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Risk analysis and safety measures: JSA, HIRA, and FTA in LPG distribution

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ABSTRACT

Industrial competition is intensifying, raising the importance of Occupational Safety and Health (OSH) practices. This study focuses on LPG distributor Fajar Sidiq Nurhidayah, a company specializing in 3 kg LPG cylinders. The lack of safety inductions and adequate Personal Protective Equipment (PPE) heightens the risk of workplace accidents, necessitating this research to mitigate such risks. Employing the Job Safety Analysis (JSA), Hazard Identification and Risk Assessment (HIRA), and Fault Tree Analysis (FTA) methods, potential hazards were identified. JSA revealed risks like collisions, being struck by the truck's back, tube pinching, and ergonomic hazards, foreseeing injuries ranging from bruises to fractures and Musculoskeletal Disorders (MSDs). HIRA uncovered six hazards: one low-risk, four medium-risk, and one high-risk. FTA pinpointed the primary danger source to be the warehouse station due to operator negligence during tube lifting, lack of PPE usage, and entangled tubes, emphasizing the worker's condition and work environment.

1. Introduction

As times evolve, job landscapes undergo significant transformations, fostering intensified competition within industries. Within the industrial sector, Occupational Safety and Health (OSH) demands keen attention, necessitating its application across all industry domains. As cited in [1] from the Occupational Safety and Health (OSH) book, the lack of adequate knowledge among workers or employees regarding OSH, provided by their respective companies, stems from a lack of awareness about the crucial significance of OSH. This knowledge gap leads to numerous industrial accidents each year, varying from non-serious to severe and, at times, even fatal incidents.

According to the Ministry of Manpower of the Republic of Indonesia the number of work accident cases in Indonesia in 2021 will reach 234,370 type [2], with the high number of work accident cases occurring, research is needed to identify and analyze hazards in the workplace, by identifying and analyzing these potential hazards, the company can carry out more prioritized handling of potential hazards that may occur and the government, which is the regulator, can supervise and emphasize the application of OHS regulations for workers. OSH problems in the industrial sector are a problem that has been extensively researched by many parties, including research on "OHS Analysis at the Dwi Jaya Motor Workshop Using the Integrated HIRA Method of the FTA Method" conducted by [3], further research on "Analysis of Occupational Accident Risk Control Section Mechanics at the Ampana PLTU Project (2x3 MW) Using the Job Safety Analysis (JSA) Method [4], and HIRA Analysis (Hazard Identification and Risk Assessment) research at Agency X in Semarang [5]. The number of studies on OHS analysis in the industrial sector shows the importance of this research.

In this research, the analysis carried out is to analyze the hazard of work accident risks using the Job Safety Analysis (JSA) method and the Hazard Identification and Risk Assessment (HIRA) method and the Fault Tree Analysis (FTA) approach. The JSA method is a risk identification that aims to provide decisions based on risk information and ensure safe operations for users [6]. JSA is used to identify potential hazards related to the steps or processes of loading and unloading work, while HIRA is used to identify potential hazards related to the environment, equipment, and/or machinery used within the area of the distributor LPG Fajar Sidiq Nurhidayah. The FTA method is used to find out the root cause of the highest HIRA score.

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OHS analysis in this study was carried out at Distributor LPG Fajar Sidiq Nurhidayah. Distributor LPG Fajar Sidiq Nurhidayah is a company active in the distribution of 3 kg LPG cylinders. This company carries out the process of loading and unloading 3 kg LPG cylinders in its warehouse. The company has an allocation of around 60,000 cylinders of 3 kg LPG per month. This allocation can be said to be quite a lot for a company engaged in the distribution of 3 kg LPG cylinders. With so many distributions, it can cause work accidents at the company because the loading and unloading process is not only carried out by employees of Distributor LPG Fajar Sidiq Nurhidayah but also carried out by bases that partner with Distributor LPG Fajar Sidiq Nurhidayah. The number of base partnering with Distributor LPG Fajar Sidiq Nurhidayah is 72 active bases. The absence of safety induction and adequate PPE also increases the risk of work accidents at Distributor LPG Fajar Sidiq Nurhidayah, so this research is needed to reduce the risk of work accidents.

2. Material and method

Distributor LPG Fajar Sidiq Nurhidayah distributes 3 kg LPG cylinders to the base, this distribution is carried out at Distributor LPG Fajar Sidiq Nurhidayah's warehouse with a manual loading and unloading process, there is no safety induction, and adequate PPE can increase the risk of work accidents, so this research is needed to reduce the risk the work accident. In this study the methods used are the Job Safety Analysis (JSA) method, the Hazard Identification and Risk Assessment (HIRA) method, and the Fault Tree Analysis (FTA) approach.

