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# ANALYSIS OF OCCUPATIONAL SAFETY AND HEALTH (K3) RISK MANAGEMENT IN CONSTRUCTION INDUSTRY (CASE STUDY: CONSTRUCTION OF NATURAL GAS TRANSMISSION PIPELINES)

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**KEYWORDS**
risk management; HOR; lifting; transmission pipeline

**ABSTRACT**

The need for gas in Indonesia is currently quite urgent, but the infrastructure to provide natural gas supplies for industry is inadequate, so the government is encouraging the development of national natural gas infrastructure. In this project, build facilities including Tie-in at the Onshore Receiving Facilities (ORF) and then build a pipeline. The ORF consists of various large instruments, the installation process of which requires the assistance of heavy equipment such as a crane. Instrument installation work at ORF using a crane is included in the critical & extreme risk because the placement will use more than one crane and this work is carried out on a platform. Apart from that, the ORF was built next to an existing LPG station, so this condition has its own potential danger. To find out the source of the biggest risks, risks that may occur, methods of risk mitigation, and the level of effectiveness of the mitigation provided, occupational safety and health risk management analysis could be carried out using the House of Risk (HOR) and Hazard Identification, Risk Assessment & Determining Control (HIRADC) method. Lifting activities on the ORF platform was the biggest source of danger and there were 15 possible risks that may occur, 3 risk agents were in the mobilization of heavy equipment activities (cranes), 5 risk events were in the crane placement activities and 7 risk events were from material transport activities and there were 36 risks agents in it, 9 risk agents for mobilization activities, 11 risk agents for crane placement activities and 14 risk agents for material transport activities. Of the 36 risk agents, 16 of them have high potential, so suggestions for risk mitigation actions were given using the HOR phase II method. By conducting discussions, there were 48 mitigation action plans that were able to reduce the potential of risk agents with 36 main preventive actions, namely suggestions for mitigation actions that had difficulty value 3 or easy to implement. After assessing the recommended preventive actions, an assessment is carried out that there was a reduction in the level of risk using the Hazard Identification, Risk Assessment & Determining Control (HIRADC) method, where there were 3 medium risk categories and 13 low-risk categories. Before recommendations for risk mitigation actions, there were 3 extreme risk categories and 13 high risk categories.

## INTRODUCTION

Currently, the need for gas is quite urgent, but the infrastructure for supplying natural gas to industry is inadequate, so the government is encouraging the development of national natural gas infrastructur (Umah, 2021). One of them is the Semarang - Batang section of the natural gas transmission pipeline which includes tie-ins at the Semarang Onshore Receiving Facillities (ORF) facility and the pipeline to the Batang Integrated Industrial Zone (KITB) area. The ORF facility itself consists of various large instruments, so the instrument installation work at ORF is included in critical & extreme risk where lifting work at ORF will use more than one crane (tandem crane) where this work will be carried out on a platform and next to the existing LPG station (Basuki, 2023).

Instrument lifting work has the potential for fatalities, property damage, lost time injury and environmental pollution. Work accidents in the tandem lifting process have occurred due to several factors, including the negligence of workers who do not work according to the SOP, lack of preparation in lifting activities so that the position of the crane becomes unstable, due to a collision between two cranes, due to the fall of a girder in a domino manner, and failure in determine the carrying load (Adomaitis, 2017; Dutch Safety Board, 2016; OSHA, 2012, 2018, 2021).

Seeing the potential for work accidents in lifting work using cranes, it can be assessed that lifting activities require a risk management system. Based on International Organization for Standardization (2018) the assessment process of risk management itself is divided into three parts, namely risk identification, risk analysis and risk evaluation. Cranes play a major role in various construction accidents, so evaluation is necessary. In this journal, a crane evaluation was carried out using the Failure Modes and Effects Analysis (FMEA) method and the results obtained that the biggest factors of crane accidents were heavy loads and working height (Sadidi et al., 2016). Another study that identified the failure of a crane used the Failure Modes and Effects Analysis (FMEA) method and said that many failures in crane operation were caused by the condition of the crane that was not prim (Strohmandl et al., 2019). Based on these two studies using the FMEA method, where the research carried out is limited to hazard identification and risk analysis without preventive risk management. Once a risk management plan is in place, the identified and analyzed hazards can be compiled to form the basis of an effective risk mitigation strategy. in previous research entitled Hazard Identification & Risk Assessment in Construction Industry by Chauhan (2018) where in the journal it is stated that the Hazard Identification & Risk Assessment method can be used for risk identification, risk analysis and risk evaluation. HIRDC can also be used to group existing risks. Risk Assessment in construction activities can also be assessed using the House of Risk (HOR) method as in previous research conducted by (Muntoha, 2019). In general, the HOR method can be used to carry out risk assessments to provide risk mitigation suggestions from construction activities.

In this study, to find out the biggest source of risk, risks that may occur, ways of mitigating risk handling and the level of effectiveness of the recommendations provided, an analysis of occupational safety and health risk management will use the HOR (House of risk) method. This HOR method is a development of FMEA and HOQ methods, based on research these methods are considered to be able to include an integrated risk management analysis, where the HOR phase I method will determine the priority level of risk agents that must be controlled and for the HOR phase II method will determine the priority of mitigation actions that can be carried out (Nyoman Pujawan & Geraldin, 2009). With the recommended risk priorities and mitigation priorities, an assessment of possible risk reduction can be carried out using the Hazard Identification, Risk Assessment & Determining Control (HIRADC) method.

