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The Influence of Work Environment, Occupational Safety and Health Training, Work Experience, and Education Level on Work Accidents through Unsafe Actions in Turn Around Activities at RU IV Cilacap

Arjon Siagian[1], Erislan[2], Sugiarto[3]
[1]Graduate School of Sahid University, Jakarta, Indonesia, arjonsiagian25@gmail.com
[2]Graduate School of Sahid University, Jakarta, Indonesia, drerislan@gmail.com
[3]Safety Program Study, Bhamada University, Slawi-Tegal, Indonesia, sugiarto.hse@gmail.com

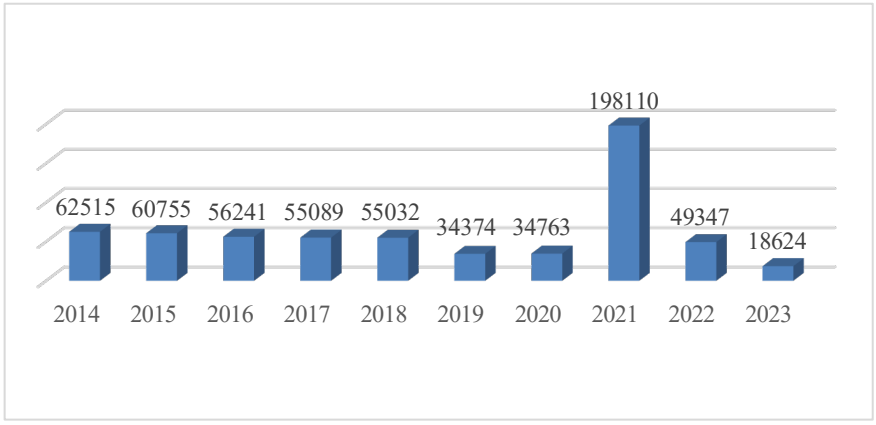
Corresponding Author: arjonsiagian25@gmail.com[1]

Abstract: Turn Around activities in the oil and gas industry involve the mobilization of thousands of temporary contract workers with non-technical backgrounds who face extreme and risky working environments, creating a high potential for work accidents that threaten lives and the operational sustainability of strategic national refineries. This study aims to analyze the influence of the work environment, occupational safety and health (OSH) training, work experience, and education level on work accidents, considering the mediating role of unsafe actions as manifestations of risky behavior that directly trigger incidents. An explanatory quantitative approach was applied through Structural Equation Modeling-Partial Least Squares, involving 242 Turn Around worker respondents to test a complex structural model. The results reveal significant findings where unsafe actions are proven to be the dominant predictor of workplace accidents, while work experience actually increases the risk of accidents both directly and through the mediation of unsafe actions due to the phenomena of overconfidence and complacency. OSH training and education levels, which should be protective, significantly increased unsafe actions because they created an illusion of competence without real practical skills, while the work environment had a direct effect on accidents but not through behavioral mediation. The academic contribution of the research lies in the empirical validation that in the ultra-complex petrochemical industry system, the Normal Accident Theory and Swiss Cheese Model are more relevant than the classic individual approach, while the practical contribution is the recommendation for a fundamental transformation of the safety management system from a quantitative-formalistic approach to the quality of interventions that are contextual to the actual operational complexity. The study concludes that workplace accidents in the context of Turn Around are the result of systemic interactions between organizational failures in providing relevant training, the mismatch between worker competencies and task demands, and the normalization of risky behavior reinforced by overconfidence from pseudo-experience and inapplicable education.

Keywords: Oil and Gas Industry, Work Accidents, Turn Around, Unsafe Actions

INTRODUCTION

Work accidents are a critical issue in the oil and gas industry, which poses high risks to Occupational Safety and Health (OSH) due to hazardous production factors such as radiation, explosions, hazardous chemicals, extreme temperatures, and fatigue (Abor et al., 2023). The International Labor Organization (ILO) noted that the global trend of fatal work accidents for the 2014-2023 period showed significant fluctuations with a gradual downward pattern from 62,515 cases (2014) to 34,374 cases (2019), but then surged dramatically to 198,110 cases (2021), largely influenced by the impact of Covid-19 (Takala et al., 2023), before declining again to 18,624 cases (2023).

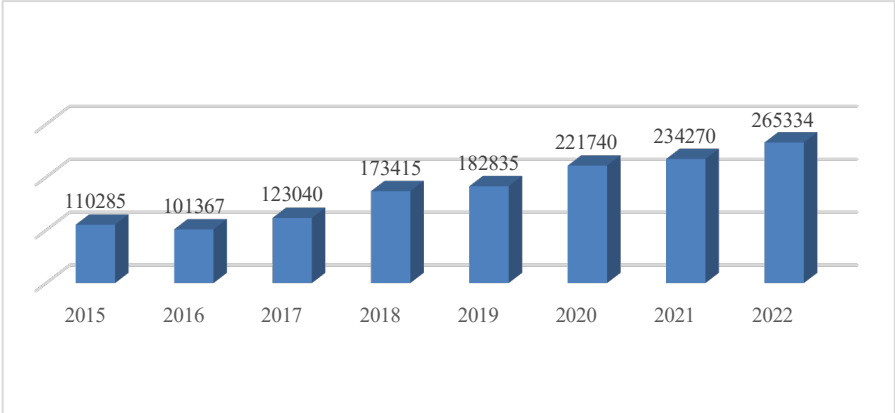


Source: Fatal work accident cases by gender and migrant status
https://rshiny.ilo.org/dataexplorer11/?lang=en&segment=indicator&id=INJ_DAYS_SEX_MIG_NB_A
accessed on May 2, 2025, at 1:40 p.m. WIB

Figure 1. Trend of Fatal Workplace Accident Cases 2014-2023

Global data shows a consistent downward trend in fatal work accidents from 2014 to 2019, reflecting improvements in occupational safety systems in various countries. However, a dramatic surge in 2021 to nearly six times the previous year's figure indicates that the Covid-19 pandemic has impacted not only public health but also occupational safety. The decline again in 2022 and 2023 indicates a gradual recovery, but the figures, which are still high compared to the pre-pandemic period, emphasize the need for a comprehensive evaluation of global occupational safety systems.