2.1. Job Safety Analysis (JSA)

Job Safety Analysis (JSA) is an inspection procedure to determine whether procedurer that have been or are being carried out have been carried out in accordance with OHS principles. JSA is also used to examine aspects of the attitude of the personnel carrying out the work. The main objective of job safety analysis is to prevent accidents from happening with the hierarchical principle of risk control. Job safety analysis has the primary goal of preventing accidents from happening by using a risk control hierarchy. JSA is one of the main steps in the process of analyzing work hazards and accidents with the goal of creating better work safety. If the hazard has been identified, the next step can be taken with control measures in the form of physical changes or improvements to work procedures that can reduce or even eliminate the risk of work accidents. In carrying out the analysis of work safety procedures, training, supervision and writing of job descriptions, commonly known as JSA, are needed to facilitate the understanding of work procedures for workers [7].

JSA is a method that many used in research on OSH. JSA is a method used to determine work sequences, identify potential hazards, and then control them. JSA is carried out before carrying out related work, so that workers know the hazards that will be faced when the work is carried out. The American National Safety Council (NSC) defines that the JSA is an instrument used to identify existing methods and identify unsafe work practices, which is then corrective action before an accident occurs [8].

In carrying out an analysis of potential job hazards using Job Safety Analysis there are four basic steps, namely [7]:

1. Choose jobs to analyze. At this stage, location determination, initial observations, and interviews are carried out to determine risks related to the work to be analyzed
2. Define sequence, and work steps. At this stage, the steps and order of work activities are determined based on previous observations.
3. Recognize and analyze hazards for each work step. At this stage identification of hazards that may occur in the activities carried out.
4. Determine the best solution to carry out each step of the job safely. At this stage a solution is determined for each hazard identified in work activities.

Risk Control Hierarchy is a sequence in the prevention and control of risks that may arise which consists of several levels in sequence. One of them is by making a control plan includin [9]:

- Elimination is a risk control that is permanent in nature, and must try to apply, and to be implemented as a top priority. Elimination is achievable by moving objects or work systems related to the workplace that are unacceptable by OHS provisions, regulations or standards or levels that exceed the permitted Threshold Value (NAV). The best way to control is by elimination because potential hazards can be eliminated.
- Substitution, the way to control substitution is to replace materials and equipment that are more dangerous with materials and equipment that are less hazardous or safer.
- Engineering Control, engineering control includes changing the structure of the work object to prevent someone from being exposed to potential hazards. The control method is carried out by providing machine guards, covering conveyor belts, making machine foundation structures with cast concrete, providing mechanical aids, providing sound absorbers on the walls of the engine room which produce high noise, and other.
- Administrative Control (Admistration Control), the control is carried out by providing a work system that can reduce the possibility of a person being exposed to potential hazards depending on the behavior of the worker and requires regular supervision to comply with this administrative control. This method includes recruiting new workers according to the type of work to be handled, setting work time and rest time, work rotation to reduce boredom and boredom, applying work procedures, rearranging work schedules, skills training, and OSH training.
- Personal Protective Equipment (PPE), PPE that is used to limit the body's exposure to potential harm

received by the body.

In determining risk control for identified hazards, the following matters must be considered: Has there been any past risk control? If there is, whether the control is adequate or not. If it is not sufficient, determine new control measures to eliminate or reduce risk to the lowest possible level [9].

2.2. *Hazard Identification and Risk Assessment (HIRA)*

Hazard Identification and Risk Assessment (HIRA) is a work accident analysis method which is used before carrying out a job or activity. The HIRA method is used to facilitate the hazard identification process. The way to complete this method is considered entirely simple in determining the level of risk and control according to risk. In addition, the HIRA method is also used as an effort made to reduce the level of risk and potential harm that will occur [5]. HIRA is a work step consisting of: the process of identifying hazards in an activity, identifying and assessing the risks of these hazards, which ends with controlling the risks and hazards that have been identified previously [10].

