

# Identification of Hazards and Risks of Forklift Activities in Warehouse Areas Using the HIRARC Method in the Green Safety Concept

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## Abstract

In warehouse operations PT XYZ, forklift activities represent one of the main sources of hazards due to direct interaction between humans, machines, and the work environment. Common risks include collisions between forklifts and pedestrians, falling loads, vehicle overturning, and impacts with warehouse structures, which may lead to serious injuries and material damage. This study aims to identify hazards and assess the risk level of forklift activities in the PT XYZ warehouse area to reduce the risk of forklift operation and provide risk control through the Green Safety concept. This study uses the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method and designs a risk control strategy based on the Green Safety concept. The results indicate five main activities that have potential risks, with the highest risk found in forklift operations along pedestrian paths and storage areas, having a risk value of 16 (high category) and a potential for collisions and worker injuries. Risk control efforts were carried out by separating forklift and pedestrian pathways, installing green reflective markings, and implementing IoT-based technologies such as distance sensors, speed limiters, and CCTV monitoring. The Green safety approach was also applied through the use of natural lighting and transparent roofing to improve visibility and energy efficiency.

**Keywords:** *hirarc, forklift, warehouse, occupational safety, green safety*

## Abstrak

Dalam aktivitas pergudangan PT XYZ, pengoperasian forklift menjadi salah satu sumber bahaya utama karena melibatkan interaksi langsung antara manusia, mesin, dan lingkungan kerja. Risiko yang sering terjadi meliputi tabrakan antara forklift dan pejalan kaki, jatuhnya muatan, tergulingnya kendaraan, serta benturan dengan struktur gudang, yang dapat menyebabkan cedera serius dan kerusakan material. Penelitian ini bertujuan mengidentifikasi bahaya dan menilai tingkat risiko aktivitas forklift di area gudang PT XYZ untuk mengurangi bahaya risiko pengoperasian forklift dan memberikan pengendalian risiko melalui konsep Green Safety. Penelitian ini menggunakan metode *Hazard Identification, Risk Assessment, And Risk Control* (HIRARC) serta merancang strategi pengendalian risiko berbasis konsep *Green Safety*. Hasil penelitian menunjukkan lima aktivitas utama yang berpotensi menimbulkan risiko, dengan risiko tertinggi terdapat pada pengoperasian forklift di jalur pedestrian dan area penyimpanan, memiliki nilai risiko 16 (kategori tinggi) yang berpotensi menyebabkan tabrakan dan cedera pekerja. Upaya pengendalian dilakukan melalui pemisahan jalur forklift dan pejalan kaki, pemasangan marka reflektif hijau, serta penerapan teknologi berbasis IoT seperti sensor jarak, speed limiter, dan CCTV monitoring. Penerapan Green safety juga dilakukan melalui penggunaan pencahayaan alami dan atap transparan untuk meningkatkan visibilitas dan efisiensi energi.

**Kata Kunci:** *hirarc, forklift, gudang, keselamatan kerja, green safety*

## 1. Introduction

Every activity or task performed by workers in the workplace always has the potential to pose risks that can endanger their health and safety. Workplace accidents not only cause physical and mental harm to workers, but also result in significant economic losses for companies, including medical costs, lost productivity, and worker compensation [1]. Therefore, the implementation of Occupational Safety and Health (OSH) is an important step in providing protection against these potential hazards. The main objective of OSH is to ensure that every individual in the workplace remains safe, healthy, and protected from the risk of accidents. With the implementation of good OSH principles, it is hoped that a safe, productive, and supportive work environment will be created for all workers [2]. A forklift is an industrial vehicle designed to move and arrange goods with high efficiency. This tool is equipped with a pair of forks

