assessment, and root cause analysis of human error as the basis for developing risk control strategies.

The study by Arief et al. (2020), which explored the causes of workplace accidents in the construction sector using a Human Factor Analysis approach, highlighted that human factors, such as negligence and lack of knowledge, play a significant role in accidents. While this research provided valuable insights into the importance of worker training and supervision, it lacked a systematic approach to identifying the root causes of accidents. Similarly, Prajapati et al. (2021) used the *HIRARC* method to assess risks in the construction industry and found that identifying environmental factors and work procedures was crucial in preventing accidents. However, their study focused primarily on risk identification and did not delve deeply into the human error aspects that directly lead to accidents.

This study addresses the gap in existing research by combining the *HIRARC* and Fishbone Analysis methods to not only identify risks but also analyze the root causes of human error in a more comprehensive manner. This approach aims to provide a better understanding of the factors contributing to accidents in construction projects and to develop more practical and effective risk control strategies.

This study aims to identify hazards, assess risks, and analyze the root causes of human error in the biodiesel construction project in South Kalimantan using the *HIRARC* and Fishbone Analysis approaches. The benefit of this study is to provide a deeper insight into the causes of workplace accidents in the construction sector and to develop more effective risk control strategies to prevent accidents caused by human error. The findings of this research are expected to offer practical recommendations for project managers and construction companies to improve safety standards on-site.

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MATERIALS AND METHODS

This study employs a qualitative descriptive approach. Data collection techniques include: (1) interviews with eight workers and supervisors (*project manager*, *supervisor*, and *SHE officer*); (2) indirect observation through photo and video documentation; (3) document review, including accident reports, *HIRARC* data, and *OHS* inspection reports; and (4) brainstorming sessions with the *project manager* and *supervisors*. Data analysis was conducted using the *HIRARC* (Hazard Identification, Risk Assessment, and Risk Control) method to identify hazards and risks, and the Fishbone Diagram to analyze the root causes of human error.

RESULTS AND DISCUSSION

Interview Analysis

Interviews with field workers revealed that unsafe actions are influenced by both individual factors and organizational system weaknesses. First, work supervision is considered weak; foremen rarely check the use of personal protective equipment (PPE) or adherence to procedures, reflecting "unsafe supervision" in the Swiss Cheese Model and a weak "Check" stage in ISO 45001. Second, worker age affects work behavior—young workers tend to be careless, while senior workers are more cautious—aligning with the Domino Theory and the concept of preconditions for unsafe acts. Third, work experience serves as a natural safeguard against human error, as experienced workers are more risk-aware. Fourth, the lack of training indicates weak organizational influence and poor implementation of the "Do" component in OHS programs.

Recommendations for improvement include: strengthening daily supervision and corrective actions, periodic training tailored to job risks, assigning tasks based on age and experience, and reinforcing OHS culture through communication and management involvement.

Hazard Identification (HIRARC)

A total of 238 potential hazards were identified across 37 work activities. About 73% were categorized as high risk, predominantly related to working at heights and operating heavy equipment. After conducting risk assessments, the risk levels of each hazard were determined. Most hazards associated with working at heights were classified as high risk before any control measures were applied. Therefore, appropriate risk control measures are necessary, such as:

1. Conducting fit-to-work assessments for all workers before performing tasks at height;
2. Requiring scaffolding personnel to inspect installed scaffolds and ensure the connectors are secure, and that all scaffolding workers hold valid licenses from the Ministry of Manpower;
3. Ensuring materials are not placed in hazardous areas.

   With the implementation of these control measures, the level of risk can be significantly reduced, allowing for safer work at heights. The HIRARC process is an integral part of the OHS management system and should be periodically reviewed or updated whenever work processes change.

Root Cause Analysis (Fishbone Diagram)

Based on interview and observation results, the main causes of human error are grouped into five categories:

1. Environment: unsafe working conditions, negative peer influence, and weak safety culture;
2. Man: low competence, poor safety awareness, age and experience influencing safe behavior;
3. Method: absence of standard procedures or procedures that are overly complex;
4. Machine: uncomfortable or unavailable PPE;
5. Material: materials not meeting specifications or unavailable when needed.

Work Program

OHS objectives are systematically designed and supported by work programs aimed at improving safety performance, with the primary target being Zero Fatality. Recommended strategies include:

1. Monthly reporting;
2. Dissemination of OHS policies;
3. Periodic and refresher training;
4. Active supervision at the worksite;
5. Evaluation and improvement of SOPs;
6. Provision of appropriate PPE and education on its use.

The work program includes objectives, targets, activities, and measurable outcomes, including frequency of implementation and expected outputs, facilitating effective evaluation and decision-making in the OHS domain.

Management's Role in Occupational Safety

Management plays a strategic role in the development and implementation of workplace safety systems through five key functions: policy setting, planning, organizing, implementation, and continuous evaluation. Safety policies reflect a commitment to zero accidents and a safe work culture.

Planning involves risk identification, emergency response planning, provision of PPE, and safety training.

Organizing is done by establishing a safety structure and assigning responsibilities at each organizational level (Ridley & Channing, 2008).

In the implementation phase, management fosters a safety culture, leads by example, and ensures procedures are enforced through consistent supervision and audits (Cooper, 1998).

The system is regularly evaluated through inspections, effectiveness measurements, and incident and near-miss analysis for continuous improvement (Hughes & Ferrett, 2011).

Challenges such as budget limitations, low worker awareness, inconsistent SOP implementation, and limited equipment are addressed through the HIRARC approach,

ongoing training, strict supervision, and regular investment in and maintenance of equipment.

Research Limitations and Constraints

This study encountered challenges such as limited access to data due to confidentiality and the need to conduct interviews remotely via Zoom because of the Covid-19 pandemic and the remote project location.

Moreover, since a qualitative approach was used and the study was conducted remotely, there were limitations in direct field observations, which prevented the full identification of some contextual information.

CONCLUSIONS

Human error is a major contributor to accidents in construction projects, particularly in work-at-height activities. The Fishbone approach effectively identifies the root causes of human error in a systematic manner. The analysis revealed that the most significant contributing factors were *Environment*, *Man*, and *Method*. As a result, the company's work programs are focused on addressing these three key areas. Improvements must be made through the implementation of an *OHS* management system based on *ISO 45001:2018* and by strengthening the safety culture at all organizational levels. Control efforts carried out by the company include safety campaigns, safety patrol programs, equipment inspections, and training.

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