The steps to identify hazards begin with determining the work to be inspected for potential risk, breaking the work into work steps, determining the critical work stages, identifying the source of the hazards, providing control, keeping records, communicating to the executor of the work, and reviewing it [10]. In HIRA there is a risk assessment. Risk assessment is a thorough process of risk identification, risk analysis and risk evaluation based on stakeholder knowledge and views. The likely severity of events is measured to prioritize the identified hazards. A risk assessment tool in the form of a risk matrix rating which is a combination of the likelihood and severity parameters with E (extreme risk), T (high risk), S (moderate risk) and R (low risk). The combination of likelihood (L) and severity (S) can determine risk assessment because the results of risk calculations are formulated as matrix multiplication presented in an effective way to provide risk estimates or risk ratings as a basis for taking risk control measures by selecting the necessary control measures [11]. Table 1 shows likelihood criteria based on (AS/NZS, 4360:2004) [12]. Table 2 shows severity criteria based on (AS/NZS, 4360:2004) [12]. Table 3 shows risk matrix table based on (AS/NZS, 4360:2004) [12].

Notation E, Extreme Risk, requires immediate countermeasures or termination of top management activities or involvement, improvement must be as soon as possible. Notation H, High Risk (high risk), requires training by management, needs corrective action as soon as possible. Notation M, Moderate Risk (medium risk), needs to be handled by related management. Notation L, Low Risk (low risk), controlled by procedures [11].

2.3. *Fault Tree Analysis (FTA)*

Fault Tree Analysis (FTA) is a method of analysis of deductive reliability techniques and safety analysis which is usually used for complex dynamic activities. FTA is a logical model with graphics representing various combinations of undesirable events [13]. FTA is a technique for identifying failures of a system [14].

Table 1.
Likelihood criteria

Level	Description	Information
A	Almost Certain	Occurs in almost all circumstances, for example, there is 1 event every day
B	Likely	It is very possible in all circumstances. For example, there is 1 incident in 1 week
C	Moderate	Can happen at any time. For example, there is 1 event in 1 month.
D	Unlikely	It may happen from time to time. For example, there is 1 event in 1 year
E	Rare	Can only occur in certain circumstances. For example, there was 1 event in more than 1 year

Table 2.
Severity criteria

Level	Description	Information
1	Insignificant	There were no injuries, very little material loss
2	Minor	Minor injuries, requiring first aid treatment, can be handled immediately at the scene, moderate material losses
3	Moderate	Missing workdays, requiring medical treatment, material losses are quite large
4	Major	Injuries result in total disability or loss of bodily functions, large material losses
5	Catastrophic	Causing death, huge material loss

Table 3.
Risk matrix

Likelihood	Severity				
	1	2	3	4	5
A	M	H	H	E	E
B	M	M	H	H	E
C	L	M	H	H	H
D	L	L	M	M	H
E	L	L	M	M	H

FTA is function oriented or commonly known as the "top down approach" because this analysis starts from the system level (top) and continues down [15].

2.4. *Identification of potential OHS hazards*

Table A1 (see Appendices) shows potential OHS hazard identification using the JSA (Job Safety Analysis) method at Distributor LPG Fajar Sidiq Nurhidayah during loading and unloading activities of 3 kg gas cylinders. Table A2 (see Appendices) shows potential OHS hazard identification using the HIRA method at Distributor LPG Fajar Sidiq Nurhidayah during loading and unloading activities of 3 kg gas cylinders. Fig. 1 shows FTA for identifying potential hazards using the FTA (Fault Tree Analysis) method at Distributor LPG Fajar Sidiq Nurhidayah.

3. Results and discussions

3.1. *Potential Hazard Analysis with the JSA*

In Table 4 it is known that there are 6 work steps carried out at Distributor LPG Fajar Sidiq Nurhidayah in the loading and unloading of 3kg gas cylinders. The first work step is that the worker parks the truck containing the filled tube with identification of the potential hazard of hitting a wall/another car/worker, with the risk that the worker may experience bruises. Risk control is the first work step, namely administrative control by making regulations in the warehouse parking area and making displays of caution when driving and PPE in the form of using a safety vest to make it easier to see.

The second work step for workers is to park a pick-up truck containing empty cylinders with identification of the potential hazard of hitting a wall/another car/worker, with the risk that the worker may suffer bruises. Risk control of the second work step is administrative control by making regulations in the warehouse parking area and making displays of caution when driving and PPE in the form of using a safety vest to make it easier to see. In steps one and two, the risk posed is only causing bruises because the steps to park the car are driven only at a speed of around 5 km/hour.