at the front that function as load supports, enabling the lifting and moving of loads that exceed human lifting capacity. In warehousing, manufacturing, and logistics facilities, forklifts are used for lifting, lowering, and moving goods between work locations. The use of forklifts increases work productivity and reduces the physical burden on workers, while also reducing the potential for injuries caused by manual lifting [3]. Risk is a combination of the likelihood of a dangerous event or exposure occurring, and the severity of injury or health impairment that may result from that event or exposure [4]. Risk can be understood as the potential for danger and the level of threat it poses, which can vary depending on how it is managed. Risk can also be measured by the impact or consequences that arise from an event [5]. Based on the Regulation of the Minister of Manpower of the Republic of Indonesia No. 8 of 2020 concerning Occupational Safety and Health (OSH) related to lifting and transporting, the elaboration also regulates the procedures for operating, inspecting, and maintaining forklifts on a regular basis. One of the forklift operating standards requires operators to have undergone training and obtained an OSH license issued by the Manpower Office [6].

PT XYZ is a company engaged in fertilizer production with a wide range of fertilizer products. Fertilizer is produced in large quantities and then stored in warehouses. Warehousing and Bagging are crucial divisions at PT XYZ. In each warehouse, there is also a bagging area for products that will be stored in the warehouse. The main problem encountered in forklift operations in the PT XYZ warehouse area is the potential for hazards that can pose risks to workers and the work environment, such as collisions, falling loads, or collisions with warehouse structures. In addition, physical conditions such as inadequate lighting and irregular forklift maintenance also increase the likelihood of accidents. Therefore, research is needed to identify sources of danger and assess the level of risk that arises during forklift activities. The results of this research can be used as a basis for establishing risk control measures and improving work safety in the warehouse environment.

To minimize these potential hazards and risks, the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) approach is used as a method of occupational safety analysis. HIRARC is a way to analyze risks that occur in the workplace and determine the severity level of occupational accident risks in that work area [7]. The use of HIRARC also helps companies comply with applicable occupational safety and health (OSH) standards and increases worker awareness and vigilance regarding workplace hazards [8]. This study integrates the concept of Green Safety, which is an operational management approach that combines occupational safety and environmental sustainability in warehousing activities, with the aim of creating a safe, energy-efficient, and people- and environment-friendly work environment. The application of this concept includes sustainability systems such as energy-efficient infrastructure, integrated risk management, and the use of technology and innovation [9]. By combining the HIRARC method and the green safety concept, it is hoped that a safe, efficient work environment can be created that supports the principles of green industry and operational sustainability of the company.

Previous research [10], shows that most studies only apply the HIRARC method, which still focuses on conventional hazard identification and risk assessment without integrating environmental sustainability aspects. Research related to safety in forklift operation [11], also tends to emphasize only technical factors, equipment conditions, and operator behavior, thus failing to combine a safety approach with the concept of green safety, which includes energy efficiency and reduction of environmental impact. This limitation indicates a gap in research on the development of a more comprehensive risk analysis model, namely one that integrates occupational safety and operational sustainability aspects simultaneously. Therefore, this study was conducted to fill this gap by applying the HIRARC method combined with the concept of green safety in forklift operations in the warehouse area of PT XYZ, so that can produce a more holistic safety approach and support the implementation of green industry.

This study aims to identify potential hazards and assess the level of risk in forklift operations in the warehouse area of PT XYZ using the HIRARC method and to design risk control strategies based on the green safety concept in order to create a safe, efficient, and sustainable work system. The results of this study are expected to serve as a reference in improving work safety performance while supporting the implementation of green industry principles through energy efficiency and reduced environmental impact in warehouse operational areas.

## 2. Material and Methods

### Data Collection

This study uses a descriptive qualitative approach to identify and analyze the level of occupational risk in forklift operations in the warehouse area of PT XYZ. Risk assessment is carried out based on the parameters of likelihood (frequency of occurrence) and severity (level of impact), in order to obtain the risk level, which is then used as the basis for determining risk control measures. The research was conducted

during the period of October–November 2025, involving forklift operators as informants. The data collection techniques used were observation and interviews.