In Indonesia, data shows a consistent upward trend from 110,285 cases (2015) to 265,334 cases (November 2022), indicating that occupational safety remains a serious challenge that requires special attention. This increase is more than double in a seven-year period, indicating an alarming rate of workplace accidents amid national industrial growth.



Source: https://data.goodstats.id/statistic/jumlah-kecelakaan-kerja-indonesia-dalam-8-tahun-terakhir-sjo5X
accessed on May 2, 2025, at 1:55 p.m. WIB

Figure 2. Indonesia's Workplace Accident Figures 2015-2022

The trend of workplace accidents in Indonesia shows a different pattern from the global trend, where there has been a consistent increase except for a small decline in 2016, which reached 101,367 cases. A significant surge began in 2017 with 123,040 cases and continued to increase until it peaked in November 2022 at 265,334 cases. This drastic increase indicates several factors such as rapid industrial growth, increased reporting of work accidents, but also a possible decline in work safety standards in line with rapid industrial expansion.

The Indonesian oil and gas industry recorded a total of 986 accidents between 2016 and 2022, with the upstream sector accounting for the majority of accidents (750 cases). However, the downstream sector had a higher rate of fatal accidents (38 cases) than the upstream sector (21 cases), despite having a lower total number of accidents (Ministry of Energy and Mineral Resources, 2022).

Table 1. Statistics on Work Accidents in the Indonesian Oil and Gas Industry 2016-2022

Sector	Description	2016	2017	2018	2019	2020	2021	2022
Upper	Light	89	55	124	122	109	67	38
	Moderate	15	20	19	12	12	6	14
	Weight	9	7	3	2	3	1	2
	Fatal	4	4	3	3	4	1	2
	Upper Subtotal	**117**	**86**	**149**	**139**	**128**	**75**	**56**
Downstream	Light	28	8	8	17	20	13	41
	Moderate	11	2	5	8	9	4	2
	Weight	-	12	2	2	4	2	-
	Fatal	4	9	7	7	1	5	5
	Downstream Subtotal	**43**	**31**	**22**	**34**	**34**	**24**	**48**
	Total Oil and Gas	**160**	**117**	**171**	**173**	**162**	**99**	**104**

Source: Ministry of Energy and Mineral Resources (2022)

Statistical analysis of workplace accidents in Indonesia's oil and gas industry shows different risk characteristics between the upstream and downstream sectors. The upstream sector, with a total of 750 cases over a seven-year period, was dominated by minor accidents, which accounted for 604 cases or 80.5% of total upstream accidents. In contrast, the downstream sector, despite recording only 236 total cases, has a much higher proportion of fatal accidents with 38 cases or 16.1% of total downstream accidents, compared to the upstream sector which only has 2.8%. This difference in risk characteristics indicates that the downstream sector, with its processing, storage, and distribution activities, has the potential for more fatal consequences despite its lower accident frequency.

PT Kilang Pertamina Internasional RU IV Cilacap, as the largest refinery in Southeast Asia with a production capacity of 348 MBSD that supplies 34% of the national fuel demand, faces the highest complexity of occupational safety risks, especially during Turn Around activities (Refinery Unit IV Cilacap, 2025). This strategic position places RU IV Cilacap as a critical national infrastructure whose operational continuity has a direct impact on Indonesia's energy security.

Production capacity data shows the dominance of RU IV Cilacap with 348 MBSD or 33.8% of PT KPI's total refinery capacity of 1,031 MBSD. This capacity exceeds that of RU V Balikpapan (260 MBSD) as the second largest refinery by a margin of 88 MBSD or 33.8%. Its strategic location in Central Java allows RU IV Cilacap to serve Indonesia's largest market, Java Island, which accounts for 60% of national fuel consumption. The operational complexity of the refinery with two production units (Oil Refinery I and II) operating in an integrated manner creates unique occupational safety challenges compared to other refineries.

Turn Around is a comprehensive periodic maintenance program to restore refinery performance to design capacity, improve operational reliability, optimize energy efficiency, and ensure compliance with regulatory standards. The uniqueness of RU IV Cilacap lies in its Turn Around pattern, which is carried out twice in four years, unlike other refineries which

generally do it once every four years. The last implementation lasted 54 days non-stop (December 28, 2024-February 19, 2025) involving the mobilization of 12,000 workers. The worker distribution pattern follows a mobilization curve that starts with 17% of workers in the first week for work area preparation, increases to 35% in the second week for equipment dismantling, and peaks at 100% in the fourth week when all maintenance activities are running simultaneously. followed by a gradual demobilization phase in the fifth week (97%) and sixth week (82%) for equipment reassembly and startup preparation, creating different safety risk dynamics in each phase.

Work accident data for RU IV Cilacap for the 2016-2025 period shows a consistent correlation between the Turn Around period and a significant increase in total incidents. This pattern confirms that refinery maintenance activities carry a much higher occupational safety risk than normal operations.

Table 2. Work Accidents at RU IV Cilacap from 2016 to 2025

Type of Workplace Accident	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Fatality	-	1	-	-	-	-	-	-	-	-
Lost Time Injury	-	-	-	-	-	-	-	-	-	-
Medical Treatment Case	3	-	2	1	-	-	2	-	-	1
First Aid	23	4	14	1	12	2	12	5	1	2
Near miss	16	8	3	2	10	4	14	7	8	7
Property Damage	2	-	1	-	4	2	1	-	-	2
Environmental Damage	1	2	6	1	-	2	1	-	-	-
Tier 1 - Process Safety	-	-	-	-	-	2	-	-	-	-
Tier 2 - Process Safety	16	1	9	3	8	3	2	-	-	-
Total Incidents	**61**	**16**	**35**	**8**	**34**	**13**	**32**	**12**	**9**	**12**

Source: Cilacap RU IV Annual Report

Analysis of accident data shows an average increase of 281% in incidents during Turn Around compared to normal years. 2016 saw the highest number of incidents with 61 cases, followed by a drastic decrease to 16 cases (2017) or a drop of 73.8%. A similar pattern recurred in each Turn Around cycle: 2018 (35 cases) increased by 118.8% from 2017, 2020 (34 cases) increased by 325% from 2019 (8 cases), 2022 (32 cases) increased by 146.2% from 2021 (13 cases), and the projection for 2025 (12 cases) increased by 33.3% from 2024 (9 cases). The consistency of this pattern confirms that Turn Around is a critical period with the highest risk of workplace accidents that requires special safety management.