The third work step is for the worker to open the tailgate of the truck by identifying the potential danger of being hit by the tub, with the risk that the worker can experience bruises and fractures. Risk control of the third work step is engineering using assistive devices, administrative control by making SOPs, and PPE in the form of gloves and safety shoes. Truck doors are heavy, because it is their weight that can pose a big risk. The work steps of the four workers unload empty cylinders from the pick-up truck to storage by identifying the potential dangers of being crushed by the tubes and being pinched by the tubes, ergonomic hazards in the form of repeated movements lifting gas cylinders, with the risk that workers can experience bruises and fractures, workers can also experience symptoms of Musculoskeletal Disorders. Risk control for the fourth work step, namely engineering by using tools in the form of trolleys, administrative control by making SOPs and displays about OHS, and PPE in the form of gloves and safety shoes.

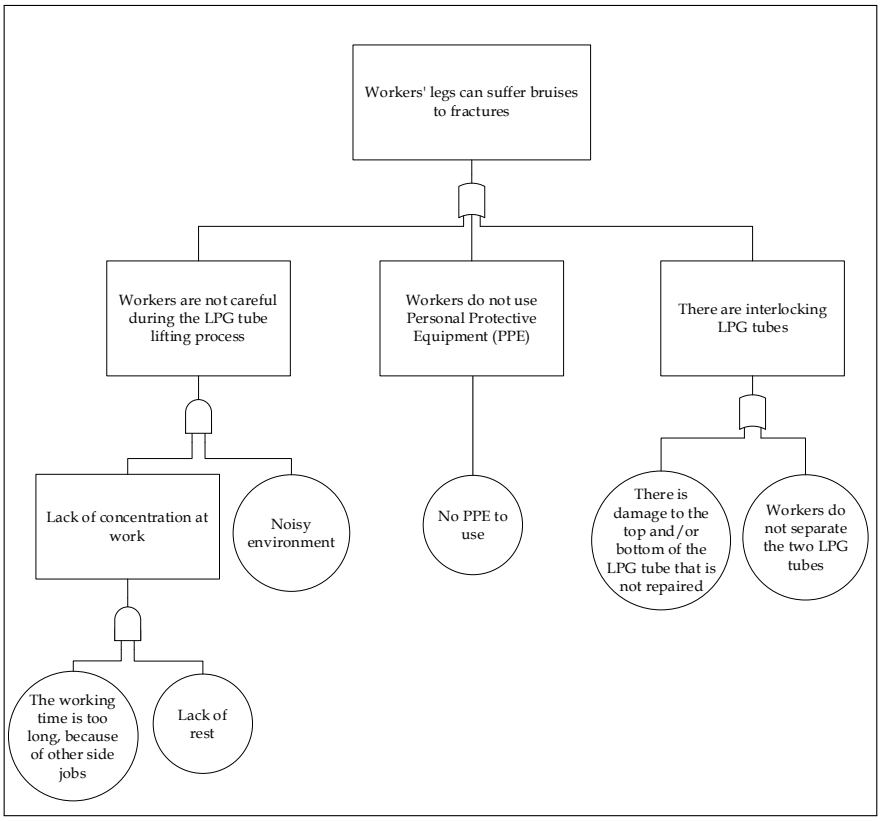

Figure 1. Identification of potential hazards with FTA (Fault Tree Analysis)

Pinched in research [16] was carried out using PPE in the form of helmets, anti-irritation goggles, dust masks, earplugs and holding a briefing before the activity. The use of tools can reduce the level of work fatigue in transporting 3 kg gas cylinders [17].

The fifth work step is for workers to unload cylinders from trucks and load them into pick-ups with identification of potential hazards of being crushed by stacks of tubes and pinched by tubes, ergonomic hazards in the form of repeated movements lifting gas cylinders, with the risk that workers can experience bruises and fractures, workers can also experience Musculoskeletal Disorders (MSDs) symptoms. Risk control of the fifth work step, namely engineering by using tools in the form of trolleys, administrative control by making SOPs and displays about OHS, and PPE in the form of gloves and safety shoes.

The 6th work step for workers to load empty cylinders from storage to a truck with identification of the potential hazard of being crushed by a pile of tubes and being pinched by the tubes, ergonomic hazards in the form of repeated movements lifting gas cylinders, with the risk that workers can experience bruises and fractures, workers can also have musculoskeletal symptoms Disorders (MSDs). Risk control for the sixth work step, namely engineering by using tools in the form of trolleys, administrative management by making SOPs and displays about OHS, and PPE in the form of gloves and safety shoes. In the loading and unloading step (Steps 4, 5 and 6) the risk of bruises and broken bones is caused by the absence of PPE provided by the company, then for the risk of MSDs it is caused by repeated loading and unloading activities (lifting gas cylinders manually without tools) repeat. MSDs are disorders of the skeletal muscles caused by the muscles receiving static loads repeatedly and continuously for long periods of time [18]. Repetitive work in the hoeing process can cause back injuries [19].