### Hazard Identification, Risk Assessment, and Risk Control (HIRARC)

Hazard Identification, Risk Assessment, and Risk Control (HIRARC) is a systematic approach aimed at preventing workplace accidents and reducing risk levels through the implementation of appropriate control measures. The HIRARC process begins with determining the type of work activity, followed by identifying potential hazards from each activity to determine the level of risk. Next, an evaluation of the identified risks is carried out, followed by the implementation of control strategies to reduce or eliminate exposure to hazards in each type of work [12]. By applying the HIRARC method, various risk factors in a work activity can be identified in a more detailed and systematic manner [13].

#### a. Hazard Identification

A hazard is defined as an inherent characteristic of a source, situation, or action that can cause adverse effects such as accidents, injuries, damage to assets, or occupational diseases. Hazard categories include physical, chemical, mechanical, electrical, ergonomic, behavioral, environmental, biological, and psychological aspects. The hazard identification process aims to thoroughly recognize every potential cause of accidents and occupational diseases that pose a risk to workers [14].

#### b. Risk Assessment

Risk Assessment is a method for assessing risk hazards in the work area by assessing the potential hazards that have been identified in order to determine the level of risk posed by these hazards. There are two parameters for analyzing risk assessment, namely severity and likelihood. The likelihood scale is measured from risks that rarely occur to those that occur frequently. The severity scale is measured based on the level of impact, from the mildest to the most severe [7]. Risk assessment is conducted to ensure that risk control in a process or activity is at an acceptable level [15]. The following is a risk assessment table according to standards.

**Table 1.** Likelihood Measurement Scale

Scale	Definition	Description
1	Almost Never	Very rarely
2	Unlikely	May occur
3	Possible	Occurs occasionally
4	Likely	Occurs frequently
5	Almost Certain	Always occurs

Source : Malaysia Ministry of Human Resources (2008)

**Table 2.** Severity Measurement Scale

Scale	Definition	Description
1	Insignificant	No injury, minor financial loss
2	Minor	Minor injuries, minor financial losses
3	Moderate	Moderate injury requiring medical treatment, significant financial loss
4	Major	Loss of workdays, permanent/partial disability, moderate environmental damage, significant material losses
5	Catastrophic	More than one person died, the losses were enormous, disrupting all company activities, and the impact was widespread and comprehensive

Source : Malaysia Ministry of Human Resources (2008)

Risk assessment is conducted by calculating the likelihood of a hazardous event occurring within a specific period and the severity of injuries or damage that may occur. The severity of possible outcomes is assessed to prioritize the identified hazards. The risk assessment tool used is a risk matrix that combines the parameters of Likelihood (L) and Severity (S) [11]. To determine the risk level of a hazard, the following formula is used:

$$Risk = Likelihood \times Severity \tag{1}$$

After obtaining the results of the value of the risk of danger using the formula above, the next step is to enter the calculation results into the risk matrix column. The risk matrix is useful for determining the level of potential hazard risk that has been identified [7]. risk matrix is a tool in risk management used to identify, evaluate, and select risks based on the likelihood of occurrence and the consequences that may arise [16]. The risk matrix is shown in **Table 3**.

**Table 3.** Risk Assessment Matrix

Likelihood (L)	Severity (S)				
	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Source : Malaysia Ministry Of Human Resources (2008)

Based on **Table 3**, risk assessment is categorized into three categories. Green indicates low risk that does not require any action. Yellow indicates moderate risk that requires action. Red indicates high risk that requires immediate action and control.

c. Risk Control

Risk control is an effort made to deal with potential hazards in the work environment. This step begins with determining the priority scale, which serves as the basis for selecting the most appropriate control method, known as the risk control hierarchy. The results of the risk assessment are used as a reference in the process of implementing these controls. This process is carried out by identifying and understanding the potential risks that may arise so that effective preventive or mitigating measures can be determined [17]. Risk control aims to reduce the possibility of hazards occurring. These control measures can be implemented by applying a control hierarchy approach [18].