Research by Tayab et al. (2020) at the Abu Dhabi National Oil Company (ADNOC) revealed the crucial finding that 80% of drilling incidents were triggered by unsafe actions, with 62% caused by human error and 40% due to inattention or lack of awareness, confirming the dominance of human factors in workplace accidents in the oil and gas industry. Observations from the study at RU IV Cilacap confirm these findings with alarming data on unsafe actions during the 2025 Turn Around.

The unsafe action observation data show a total of 4,133 cases, with the ‘Work Equipment’ category dominating (2,482 cases) or 60.1% of the total unsafe actions. This high number of cases indicates a systemic problem in the use of work equipment, which may be caused by a combination of factors such as workers' unfamiliarity with refinery equipment, misunderstanding of usage procedures, or non-standard equipment conditions. The "Safe Position" category with 671 cases (16.2%) and "Working at Height" with 578 cases (14%) indicate significant ergonomic and gravitational risks. Meanwhile, "Hot Work" (158 cases), "Line of Fire" (150 cases), and "Lifting Operations" (94 cases), although smaller in number, have a higher potential for fatal consequences.

Research observations revealed that the majority of Turn Around workers had significant limitations due to their low educational background (elementary to high school) and minimal

experience in the oil and gas industry. The workers came from professions such as fishermen, pedicab drivers, farmers, and construction workers who joined temporarily to earn additional income. The work environment at RU IV Cilacap is extremely complex, with exposure to flammable hydrocarbons, heights, heavy equipment movement, hazardous chemicals, extreme noise, high-pressure steam areas, and confined spaces that only allow one person to enter. OSH training, which should have been the main mitigation measure, only lasted two months out of a total of two years of preparation, with superficial briefings that failed to provide a substantive understanding of the specific hazards of Turn Around. The combination of these factors created systemic conditions conducive to unsafe actions and ultimately led to workplace accidents.

The novelty of this research lies in the placement of the unsafe action variable as an intervening variable that links risk factors (work environment, OSH training, work experience, education level) with work accidents, filling the gap in previous research that showed contradictory results. The urgency of this research is very significant considering that RU IV Cilacap is a strategic national refinery with a unique Turn Around pattern twice in four years, which increases risk exposure. This study aims to analyze the influence of work environment, OSH training, work experience, and education level on work accidents through unsafe action as an intervening variable in Turn Around activities at PT Kilang Pertamina Internasional RU IV Cilacap, to provide practical recommendations in developing comprehensive risk mitigation strategies for the Indonesian oil and gas industry.

METHOD

Research Hypotheses

1. **Ha1: Work Environment Indirectly Influences Work Accidents Through Unsafe Actions**

Based on the research by Wang et al. (2024) and Soltanzadeh et al. (2021), the work environment influences workplace accidents through the mediating role of unsafe actions. Inadequate environmental conditions can trigger unsafe actions that ultimately lead to workplace accidents.

2. **Ha2: OSH Training Indirectly Influences Work Accidents Through Unsafe Actions**

Based on research by Smaz & Sahroni (2021) and Tarigan et al. (2023), OSH training influences work accidents through the mediating role of unsafe actions. Effective training can reduce unsafe actions, which ultimately lowers the rate of work accidents.

3. **Ha3: Work Experience Indirectly Influences Work Accidents Through Unsafe Actions**

Based on research by Soltanzadeh et al. (2021) and Haas et al. (2019), work experience influences workplace accidents through the mediating role of unsafe actions. Adequate experience can reduce unsafe actions, which ultimately lowers the rate of workplace accidents.

4. **Ha4: Education Level Indirectly Influences Work Accidents Through Unsafe Actions**

Based on research by Soltanzadeh et al. (2021) and Mayandari & Inayah (2023), education level influences workplace accidents through the mediating role of unsafe actions. A high level of education can reduce unsafe actions, which ultimately lowers the rate of workplace accidents.

5. **Ha5: Work Environment Influences Work Accidents**

Based on the research by Winarto et al. (2016), the work environment directly influences workplace accidents. Inadequate work environment conditions can directly cause workplace accidents.

6. **Ha6: OSH Training Influences Work Accidents**

Based on the research by Aryanto et al. (2016), OSH training directly affects workplace accidents. Effective OSH training can directly reduce the rate of workplace accidents.

7. **Ha7: Work Experience Influences Work Accidents**

Based on research by Haas et al. (2019), work experience directly influences workplace accidents. Adequate work experience can directly reduce the rate of workplace accidents.

8. **Ha8: Education Level Influences Work Accidents**

Based on research by Chan et al. (2023), education level directly affects workplace accidents. A high level of education can directly reduce the rate of workplace accidents.

9. **Ha9: Unsafe Actions Influence Work Accidents**

Based on research by Nasution et al. (2024) and Asfian et al. (2021), unsafe actions directly affect work accidents. Unsafe actions can directly cause work accidents.

METHOD

This study uses a survey method with an explanatory quantitative approach to test the causal relationship between variables through the Structural Equation Modeling (SEM) technique with the help of SmartPLS 3 software (Hair et al., 2014).