In reference to heavy equipment or vehicles in this article using a forklift can cause serious injury [20], while in JSA the gas cylinders of a truck vehicle cause bruises because the speed of the truck being driven is only 5 km/hour. The results of risk control using JSA are predicted to minimize the potential for accidents and employee occupational health, and help improve performance [21].

3.2. *Hazard Analysis Using the HIRA*

In Table 5 it is known that there are six hazard findings, the first finding is that the handle of the tube is broken, with a risk the workers' hands can be scratched or bruised. The second hazard found is that the rubber carpet is slippery because it is struck to water, with the risk that workers can sprain. Slips can also be caused by oil spills, as in research [22] on practical activities in the laboratory. The third hazard found is that the top and bottom of the tube is damaged, the risk is that workers can experience bruises and fractures. Avoid using dented tubes, tubes with rusty and dented bottoms are more prone to leaks [23]. The fourth hazard finding is that workers do not use PPE, resulting in a risk of bruising fingers and breaking bones. The fifth hazard finding is that workers do not use PPE with the risk that workers' feet can experience bruises, and fractures. The sixth hazard finding is the door of the tailgate which is heavy with the risk that workers can experience bruises and broken bones. This hazard originates from the tailgate door. In research, the installation process of the hydraulic system has a potential risk of being crushed by the drum of a truck with a very high risk value [24]. Hazards 3 to 6 have a risk severity level that is at the same level, namely moderate, with information that it can cause lost workdays, requires medical treatment, material losses are quite large, but at hazard 5, workers do not use PPE, safety shoes have a high probability of hazard 3, 4, and 6, only have an unlikely probability level, however the 5th hazard has a higher level of risk with hazard risk index 3B, risk assessment category H, so that risk priority is obtained form of high risk.

3.3. *Identification of the Highest Hazard Potential with the FTA*

In the data processing, it was obtained that the top event in the FTA analysis came from the 5th hazard finding, namely a warehouse place/station with hazard findings in the form of workers not using PPE safety shoes. Based on the hazard, the top event is obtained in the form of a worker's leg that can experience bruises and fractures. Based on the logic gate (logic event OR) the top event is caused by three top events, namely the first top event in the form of an operator who is not careful in the process of lifting the tube, the second top event in the form of an operator not using personal protective equipment (PPE), the third top event in the form of there are interlocking tubes. For top events caused by operators not being careful during the tube lifting process.

Based on the logic gate, the top event is caused by one top event and one basic event, namely lack of concentration at work and a noisy environment. Lack of caution when working can also occur due to workers being sick, workers not concentrating, and workers being in a hurry at work [25]. Lack of focus/concentration in research [26] was caused by operators being bored and the production floor being uncomfortable. Based on the logic gate (logic event AND), the top event was caused by two basic events, namely working hours that were too long, due to other side jobs outside working hours at Distributor LPG Fajar Sidiq Nurhidayah and lack of rest time for workers.

Top event operators do not use personal protective equipment (PPE) based on this logic gate, because there is no PPE that can be used, in contrast to research [27], workers do not use PPE because there are no strict sanctions, therefore, it is better if Distributor LPG Fajar Sidik Nurhidayah has provided PPE and supervised

workers so that they always use PPE. The reference made by Daulay and Nuruddin [3] stated that the root cause of the accidents that occurred were caused by three factors, including tools, humans, and the environment. From the tool factor, accidents occur because the condition of the tool is not good, and there is no protection for the tool used. When viewed from the human factor, accidents that occur are caused by workers' lack of focus, negligence, and neglect of the use of personal protective equipment, while from environmental factors work accidents occur due to an environment that is not conducive. FTA is an effective tool, but if it is used on more and more complex systems, the fault tree will get bigger and take longer to work on [28].

4. Conclusions

Loading and unloading activities at Distributor LPG Fajar Sidik Nurhidayah using the JSA method produce six work method steps, with risk control that can be carried out by engineering, administrative, and using personal protective equipment. In the HIRA method, the highest number of risk assessments was found to be medium risk, with one high risk.

The root of the problem that is sought using FTA is caused by workers not being careful during the lifting process, workers not using PPE, and there are tubes that are intertwined.

Declaration statement

Nustin Merdiana Dewantari: **Conceptualization, Methodology, Supervision, Writing – Original draft**. Muhamad Ferdianyah: **Conceptualization, Resources, Writing, validation, Data Curration**. Lely Herlina: **Conceptualization, Writing, Validation, Data Curration.** Ade Sri Mariawati: **Conceptualization, Writing, Validation, Data Curration.** Ani Umyati: **Conceptualization, Resources, Writing, validation, Data Curration.**

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The authors confirm that the data supporting the findings of this study are available within the article or its suplementary materials.