**Green Safety**

Green Safety is an occupational safety concept that integrates accident prevention efforts with environmental sustainability. Green Safety combines safety risk control with environmental performance in warehouse operations to create a safe, efficient, and environmentally friendly work system. This concept emphasizes that safety strategies should not only focus on worker protection but also support energy savings, emission reduction, and resource optimization as part of implementing green industry principles [1]. Green Safety combines two main pillars that is risk mitigation and environmental performance. Safety systems must protect workers while minimizing energy use, reducing emissions, and maximizing resource efficiency. This concept emphasizes that safety and sustainability are not separate objectives, but rather a unified whole in modern warehouse operations management [9].

**3. Results and Discussion**

**Hazard Identification**

The hazard identification process was carried out during the research by directly observing forklift operations in the warehouse area, conducting interviews with several parties, and reviewing field conditions to obtain a realistic picture of potential hazards. There were five forklift activities that presented risks from unsafe actions. The results of this risk identification are presented in Table 4.

**Table 4.** Hazard Risk Identification

Activity	Hazard	Risk
Driving a forklift in the warehouse and bagging area	Driving on uneven surfaces	Shaking of the load, causing it to fall
	Driving on pedestrian paths and product storage areas	Collisions with pedestrians and storage in warehouse areas
Transporting product loads from the bagging area	Transporting excessive loads	Unstable loads that could fall on nearby operators

Activity	Hazard	Risk
Transporting loads to the warehouse storage area	Transporting loads at high speeds	Unstable cargo falling and causing damage, collisions with pedestrians or products
	Carrying excessive loads	Low visibility, resulting in collisions with warehouse pillars/walls and nearby workers
Transporting product cargo to the warehouse platform area	Cargo falling from forks	Product load falls, causing damage and hitting workers
	Incorrect placement of load	Piled loads that are unstable can collapse and fall on workers
Carrying and replacing pallets in the bagging machine area	Pallets are unstable when placed in the bagging machine area	Pallets fall and are damaged

### Risk Assessment

After the Hazard Identification stage is completed, the identification results are used as the basis for conducting a risk assessment. Risk assessment is a process to measure the level of risk and determine whether the risk is acceptable or not. This analysis aims to determine the level of risk by considering two main parameters, namely the likelihood of occurrence and the severity of the impact, to obtain a risk rating. The risk rating indicates the classification of risk as low, medium, or high. The determination of likelihood and severity values refers to the Malaysian Ministry of Human Resources (2008) standard, and the risk assessment process is carried out on all identified potential hazards [17].

**Table 5.** Risk Assessment

Activity	Hazard	L	S	L X S	Risk
Driving a forklift in the warehouse and bagging area	Driving on uneven surfaces	3	1	3	L
	Driving on pedestrian paths and product storage areas	4	4	16	H
Transporting product loads from the bagging area	Transporting excessive loads	3	2	6	M
Transporting loads to the warehouse storage area	Transporting cargo at high speed	3	3	9	M
	Carrying excessive loads	2	2	6	M
Transporting product cargo to the warehouse platform area	Cargo falling from the forks	2	3	6	M
	Incorrect placement of cargo on the platform	3	2	6	M
Carrying and replacing pallets in the bagging machine area	Pallets are unstable when placed in the bagging machine area	3	1	3	L

### Risk Control

The following is to complete risk control for all potential hazards, including those with low to high risk levels. The application of these standards aims to reduce the frequency of workplace accidents and minimize the possibility of hazards in the work environment [19]. Risk control recommendations are shown in **Table 6**.

**Table 6.** Risk Control

Activity	Hazard	Risk Control
Driving a forklift in the warehouse and bagging area	Driving on uneven surfaces	Regular inspection and maintenance of floor conditions (flat, no holes, not slippery) and forklift suspension parts
	Driving on pedestrian paths and product storage areas	Separating forklift traffic lanes from pedestrian lanes and product storage areas with clear markings/signs