Population and Sample

The population of this study consists of all field workers participating in the Turn Around program at PT Kilang Pertamina Internasional RU IV Cilacap in 2025, totaling approximately 12,000 people. The sample size was determined to be 210 respondents based on the method proposed by Hair et al. (2014) for SEM analysis, using the formula of a minimum of 5 x the number of indicators (5 x 42 = 210). The sampling technique used non-probability sampling with purposive sampling, with the criteria being workers who were specifically recruited for the 2025 Turn Around program, were directly involved in refinery maintenance with physical access to the field work area, had participated in at least 2 Turn Around programs, and were willing to participate voluntarily.

Research Object , and Analysis Unit

The research object is the factors that influence workplace accidents with a focus on Turn Around activities at PT Kilang Pertamina Internasional RU IV Cilacap in 2024. The unit of analysis in this study is field workers involved in Turn Around activities at PT Kilang Pertamina Internasional RU IV Cilacap in 2025.

Data Collection Method

Data Collection

This study uses a data collection method through an online questionnaire using Google Forms distributed via WhatsApp to Turn Around workers at PT Kilang Pertamina Internasional RU IV Cilacap. The questionnaire used a Likert scale with a score range of 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), to 5 (Strongly Agree) to measure the variables of work environment, OSH training, work experience, education level, unsafe actions, and work accidents.

Concept Operationalization

Table 3. Operationalization of Concepts

No	Variable	Operational Definition	Indicators
1	Work Environment (X_1)	The dynamic interaction between workers, systems, and equipment that must be managed effectively through a comprehensive understanding of socio-technical dynamics.	1) Physical Work Environment 2) Supportive Work Environment 3) Perceived Control Over Work 4) Positive Challenges at Work 5) Work Capacity Related to Physical Demands 6) Work Capacity Related to Psychosocial Demands Source: Bjerkan (2010)
2	Occupational Safety and Health (OSH) Training (X_2)	Comprehensive training on various potential hazards that workers may encounter in their daily activities and proper safety practices to minimize the risk of accidents and injuries.	1) Safety induction 2) Safety training 3) Use of PPE training 4) Accident prevention 5) Hazard awareness 6) Safety measures 7) Documentation and reporting 8) Safety compliance 9) Safety knowledge Source: Quaigrain et al. (2022)
3	Work Experience (X_3)	A dynamic combination of high safety awareness, deep technical expertise, and continuous collaborative learning.	1) Job insecurity 2) Job demands 3) Job control 4) Negative acts 5) Work-family conflict 6) Job satisfaction 7) Work involvement 8) Work enjoyment Source: Burke et al. (2008)
4	Level of Education (X_4)	A comprehensive approach that integrates various disciplines to prepare competent and adaptive professionals.	1) Formal education level 2) Graduation suitability 3) Formal education Source: Manao et al. (2022)
5	Unsafe action (Z)	A dominant factor in incidents and accidents in the oil and gas industry, rooted in human error in various forms, including incorrect decision-making, improper execution of actions, or negligence in taking necessary actions.	1) Improper Decision Making 2) Lack of Knowledge of Hazards Present 3) Inattention to Footing & Surroundings 4) Improper Position or Posture for the Task 5) Routine Activity without Thought 6) Failure to Warn 7) Distracted by Other Concerns 8) Violation by Individual 9) Violation by Supervisor 10) Violation by Group Source: Tayab et al. (2020)
6	Work Accident (Y)	An unexpected and unplanned event in the work environment that results in injury, illness, or even death for workers.	1) Management and Workforce Engagement on Safety 2) Competence 3) Emergency Management 4) Personal Safety 5) Number of Incidents and Near Misses 6) Hazard Identification and Risk Assessment Source: Tang et al. (2017)

Source: Processed by the researcher (2025)

Data Analysis Methods

Descriptive Analysis

In this study, descriptive analysis was used to describe the demographic characteristics of respondents and research variables through statistical measures of mean without making generalizations.

Inferential Analysis

Reflective Measurement Model

The reflective measurement model is an approach in which latent constructs are considered to be the causes that create variation in their indicators (Hanafiah, 2020). The indicators are reflections or manifestations of the constructs being measured, with causality arrows moving from the constructs to the indicators.

Outer Model (Measurement Model)

The evaluation of the outer model aims to ensure the validity and reliability of the measuring instrument through a series of statistical tests. Convergent validity is measured through outer loading (≥ 0.70) and Average Variance Extracted/AVE (≥ 0.50), while construct reliability is evaluated using Composite Reliability/CR and Cronbach's Alpha/CA (minimum 0.70). while discriminant validity is tested through three methods, namely the Fornell-Larcker Criterion (square root of AVE > correlation between constructs), Cross Loading (highest outer loading on its own construct), and Heterotrait-Monotrait Ratio/HTMT (< 0.85 for different constructs or < 0.90 for similar constructs).

Inner Model (Structural Model)

The inner model evaluation tested the causal relationship between variables to validate the theory underlying the research through five main indicators. Effect Size/ f^2 measures the contribution magnitude small (0.02), medium (0.15), and large (0.35). The Coefficient of Determination (R^2) shows the proportion of variance with categories of weak (0.19), moderate (0.33), and substantial (0.67), Goodness of Fit/GoF as a comprehensive evaluation of model quality, Predictive Relevance/Q^2 evaluates predictive ability (> 0 indicates a good model), and Standardized Root Mean Square Residual/SRMR measures the difference in the correlation matrix with a value of < 0.10 indicating a good fit and < 0.08 indicating a very good fit.

Hypothesis Testing

Hypothesis testing was conducted through a bootstrapping procedure to estimate the statistical significance of the relationship between constructs, consisting of direct effects that evaluate the direct causal relationship between exogenous and endogenous variables without mediating variables, and indirect (mediation) effects that evaluate the mediating effect through mediator variables, where both tests use t-statistic significance criteria ≥ 1.96 and p-value ≤ 0.05 (Preacher & Hayes, 2008).