References

[1] A. Hasibuan *et al.*, *Keselamatan dan Kesehatan Kerja*. Padang: PTGlobal Eksekutif Teknologi, 2022.

[2] K. ketenagakerjaan RI, "Profil Keselamatan dan Kesehatan Kerja Nasional Indonesia Tahun 2022," 2022.

[3] R. F. Daulay and M. Nuruddin, "Analisis OHS di bengkel Dwi Jaya Motor dengan Menggunakan Metode HIRA Terintegrasi M," *JUSTI (Jurnal Sist. Dan Tek. Ind.*, vol. 2, no. 4, pp. 571–579, 2021, doi: 10.30587/justicb.v2i4.4246.

[4] S. S. C. Balili and F. Yuamita, "Analisis Pengendalian Risiko Kecelakaan Kerja Bagian Mekanik Pada Proyek PLTU Ampana (2x3 MW) Menggunakan Metode Job Safety Analysis (JSA)," *J. Teknol. dan Manaj. Ind. Terap.*, vol. 1, no. 2, pp. 61–69, 2022, doi: 10.55826/tmit.v1iII.14.

[5] E. H. Prasetyo, Suroto, and B. Kurniawan, "Analisis Hira (Hazard Identification and Risk Assessment) Pada Instansi X di Semarang," *J. Kesehat. Masy.*, vol. 6, no. 5, pp. 519–528, 2018. doi: 10.14710/jkm.v6i5.22089.

[6] E. Albrechtsen, I. Solberg, and E. Svensli, "The application and benefits of job safety analysis," *Saf. Sci.*, vol. 113, no. December 2018, pp. 425–437, 2019, doi: 10.1016/j.ssci.2018.12.007.

[7] N. Nurkholis and G. Adriansyah, "Pengendalian Bahaya Kerja Dengan Metode Job Safety Analysis Pada Penerimaan Afval Lokal Bagian Warehouse Di PT. ST," *Tek. Eng. Sains J.*, vol. 1, no. 1, p. 11, 2017. doi: 10.5281/zenodo.1115956.

[8] A. U. Abidin and I. Ramadhan, "Penerapan Job Safety Analysis, Pengetahuan Keselamatan dan Kesehatan Kerja terhadap Kejadian Kecelakaan Kerja di Laboratorium Perguruan Tinggi," *J. Berk. Kesehat.*, vol. 5, no. 2, p. 76, 2019. doi: 10.20527/jbk.v5i2.7827.

[9] I.Ismara, *Keselamatan dan Kesehatan Kerja (OHS)*. Yogyakarta: Tim OHS FT UNY, 2014.

[10] F. Moniaga and V. S. Rompis, "Analisa Sistem Manajemen Kesehatan Dan Keselamatan Kerja (SMOHS) Proyek Konstruksi Menggunakan Metode Hazard Identification and Risk Assessment," *J. Ilm. Realt.*, vol. 15, no. 2, pp. 65–73, 2019. doi: 10.52159/realtech.v15i2.4.

[11] G. Smarandana, A. Momon, and J. Arifin, "Penilaian Risiko OHS pada Proses Pabrikasi Menggunakan Metode Hazard Identification, Risk Assessment and Risk Control (HIRARC)," *J. INTECH Tek. Ind. Univ. Serang Raya*, vol. 7, no. 1, pp. 56–62, 2021. doi: 10.30656/intech.v7i1.2709.

[12] AS/NZS 4360, *Risk Management AS/NZS 4360:2004*. 2004, p. 30.

[13] S. N. Trisaid, "Analisis Risiko Kecelakaan Kerja Pada Kegiatan Rig Service Menggunakan Metode HIRARC Dengan Pendekatan FTA," *J. Ilm. Tek. Ind.*, vol. 8, no. 1, pp. 25–33, 2020. doi: 10.24912/jitiuntar.v8i1.6343.

[14] E. Ruijters and M. Stoelinga, "Fault tree analysis: A survey of the state-of-the-art in modeling, analysis and tools," *Comput. Sci. Rev.*, vol. 15, pp. 29–62, 2015, doi: 10.1016/j.cosrev.2015.03.001.