Activity	Hazard	Risk Control
Transporting product loads from the bagging area	Transporting excessive loads	Setting maximum height and weight limits for transport capacity according to forklift manufacturer specifications, adding a spotter in the bagging machine area
Transporting loads to the warehouse storage area	Transporting cargo at high speed	Speed alarm sensors and speed limiters are installed on the forklift, increasing area supervision by safety officers or CCTV
	Carrying excessive loads	Install alarm sensors and guard rails in areas prone to collisions, set maximum forklift load capacity limits
Transporting product cargo to the warehouse platform area	Cargo falling from the forks	Inspect and maintain the forks, check the forklift path, and limit the maximum speed of the forklift
	Incorrect placement of cargo on the platform	Ensure that the load placement area is clearly visible and mark the pallet positioning, train forklift operators on safe lifting and lowering techniques
Carrying and replacing pallets in the bagging machine area	Pallets are unstable when placed in the bagging machine area	Inspect and maintain the condition of forklift forks, add a spotter in the bagging machine area

### Green Safety

Based on the results of identification using the HIRARC method, it is known that forklift activities in the warehouse area have a moderate to high risk potential, especially in terms of collisions with pedestrians, load instability, and low visibility in the work area. Therefore, efforts are needed to improve warehouse management and design that not only focus on controlling these hazards but also integrate green safety principles to support operational safety and sustainability. Improvements are focused on facility design, management systems, and supporting technologies that reduce the potential for workplace accidents while also considering energy efficiency and environmental impact. One of the main steps is to change the layout of the warehouse walkways by separating the forklift operational lanes and pedestrian lanes using reflective green markings made from recycled materials.

In addition, the implementation of natural lighting systems and automatic sensors can optimize energy efficiency and support operator visibility, especially in areas with a high risk of collision. The use of transparent warehouse roofs can provide better lighting during transportation activities, thereby reducing dependence on electrical energy. Through these efforts, it is possible to improve the quality of lighting during transportation activities and also reduce dependence on electrical energy as well as open up opportunities for the use of renewable energy as a form of commitment to safe and sustainable energy efficiency [20]. From a safety perspective, installing proximity sensors on warehouse pillars and walls, speed limiters, and an IoT-based forklift monitoring system (CCTV monitoring) can prevent incidents caused by excessive speed or unsafe operating distances. The use of advanced technologies such as the Internet of Things (IoT) contributes significantly to improving the effectiveness of the Occupational Safety and Health risk management system [21]. In addition, the implementation of operator training programs on forklift hazards needs to be developed to increase awareness of safety and environmental responsibility in every operational activity. Routine checks and maintenance of forklifts before operation are also important to ensure that all units are in safe and usable condition so that the risk of accidents can be minimized.

### 4. Conclusion

Based on the results of research conducted using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) on forklift operational activities in the warehouse area of PT XYZ, there are 5 forklift operating activities in the warehouse area, namely driving forklifts in the warehouse and bagging areas, transporting product loads from the bagging area, carrying loads to the warehouse storage area, transporting product loads to the warehouse platform area, and carrying and returning pallets to the bagging machine area. Through the risk identification and assessment process, it was found that the highest risk was in driving forklifts on pedestrian paths and in storage areas, with a risk value of 16 (high category).

This risk has the potential to cause collisions and serious injuries to workers in the vicinity of forklift operations. The activity with the highest risk level was found to be operating forklifts on pedestrian paths and in product storage areas, with a risk value of 16, which is classified as high. This risk has the potential to cause serious accidents such as collisions and injuries to workers in the vicinity of the operation area. The control measure implemented is the separation of forklift and pedestrian paths. The Green Safety concept is implemented to reduce the risk of accidents while supporting energy efficiency and operational sustainability.

This implementation can be carried out by improving the warehouse layout by separating forklift and pedestrian paths using green reflective markings, applying natural lighting in the form of transparent roofs, and using IoT-based supporting technologies such as distance sensors, speed limiters, and monitoring systems (CCTV monitoring). In addition to technical aspects, improving the competence and awareness of forklift operators through work safety training, as well as conducting routine inspections and maintenance of forklifts, are important factors in reducing the potential for accidents. This study has limitations because it does not include an analysis of social aspects, such as worker behavior and communication dynamics between operators, which have the potential to affect the effectiveness of risk control.

Therefore, further research is recommended to integrate social studies, such as the level of compliance with safety procedures and the impact of technology implementation on comfort, safety, and interactions between workers in order to produce a more comprehensive evaluation of the effectiveness of risk control implementation with the Green Safety concept in warehouse operations.