RESULTS AND DISCUSSION

Overview of Research Object

PT Kilang Pertamina Internasional RU IV Cilacap is the largest oil refinery in Indonesia with a capacity of 348 MBSD, located in Lomanis Village, Cilacap Tengah District, Cilacap Regency, Central Java. This refinery plays a strategic role as the main supplier of fuel oil on the island of Java, contributing 34% of the national fuel oil demand and capable of producing the most comprehensive range of products, including Premium, Kerosene, Solar, Pertamax, asphalt, and base oil. The operational structure consists of an integrated complex comprising Fuel Oil Complex (FOC) I and II, Lube Oil Complex (LOC) I, II, and III, and the Paraxylene Petrochemical Refinery, covering a total area of 526 hectares. The strategic location in Cilacap

was chosen based on the geographical advantages of its ideal natural harbor, available distribution infrastructure, and its position as the center of industrial development in the southern part of Java.

Data Findings and Data Analysis

Data Findings

Descriptive Analysis of Respondent Demographic Characteristics

This study successfully collected data from 242 respondents who were field workers on the Turn Around project at PT Kilang Pertamina Internasional RU IV Cilacap, exceeding the minimum sample of 210 respondents. Data collection took place from June 19 to 23, 2025. The respondent profile was dominated by males (93%), the 31-40 age group (32.2%), married status (84.3%), originally from the Cilacap area (72.3%), with a diploma/bachelor's degree (55%), employed by PT Kilang Pertamina Internasional (51.7%), earning above IDR 7 million (47.5%), permanent employee status (40.9%), and working in the HSSE division (40.5%). Conversely, the lowest percentages were female respondents (7%), those aged over 50 (14.5%), divorced (2.5%), from other regencies/cities in Central Java (12%), uneducated/did not complete elementary school (0.8%), contractor employees (48.3%), with an income of IDR 1-3 million (14%), daily workers (3.3%), and the Maintenance division (16.5%), indicating that the Turn Around project was dominated by adult male workers with higher education from the local area with permanent employee status who focused on occupational safety aspects.

Inferential Analysis

Outer Model

The outer model evaluation was conducted with 242 respondents and 42 initial indicators, which were then eliminated to 36 indicators after removing six indicators with outer loadings below 0.70. The final measurement model showed optimal convergent validity with all indicators meeting the minimum outer loading criteria of 0.70 (range 0.702-0.923) and AVE values ranging from 0.611 to 0.843. The construct reliability was excellent, with Composite Reliability (CR) ranging from 0.857 to 0.948 and Cronbach's Alpha ranging from 0.750 to 0.939. Discriminant validity was met through the Fornell-Larcker Criterion, Cross Loading, which showed that each indicator had the highest outer loading on its own construct, and HTMT, with most values below 0.85 except for the relationship between Work Accidents and Unsafe Actions (0.896), which was still acceptable due to conceptual relevance.

Inner Model

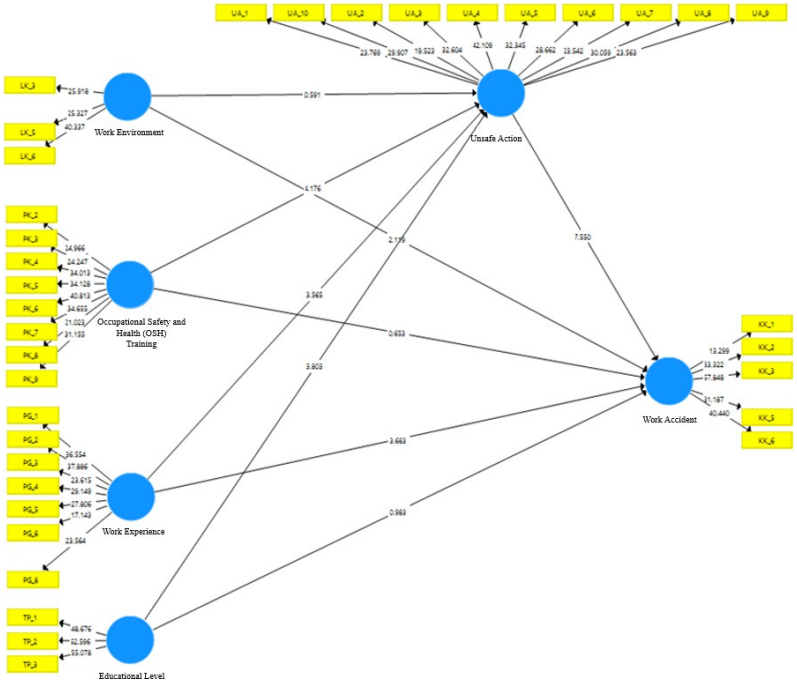
The structural model shows excellent predictive ability with a coefficient of determination (R^2) for work accidents of 0.740 and unsafe actions of 0.651, which are in the substantial category. The effect size shows significant variation, with Unsafe Action contributing the most to workplace accidents (f^2=0.354) with a large effect, while Work Experience (f^2=0.114) and OSH Training on Unsafe Action (f^2=0.127) show a moderate effect size. The model has adequate predictive relevance with Q^2 for work accidents of 0.484 and unsafe actions of 0.413 (both > 0), as well as an SRMR value of 0.063, which is below the threshold of 0.08, confirming a very good model fit in representing the correlation structure of empirical data.

Hypothesis Testing

Outer Loading (Bootstrapping)

After the structural model met the inner model evaluation criteria, the next step was to test the research hypothesis through the bootstrapping procedure. The bootstrapping procedure was performed using 5000 subsamples to ensure the stability of the results and the accuracy of

the parameter estimates, with the hypothesis testing criteria using a significance level of α = 0.05.



Source: Primary data processed with SmartPLS Version 3 (2025)

Figure 3. Bootstrapping

The results of the outer loading bootstrapping analysis show that all indicators in all research variables have t statistics values > 1.96 and p-values < 0.05, so they are declared valid and significant. The indicators with the highest loadings for each variable were TP_2 (Graduation Suitability) at the education level (0.923), KK_3 (Emergency Management) in work accidents (0.874), UA_5 (Routine Activities without Thinking) in unsafe actions (0.848), PK_6 (Safety Actions) on OSH training (0.840), LK_6 (Work Capacity Related to Psychosocial Demands) on work environment (0.838), and PG_2 (Job Control) on work experience (0.836). Although some indicators showed the lowest loadings, such as KK_1 (0.702), PG_6 (0.712), UA_2 (0.725), PK_2 (0.755), LK_3 (0.781), and TP_1 (0.911), all remained in the significant and acceptable category for further analysis.