[15] D. P. Sari, K. F. Marpaung, T. Calvin, Mellysa, and N. U. Handayani, "Analisis Penyebab Cacat Menggunakan Metode FMEA Dan FTA Pada Departemen Final Sanding PT Ebako Nusantara," *Pros. SNST*, vol. 1, no. 1, pp. 125–130, 2018. doi: 10.36499/psnst.v1i1.2338.

[16] D. P. Restuputri, Eriko, and A. Sulaksmi, "Identifikasi Dan Pengendalian Risiko Di Bagian Produksi 1 Dalam Upaya Pencapaian Zero Accident Menggunakan Metode Hazard Identification and Risk Assessment (HIRA)," *Semin. Nas. Teknol. dan Rekayasa*, pp. 24–31, 2016, doi: 10.22219/sentra.v0i2.1827.

[17] R. N. Purnomo, J. Mulyono, and H. Santosa, "Perancangan Alat Angkut Tabung Lpg 3 Kg yang Ergonomis (Studi Kasus Di UD. X)," *J. Ilm. widya Tek.*, vol. 16, no. 1, p. 8, 2017, doi: 10.33508/wt.v16i1.964.

[18] R. Asnel and A. Pratiwi, "Analisis Faktor-Faktor Yang Mempengaruhi Keluhan Musculoskeletal Disorder Pada Pekerja Laundry," *Public Heal. Saf. Int. J.*, vol. 1, no. 01, pp. 45–53, 2021, doi: 10.55642/phasij.v1i01.23.

[19] M. F. Nugroho, E. Mas'idah, and S. B. Utomo, "Analisa Potensi Bahaya Pada Proses Produksi Paving Menggunakan Metode Job Safety Analysis," *J. Tek. Ind.*, vol. 1, no. 1, pp. 31–40, 2022, doi: 10.30659/jurti.1.1.31-40.

[20] S. Y. Arisma and I. Mashabai, "Analisa & Estimasi Penurunan Risiko Dengan Job Safety Analysis Pada Departemen Warehouse Di PT. Amman Mineral Nusa Tenggara," *J. Ind. Teknol. Samawa*, vol. 1, no. 1, pp. 22–33, 2020, doi: 10.36761/jitsa.v1i1.586.

[21] A. Wildan, T. Sukwika, K. Kholil, P. Studi, and T. Lingkungan, "Potensi Bahaya pada Proses Pembuatan Tablet Onkologi Menggunakan Metode HIRA JSA," *J. Appl. Manag. Res.*, vol. 2, no. 1, pp. 53–65, 2022, doi: 10.36441/jamr.v2i1.850.

[22] A. Y. Tripariyanto and S. Rahayuningsih, "Penerapan Metode HIRA dan Fishbone Diagram Pada Praktek Siswa SMK yang Menimbulkan Risiko Kecelakaan Kerja pada bengkel Ototronik SMK," *J. Ilm. Tek. dan Manaj. Ind. Univ. Kadiri*, vol. 3, no. 2, pp. 90–103, 2020, doi: 10.30737/jatiunik.v3i2.841.

[23] R. Vhalery, "Pelatihan dan Pendampingan Keamanan Gas dan Air Galon AQUA di UD.Arida Tirta Jaya (FF.Tirta) Jakarta Timur," *J. Pengabdi. Masy. Edumi*, vol. 1, no. 1, pp. 8–18, 2022, doi: 10.61193/jpme.v1i1.7.

[24] M. B. Anthony, "Identifikasi dan Analisis Risiko Keselamatan dan Kesehatan Kerja (OHS) pada Proses Instalasi Hydraulic System Menggunakan Metode HIRA (Hazard Identification and Risk Assesment) di PT. HPP," *J. Media Tek. dan Sist. Ind.*, vol. 4, no. 2, pp. 60–70, 2020, doi: 10.35194/jmtsi.v4i2.1030.

[25] A. S. Mariawati, A. Umyati, and F. Andiyani, "Analisis penerapan keselamatan kerja menggunakan metode Hazard Identification Risk Assessment (HIRA) dengan pendekatan Fault Tree Anlysis (FTA)," *Ind. Serv.*, vol. 3c, no. 1, pp. 293–300, 2017, doi: 10.36055/jiss.v3i1c.2108.

[26] H. Suliantoro, N. Susanto, H. Prastawa, I. Sihombing, and A. Mustikasari, "Penerapan Metode Overall Equipment Effectiveness (Oee) Dan Fault Tree Analysis (Fta) Untuk Mengukur Efektifitas Mesin Reng," *J@ti Undip J. Tek. Ind.*, vol. 12, no. 2, p. 105, 2017, doi: 10.14710/jati.12.2.105-118.