## 5. References

- [1] M. Khatami, F. Putra, L. M. Zainul, K. Rusba, dan Y. Nawawi, "Inovasi K3 : Integrasi AI dan IoT untuk Meningkatkan Keselamatan Kerja," *Ranah Res. J. Multidiscip. Res. Dev.*, vol. 6, no. 5, hal. 2231–2239, 2024.
- [2] R. R. Simbolon, F. P. Harramain, M. Rizaldi, P. Sonjaya, J. A. Niaga, dan P. N. Bandung, "Pentingnya Penerapan Keselamatan Dan Kesehatan Kerja ( K3 ) Sebagai Faktor Penentu Optimalisasi Produktivitas Kerja Occupational Safety And Health ( OSH ) Implementation As A Determinant Of Work Productivity Optimization terjadinya sebuah kecelakaan tingg," *Pajam. Pajak dan Manaj. Keuang.*, no. 3, hal. 17–31, 2024.
- [3] T. N. Utami, C. A. Amanda, N. I. Azri, dan A. Arya, "Bahaya Fisik Pada Pengoperasian Forklift Di PT. X," *Prepotif J. Kesehat. Masy.*, vol. 8, hal. 6680–6690, 2024.
- [4] R. N. Hasibuan, S. K. Intan, dan H. Mahyar, "Analisis Risiko Konstruksi Bangunan Gedung Bertingkat Sedang Dengan Metode HIRARC," *J. Serambi Eng.*, vol. IX, no. 4, 2024.
- [5] U. F. Fitriani dan N. R. Jar, "Analisis Risiko dan Bahaya Kecelakaan Kerja di TPA Karangdiyeng Kabupaten Mojokerto," *J. Serambi Eng.*, vol. IX, no. 2, hal. 9151–9158, 2024.
- [6] A. Musyafa, N. N. Triana, dan A. A. Widi Rahayu, "Identifikasi Faktor Kecelakaan Kerja Operasional Forklift Dengan Menggunakan Metode JSA, Stop Six, Dan Pendekatan HIRADC (Studi Kasus: Departemen PPIC PT IPP, Bekasi – Jawa Barat)," *J. Teknol. dan Manaj. Ind. Terap.*, vol. 4, no. 2, hal. 340–349, 2025.
- [7] R. Amalia, D. Herwanto, dan W. Rana Zahra, "Analisis Potensi Bahaya Dan Risiko Kecelakaan Kerja Dengan Menggunakan Metode Hazard Identification Risk Assessment and Risk Control (Hirarc) Pada Pemotongan Kayu," *Ind. Inov. J. Tek. Ind.*, vol. 13, no. 1, hal. 13–19, 2023, doi: 10.36040/industri.v13i1.4523.
- [8] A. A. Gani, N. Rahdiana, dan W. T. Sasmi, "Penerapan Metode Hazard Identification Risk Assessment And Risk Control ( HIRARC ) Sebagai Pengendalian Risiko Kecelakaan Kerja (Studi Kasus Pada PT. Pilar Cakrawala)," vol. 4, no. 4, hal. 1519–1527, 2025.
- [9] M. H. M. Al-naser, S. S. Almehmeed, dan A. M. Al-subaie, "Sustainable Warehouse Operations Safety: Integrating Risk Mitigation and Environmental Performance in Modern Logistics," *Glob. J. Manag. Bus. Res.*, vol. 25, no. 5, 2025.
- [10] P. Dwiansyah, "Usulan Pengendalian Risiko Keselamatan Dan Kesehatan Kerja Menggunakan Metode HIRARC di PT Buana Niaga Bersama," *J. Serambi Eng.*, vol. VIII, no. 2, hal. 5817–5824, 2023.
- [11] H. R. Rahman, Nelyana Ashara, Alivia Klarissa Faradilah, Siti Sahara, dan Vivian Karim Ladesia, "Analisis Risiko Keselamatan Kerja Terhadap Aktivitas Forklift di PT Pertamina Lubricants Unit Production Jakarta," *J. TESLINK Tek. Sipil dan Lingkung.*, vol. 5, no. 2, hal. 8–15, 2023, doi: 10.52005/teslink.v5i2.242.