Testing the Hypothesis of Indirect Effect (Mediation)

The indirect effect hypothesis testing aims to evaluate the mediating effect in the structural model through the bootstrapping method with t-statistic criteria ≥ 1.96 and p-value ≤ 0.05.

Table 4. Results of Indirect Effect Hypothesis Testing

Effect	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P-values	Notes
Work Environment → Unsafe Action → Work Accident	0.020	0.020	0.035	0.582	0.561	Rejected
Occupational Safety and Health Training → Unsafe Action → Work Accident	0.177	0.178	0.048	3.712	0.000	Significant Accepted
Work Experience -> Unsafe Action → Work Accident	0.157	0.163	0.052	3.018	0.003	Significant Accepted
Education Level → Unsafe Action → Work Accident	0.109	0.107	0.032	3.399	0.001	Significant Accepted

Source: Primary data processed with SmartPLS Version 3 (2025)

1. Hypothesis 1

The test results show that the Work Environment does not have a significant indirect effect on Work Accidents through Unsafe Action (original sample = 0.020; t-statistic = 0.582 < 1.96; p-value = 0.561 > 0.05). Although the Work Capacity Related to Psychosocial Demands indicator showed the highest loading (0.838), there was a disconnect with the manifestation of Routine Activity without Thought (0.848) as the strongest Unsafe Action indicator. This research gap is not in line with Wang et al. (2024) and Nwankwo et al. (2022), who found the significance of the work environment, but is consistent with Alayyannur & Arini (2021) and Winarto et al. (2016) in the Indonesian context. H_{o1} is accepted, H_{a1} is rejected.

2. Hypothesis 2

OSH training has a significant positive indirect effect on Work Accidents through Unsafe Action (original sample = 0.177; t-statistic = 3.712 > 1.96; p-value = 0.000 < 0.05). The Safety Measures indicator regarding understanding of safety procedures showed the highest loading (0.840), which effectively mediated the prevention of routine activities without thinking. These findings are in line with Smaz & Sahroni (2021), Syamtinningrum et al. (2018), and Tarigan et al. (2023), which confirm the crucial role of training in preventing unsafe actions, although they differ from Winarto et al. (2016). H_{o2} is rejected, H_{a2} is accepted.

3. Hypothesis 3

Work experience has a significant positive indirect effect on Work Accidents through Unsafe Action (original sample = 0.157; t-statistic = 3.018 > 1.96; p-value = 0.003 < 0.05). The Job Control indicator shows the highest loading (0.836), but paradoxically increases accidents through the phenomenon of overconfidence that triggers complacency in routine activities. These results are in line with Soltanzadeh et al. (2021), Agustin & Harianto (2019), and Haas et al. (2019), who identified experience as a critical factor in shaping unsafe behavior. H_{o3} is rejected, H_{a3} is accepted.

4. Hypothesis 4

Education level has a significant positive indirect effect on Work Accidents through Unsafe Action (original sample = 0.109; t-statistic = 3.399 > 1.96; p-value = 0.001 < 0.05). The Graduation Relevance indicator shows the highest loading (0.923), but creates a paradox of academic overconfidence that ignores practical awareness. These findings are in line with Chan et al. (2023) and Soltanzadeh et al. (2021), but contrast with Mayandari & Inayah (2023), Eka Putri & Wahyuningsih (2022), and Aryanto et al. (2016), who found no significant relationship in the Indonesian context. H_{o4} is rejected, H_{a4} is accepted.

Direct Effect Hypothesis Testing

The direct effect hypothesis test uses the bootstrapping method to evaluate the direct causal relationship between variables with the criteria of t-statistic ≥ 1.96 and p-value ≤ 0.05.

Table 5. Results of Direct Effect Hypothesis Testing

Effect	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P-values	Notes
Work Environment → Work Accidents	0.103	0.103	0.049	2.119	0.035	Significant Accepted
Occupational Safety and Health Training → Work Accidents	-0.054	-0.051	0.082	0.653	0.514	Rejected
Work Experience → Work Accident	0.333	0.322	0.090	3.683	0.000	Significant Accepted
Education Level → Work Accidents	0.053	0.057	0.053	0.983	0.326	Rejected

Effect	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P-values	Notes
Unsafe Action → Work Accident	0.513	0.517	0.068	7.550	0.000	Significant Accepted

Source: Primary data processed with SmartPLS Version 3 (2025)

1. Hypothesis 5

The test results show that the Work Environment has a significant positive effect on Work Accidents (original sample = 0.103; t-statistic = 2.119 > 1.96; p-value = 0.035 < 0.05). The Work Capacity Related to Psychosocial Demands indicator shows the highest loading (0.838) correlated with Emergency Management as the strongest reflection of work accidents (0.874), creating a paradox where a work environment that should be protective actually increases the risk of accidents. These findings are in line with Wang et al. (2024) and Nwankwo et al. (2022), but contradict Alayyannur & Arini (2021) in the context of Indonesian fishermen. H_{o5} is rejected, H_{a5} is accepted.

2. Hypothesis 6

The test results show that OSH training has a negative but insignificant effect on Work Accidents (original sample = -0.054; t-statistic = 0.653 < 1.96; p-value = 0.514 > 0.05). Although the Safety Measures indicator shows the highest loading (0.840), there is a disconnect with the reality of accidents, which is predominantly reflected through Emergency Management (0.874), indicating a gap between the focus on routine procedure training and the need for emergency preparedness. These results are consistent with Winarto et al. (2016) but contrast with Syamtinningrum et al. (2018) and Tarigan et al. (2023). H_{o6} is accepted, H_{a6} is rejected.