[27] M. Yusuf, T. I. Oesman, and N. A. Wicaksono, "Pemberdayaan Karyawan Dalam Penerapan Keselamatan dan Kesehatan Kerja Berbasis Fault Tree Analysis," *J. Ergon. Indones. (The Indones. J. Ergon.*, vol. 6, no. 1, p. 52, 2020, doi: 10.24843/JEI.2020.v06.i01.p07.

[28] A. A. Baig, R. Ruzli, and A. B. Buang, "Reliability Analysis Using Fault Tree Analysis: A Review," *Int. J. Chem. Eng. Appl.*, vol. 4, no. 3, pp. 169–173, 2013, doi: 10.7763/IJCEA.2013.V4.287.

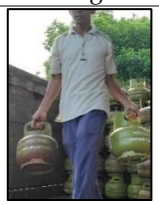
Appendices

Table 4.
Identification of Potential Hazards in OHS with the JSA (Job Safety Analysis) Method

No	Work Steps	Identification of Potential Hazards	Risk	Risk Control
1.	Workers park a truck filled with cylinders	Crashing into a wall/another car/worker	Workers may experience bruising	Elimination: - Subtitution: - Engineering: - Administration: make rules in the warehouse parking area and make a display of being careful in driving. Personal Protective Equipment (PPE): Wear a safety vest to make it easier to see
2.	Workers park a pick-up truck filled with empty cylinders	Crashing into a wall/another car/worker	Workers may experience bruising	Elimination: - Subtitution: - Engineering: - Administration: make rules in the warehouse parking area and make a display of being careful in driving. Personal Protective Equipment (PPE): Wear a safety vest to make it easier to see
3.	The worker opens the tailgate of the truck	Got hit by a tub	Workers can experience bruises and fractures	Elimination: - Subtitution: - Engineering: using tools Administration: establish standard operating procedures (SOP) Personal Protective Equipment (PPE): gloves and safety shoes
4.	Workers unload empty cylinders from pickup trucks to storage	Being crushed by the tube and being pinched by the tube, an ergonomic hazard in the form of repetitive movements of lifting the gas cylinder	Workers can experience bruises and broken bones, workers can also experience symptoms of Musculoskeletal Disorders (MSDs).	Elimination: - Subtitution: - Engineering: using a trolley Administration: make SOP and display about OHS Personal Protective Equipment (PPE): gloves and safety shoes
5.	Workers unload cylinders from trucks and load them into pickup trucks	Being hit by a pile of cylinders and being pinched by the tubes, ergonomic dangers include the repetitive movement of lifting the gas cylinder	Workers can experience bruises and broken bones, workers can also experience symptoms of Musculoskeletal Disorders (MSDs).	Elimination: - Subtitution: - Engineering: using a trolley Administration: make SOP and display about OHS Personal Protective Equipment (PPE): gloves and safety shoes
6.	Worker loading empty cylinders from storage onto truck	Buried by piles of cylinders and pinched by tubes, an ergonomic hazard in the form of repetitive movements of lifting gas cylinders	Workers can experience bruises and broken bones, workers can also experience symptoms of Musculoskeletal Disorders (MSDs).	Elimination: - Subtitution: - Engineering: using a trolley Administration: make SOP and display about OHS Personal Protective Equipment (PPE): gloves and safety shoes

Table A2.
Identification of Potential Hazards in OHS with the HIRA (Hazard Identification and Risk Assessment) Method

No	Location	Description of Hazard Findings	Risk	Hazard Source	Severity Level	Opportunity Level	Hazard Risk Index	Risk Assessment Category	Risk Priority
1.	Warehouse	 The tube handle is broken	Workers' hands may be scratched and/or bruised	Tube	2	C	2C	M	Medium Risk

No	Location	Description of Hazard Findings	Risk	Hazard Source	Severity Level	Opportunity Level	Hazard Risk Index	Risk Assessment Category	Risk Priority
2.		 Slippery rubber carpet exposed to water	Rubber Carpet	Rubber Carpet	2	D	2D	L	Low Risk
3.		  The top/bottom of the tube is damaged	Workers can experience bruises and fractures	Tube	3	D	3D	M	Medium Risk
4.		 Workers do not use PPE gloves	Workers' fingers can experience bruising to fractures	Tube	3	D	3D	M	Medium Risk
5.		 Workers do not use PPE safety shoes	Workers' feet can experience bruising to fractures	Tube	3	B	3B	H	High Risk
6.		 Heavy tailgate door	Workers can experience bruises and fractures	Tailgate door	3	D	3D	M	Medium Risk