- [12] Della Putri Adjani dan Restu Hikmah Ayu Murti, "Identifikasi Bahaya Menggunakan Metode HIRARC Pada Pekerjaan Pemeliharaan Gardu dan Jaringan Distribusi PT PLN UP3 Cengkareng," *Antigen J. Kesehat. Masy. dan Ilmu Gizi*, vol. 2, no. 2, hal. 39–51, 2024, doi: 10.57213/antigen.v2i2.257.
- [13] Y. V. Pramesthi, "Identifikasi dan Pengendalian Bahaya K3 Pada Aktivitas Suplai Air Bersih untuk Kapal di Dermaga XYZ Menggunakan Metode JSA dan HIRARC," *J. Serambi Eng.*, vol. X, no. 1, hal. 12326–12334, 2025.
- [14] Ajeng Afriza dan Sinta Dewi, "Analisis Risiko Kesehatan Dan Keselamatan Kerja Pada Area Proses PT. XYZ Menggunakan Metode HIRARC," *Jupiter Publ. Ilmu Keteknikan Ind. Tek. Elektro dan Inform.*, vol. 2, no. 1, hal. 67–77, 2024, doi: 10.61132/jupiter.v2i1.54.
- [15] F. Rahman dan D. Herwanto, "Identifikasi, Penilaian dan Pengendalian Risiko Kecelakaan Kerja dengan Metode HIRARC di PT ABC," *J. Ilm. Wahana Pendidik.*, vol. 8, no. 2, 2022, doi: 10.5281/zenodo.6138505.
- [16] J. L. Allo, "Evaluasi Kecelakaan Kerja Penyimpanan Material Berat di Gudang Logistik Menggunakan HIRARC," *J. Ind. Eng. Technol.*, vol. 1, no. 1, hal. 55–62, 2025.
- [17] S. C. Sudiantoro, E. Lestari, dan M. Zein, "Analisis Pengendalian Risiko Kecelakaan Kerja pada Proses Produksi di PT. XYZ menggunakan Metode Hazard Identification Risk Assessment and Risk Control," *J. Ilm. Inov.*, vol. 23, no. 1, hal. 27–33, 2023, doi: 10.25047/jii.v23i1.3829.
- [18] D. H. Wibowo, N. Pangastuti, dan S. Parningotan, "Analisis Risiko K3 Dengan Menggunakan Metode Hazard Identification , Risk Assessment and Risk Control ( HIRARC ) Pada Gedung HDI Hive Menteng," *Venus J. Publ. Rumpun Ilmu Tek.*, vol. 2, no. 4, 2024.
- [19] H. Fadili, M. F. Perdana, Suryadi, dan D. Suryapranatha, "Identifikasi Potensi Bahaya Keselamatan Dan Kesehatan Kerja Dengan Menggunakan Metode HIRARC: (Studi Kasus: PT. GGS)," *J. Teknol. dan Manaj. Ind. Terap.*, vol. 4, no. 3, hal. 802–814, 2025.
- [20] P. D. Purnama dan H. N. Azizah, "Determination of Building Assets and Equipment Requirements Based on Sustainable Warehouse Concepts for PT Kansai Prakarsa Coatings," *J. Infrastruct. Facil. Asset Manag.*, vol. 7, no. 3, hal. 45–54, 2025.
- [21] A. T. Husna, M. Suluhniate, dan M. Harahap, "Model Integrasi K3 dan Manajemen Risiko untuk Meningkatkan Daya Saing Organisasi," *J. Penelit. Multidisiplin Ilmu*, vol. 4, no. 1, hal. 3055–3066, 2025.
- [22] Department of Occupational Safety and Health, Ministry of Human Resources Malaysia, *Guidelines for Hazard Identification, Risk Assessment and Risk Control*, Malaysia, 2008.