3. Hypothesis 7

The test results show that Work Experience has a significant positive effect on Work Accidents (original sample = 0.333; t-statistic = 3.683 > 1.96; p-value = 0.000 < 0.05). The Job Control indicator shows the highest loading (0.836) but paradoxically contributes to an increase in accidents, indicating a phenomenon of overconfidence where experienced workers with high control tend to take greater risks. This unique finding contradicts Agustin & Harianto (2019), Soltanzadeh et al. (2021), and Haas et al. (2019), which show a negative relationship between experience and accidents. H_{o7} is rejected, H_{a7} is accepted.

4. Hypothesis 8

The test results show that Education Level has a positive but insignificant effect on Work Accidents (original sample = 0.053; t-statistic = 0.983 < 1.96; p-value = 0.326 > 0.05). Although the Graduation Relevance indicator shows a very high loading (0.923), it has no significant effect on accident prevention, indicating a gap between theoretical knowledge and practical skills in dealing with emergency situations. These results are in line with Aryanto et al. (2016), Mayandari & Inayah (2023), and Eka Putri & Wahyuningsih (2022), but contrast with Chan et al. (2023) and Soltanzadeh et al. (2021). H_{o8} is accepted, H_{a8} is rejected.

5. Hypothesis 9

The test results show that Unsafe Action has a significant positive effect on Work Accidents (original sample = 0.513; t-statistic = 7.550 > 1.96; p-value = 0.000 < 0.05). The Routine Activity without Thought indicator shows the highest loading (0.848), which is consistent with Emergency Management (0.874) as the strongest reflection of work accidents. The indicates a direct link between loss of alertness in routines and emergency situations. These findings are consistently supported by Wang et al. (2024), Smaz & Sahroni (2021), Syamtinningrum et al. (2018), Tarigan et al. (2023), Soltanzadeh et al. (2021), Nasution et al. (2024), and Asfian et al. (2021). H_{o9} is rejected, H_{a9} is accepted.

Data Analysis

The Influence of the Work Environment through Unsafe Actions on Work Accidents

The results show that the work environment does not have a significant effect on work accidents through unsafe actions, with a coefficient value of 0.020 and a p-value of 0.561. Field conditions show the extreme complexity of the refinery environment, with exposure to flammable hydrocarbons, high-pressure areas up to 400°C, and very high equipment density. Outer loading analysis revealed that indicator LK_6 on the ability to maintain full concentration when facing work pressure had the highest contribution. This finding is in line with the Normal Accident Theory (Le Coze, 2015; Schochlow & Dekker, 2019) where accidents are a normal consequence of complex and closely paired systems such as oil refineries. Workers with non-technical backgrounds are unable to understand unexpected interactions between system components, making them direct victims of inherent systemic hazards according to the Swiss Cheese Model (Larouzée & Guarnieri, 2015; da Cunha et al., 2022).

The Effect of OSH Training through Unsafe Actions on Work Accidents

The results of the study show that OSH training has a significant effect on work accidents through unsafe actions with a coefficient value of 0.177 and a p-value of 0.000, but with a positive direction that indicates a paradoxical phenomenon. The reality in the field confirms that out of 10,000 prospective workers recruited, only 7,500 passed the selection process but received only 2 months of training out of a total of 2 years of preparation. Outer loading analysis shows that indicator PK_6 on understanding safety procedures has the highest contribution but actually increases unsafe actions. This paradoxical finding is explained through the Updated Domino Theory (Bird, 1974 in G. P. Sabet et al., 2013; Hosseinian & Torghabeh, 2012) as a failure in the first domino, namely the loss of management control that provides inadequate training programs. The Swiss Cheese Model perspective (Reason, 1990 in da Cunha et al., 2022) shows that ineffective OSH training programs become latent failures in the organizational defense system. Superficial training creates a false sense of confidence without real competence, encouraging risky behavior because trainees feel they have been trained.

The Influence of Work Experience through Unsafe Actions on Work Accidents

The results show that work experience has a significant effect on work accidents through unsafe actions with a coefficient value of 0.157 and a p-value of 0.003, indicating that longer experience actually increases the tendency to engage in unsafe behavior. Field data explains this paradox, where the majority of Turn Around workers have sporadic experience from various professions such as fishermen, farmers, and construction workers who participate every 2-4 years. Outer loading analysis shows that indicator PG_2 on the ability to control work well has the highest contribution but interacts destructively with UA_5 on awareness in repetitive work. These findings are explained through the Swiss Cheese Model (Shabani et al., 2024; Wiegmann et al., 2022), where pseudo-experience creates complacency as a latent dangerous condition, with veteran workers opening holes in the behavioral defense layer due to overconfidence. Heinrich's Domino Theory framework (1931 in COSM, 2023) shows that irrelevant work experience becomes a manifestation of individual errors driven by inappropriate attitudes, namely overconfidence and complacency.

The Influence of Education Level through Unsafe Actions on Work Accidents

The results show that education level has a significant effect on work accidents through unsafe actions ($\beta = 0.109$; $p = 0.001$), indicating that higher education actually increases the tendency to engage in unsafe behavior. Field conditions show that the educational spectrum of workers is very broad, ranging from those who have not completed elementary school to high school graduates, with highly educated workers tending to have greater responsibilities without adequate technical training. Outer loading analysis reveals that the TP_2 indicator on the

relevance of educational material in understanding safety procedures has the highest contribution but interacts counterproductively with vigilance in repetitive activities. This paradoxical finding reflects the failure of Heinrich's accident prevention method (COSM, 2023), namely personnel adjustment, where the recruitment system fails to place highly educated non-technical individuals in appropriate tasks. The Swiss Cheese Model (Shabani et al., 2024) explains that educational disparities create latent conditions that undermine organizational defenses through poor communication and artificial hierarchies resulting from professional egos.

The Influence of the Work Environment on Workplace Accidents

The results show that the work environment has a direct and significant effect on work accidents with a coefficient value of 0.103 and a p-value of 0.035, confirming that physical factors in the work environment have a direct impact on worker safety. The reality of the Turn Around environment reflects extreme complexity with a gradual shutdown process from an operating temperature of 400°C, a dense work area with a 500-ton crane, and worker distribution reaching a peak of 100% in the fourth week. Outer loading analysis shows that indicator LK_6 on the ability to maintain full concentration when facing work pressure interacts directly with KK_3 on the ability to cope with emergencies. This significant direct influence is strong empirical validation for Normal Accident Theory (Perrow, 1984; Le Coze, 2015; Schochlow & Dekker, 2019), where the Turn Around environment with high interactive complexity and tight coupling becomes a system where accidents are a normal and inevitable outcome. These findings also indicate a failure in the implementation of the Occupational Safety Management Standard PP No. 50 of 2012 and ISO 45001 (Podrecca et al., 2024), which emphasize a proactive, risk-based approach.

The Effect of OSH Training on Work Accidents

The results of the study indicate that OSH training does not have a significant direct effect on workplace accidents, with a coefficient value of -0.054 and a p-value of 0.514, even though the negative effect is in line with theoretical expectations. Field investigations revealed the root cause of the ineffectiveness, whereby the actual training lasted only two months out of a two-year Turn Around preparation period, with a focus on superficial briefings that failed to transfer substantive knowledge about the complexity of refinery hazards. Outer loading analysis showed a substantial gap between indicator PK_6 on understanding preventive safety procedures and KK_3 on reactive emergency response knowledge. This insignificance reflects a systemic failure in the Swiss Cheese Model (Reason, 1990 in Larouzée & Guarnieri, 2015; Wiegmann et al., 2022) where superficial OSH training created a functionally non-existent layer of defense. The Updated Domino Theory (Bird, 1974 in G. P. Sabet et al., 2013; Hosseinian & Torghabeh, 2012) shows that management failed on the first domino by implementing an inadequate training program as a risk control.

The Influence of Work Experience on Workplace Accidents

The results of the study show that work experience has a direct and significant effect on workplace accidents with a coefficient value of 0.333 and a p-value of 0.000, indicating that workers with longer experience tend to experience more accidents. Field analysis explains this paradox where experienced Turn Around workers are those who participate sporadically every 2-4 years but rely on irrelevant old memories, creating a skilled but rusty phenomenon with dangerous overconfidence. Outer loading analysis shows that the PG_2 indicator on the ability to control work is positively correlated with KK_3 on emergency handling ( ), but control under normal conditions is very different from the ability to handle emergencies. These findings are consistent with the Normal Accident Theory (Perrow, 1984; Le Coze, 2015), where experienced workers operate with outdated mental models that are incompatible with the current system

configuration, creating unexpected interactions in complex systems. The DuPont Accident Theory (United Steelworkers International Union, 2005) has been criticized because the unsafe actions of experienced workers are not momentary procedural violations but rather manifestations of overconfidence, normalization of deviation, and fatigue from financial pressure.

The Influence of Education Level on Work Accidents

The results of the study show that education level does not have a significant direct effect on work accidents with a coefficient value of 0.053 and a p-value of 0.326, although the total effect is significant through the mediation of unsafe actions. The reality in the field shows that the distribution of workers' education is very heterogeneous, ranging from those who have not completed elementary school to high school, but almost none have specific technical education in the oil and gas industry, so high school graduates are no safer than elementary school graduates when facing specific refinery hazards. Outer loading analysis reveals a fundamental gap between the TP_2 indicator on the relevance of educational material in understanding safety procedures and the KK_3 indicator on practical knowledge of emergency response. This insignificance supports the research paradigm that adopts a systemic approach such as the Normal Accident Theory and Swiss Cheese Model (Perrow, 1984; Reason, 1990), which shifts the focus from individual attributes to system characteristics. These findings are also in line with the philosophy of the modern safety management standard ISO 45001 and PP No. 50 of 2012 (Podrecca et al., 2024), which focus on competencies relevant to the task rather than academic qualifications.

The Influence of Unsafe Actions on Work Accidents

The results of the study show that unsafe actions have a direct and highly significant effect on work accidents with a coefficient value of 0.513 and a p-value of 0.000, confirming unsafe behavior as the main determinant of work accidents. Field observation data showed a total of 4,133 unsafe action incidents, with Work Equipment dominating 2,482 incidents, followed by Safe Positioning with 671 incidents, and Working at Height with 578 incidents, distributed with critical peaks in the first and last weeks of Turn Around. Outer loading analysis shows strong coherence between indicator UA_5 on vigilance in repetitive work and KK_3 on the ability to cope with emergencies, where loss of vigilance directly leads to emergency situations. This dominant influence validates the fundamental pillars of classical safety theory, including Heinrich's Domino Theory (1931 in Y. Wang, 2018; COSM, 2023), where unsafe action is the third domino that directly causes accidents, and DuPont's Accident Theory (United Steelworkers International Union, 2005), which states that 96% of accidents stem from unsafe behavior. The Swiss Cheese Model (Reason, 1990 in da Cunha et al., 2022) explains unsafe actions as active failures at the front line that penetrate the last layer of defense.

CONCLUSION

This study reveals significant findings in the context of Turn Around work safety at PT Kilang Pertamina Internasional RU IV Cilacap, where factors that theoretically should improve safety actually contribute to an increase in work accidents. OSH training, work experience, and education level were found to significantly increase unsafe actions that led to accidents, with work experience being the most dominant factor (total effect 0.490), while unsafe actions remained the strongest direct predictor of workplace accidents (0.513). These findings fill an important research gap by revealing the mechanisms of overconfidence, complacency, and false confidence that occur when safety interventions are not aligned with the complexity of the actual work system, while also providing a generalization of the theory that in ultra-complex systems such as the petrochemical industry, the Normal Accident Theory and Swiss Cheese Model are more relevant than Heinrich's individual approach, because systemic failures and the

misalignment between formal competencies and practical needs are the primary determinants of accidents. The contribution of this research to the development of OSH management science is the dismantling of linear assumptions in safety management systems and the introduction of a new paradigm that in high-risk work environments, the quality and relevance of safety interventions are more crucial than the quantity or formality of the programs implemented.

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