## RESEARCH METHOD

### Identify potential hazards and causes of hazards

Identifying potential dangers and causes of danger begins by searching for secondary data that can identify potential dangers and causes of danger. Potential hazards and possible causes of harm will be scored based on the level of likelihood (occurrence), severity (Severity) and the correlation between the two. This assessment was carried out using a questionnaire given to 35 workers who had job relevance.

The technique used in determining the sample is by using a non-probability purposive sampling technique, this technique is carried out by taking a non-probability sample where the unit is selected because the unit has the characteristics needed in the sample (Fauzy, 2019; Parveen & Showkat, 2017). The respondents who were sampled were workers in the HSE and construction departments. Sampling was carried out on office workers and field workers.

Risk assessment is carried out based on AS/NZS 4360 1999 which has been modified by (Iskandar, 2022). Questionnaire

***House of risk* phase I**

Severity, occurrence and correlation values can be used for phase I HOR calculations with output in the form of ARP values or potential risk agents. The HOR I method will use formula 1.

$$ARP_j = O_i \sum S_i R_{ij} (1)$$

Information:

$ARP_j$= Potential risk agents

$O_i$=Possible Value (Occurrence)

$S_i$=Severity Value (Severity)

$R_{ij}$= Correlation Value between Possibility Value and Severity Value

***House of risk* phase II**

Potential risk agents (ARP) obtained will be given risk mitigation suggestions which can be assessed using the House of risk phase II method. Identification of relevant mitigation actions is carried out through a literature study process and then discussed by related parties. The mitigation action points obtained were measured by measuring the correlation and the level of difficulty for its application through discussions and interviews.

The correlation value and implementation difficulties have been known, phase II HOR calculations are carried out with the output in the form of priorities in taking effective action (preventive action). The HOR II method will calculate the level of effectiveness and total effectiveness.

$$TE_k = \sum ARP_j E_{jk} (2)$$

Information:

$ARP_j$= Potential risk agents

$TE_k$=Effectiveness level

$E_{jk}$= Correlation value between potential risk agents and recommended mitigation actions

$$ETD_k = \frac{TE_k}{D_k} (3)$$

Information:

$ETD_k$= Total Effectiveness

$TE_k$=Effectiveness level

$D_k$= Difficulty level of implementation

**HIRADC**

In this study the HIRADC method was carried out to see the potential risk reduction found in the HOR phase I method. Then a mitigation action plan was carried out in the HOR Phase II method, in the HIRADC method an assessment of potential risk reduction and risk grouping was carried out.

The risks that will be calculated in the HIRADC table used are priority risks obtained from the ARP calculation of the House of risk I method and the controls used are priority control results from the House of risk II method.

**Analysis of Results and Discussion**

This results analysis step is carried out after collecting, summarizing and processing the data. The results of this research data processing are then analyzed and interpreted to draw conclusions that are in accordance with the research objectives regarding risk management analysis in the Semarang – Batang Natural Gas Transmission Pipeline Development Project.

## RESULTS AND DISCUSSION

### Identification of hazards and causes of hazards.

This hazard identification uses the history of work accidents that occurred from the start of the project to April 2023. During the course of this project there were 4 work accidents including 1 property damage and 3 near misses. Based on history, there were 2 work accidents which were divided into near-miss and property damage that occurred in lifting activities for both loading and unloading material activities, 1 near-miss occurred in mobilization activities and 1 near-miss occurred during drilling activities using the HDD system. So lifting activities are the biggest source of risk that can occur.

Based on the results of literature studies and field observations, 15 risk events were found in instrument lifting activities on platforms. Lifting activities are divided into three activities, namely mobilization, crane placement and lifting activities. There are risk events in these three activities, in mobilization activities there are 3 risk events, in crane placement activities there are 5 risk events and there are 7 risk events in lifting activities. The details of risk events observed for lifting activities are listed in Table 1.

**Table 1. Risk Events**

| RISK CODE | RISK EVENTS |
|---|---|
| **Mobilization Activities** | |
| E1 | Traffic accident |
| E2 | Hit an immovable object |
| E3 | Burn out syndrome |
| **Crane Placement Activities** | |
| E4 | Pinched tool |
| E5 | Scratched/punctured |
| E6 | Ergonomics |
| E7 | Cranes hit an existing station |
| E8 | Getting hit by equipment |
| **Appointment Activities** | |
| E9 | Crushed material |
| E10 | Hit by swing crane |
| E11 | Get caught up in the tagline |
| E12 | Heavy equipment overturned |
| E13 | Explode |
| E14 | Fire |
| E15 | The instrument overwrites the existing station |

Based on the results of the questionnaires given to workers who are placed in offices and fields, the results are slightly different, this is the risk event number E2, E3 and E4. The background that makes the difference in the assessment can be caused by several factors such as minimal worker skills and knowledge, educational background, and previous work experience.

In mobilization activities, there are three possible events that can affect risk, including traffic accidents, cranes or heavy equipment hitting immovable objects, and burn out syndrome. Traffic accidents that occur involving heavy equipment often occur, one of which is a collision between the B-9387-PD crane car and the KLB KP/10084 Train, Banyuwangi – Madiun Department, this happened in July 2014 (Dan & Jalan, 2021). Heavy equipment that has hit immovable objects has also occurred, one of which is the Rafter Crane which crashed into a resident's house during the mobilization process in Labuan Bajo (Ninu, 2022) and a truck crane accident that hit an electricity pole (Zulfahmi, 2022). Burn out syndrome can be caused by working too much as a result of working on a project late. Delays in work can be caused by material delays and factors that influence them as stated (Kurniawan & Rudi, 2019). that there are six factors of delay in project work, one of which is the delay in delivery or provision of equipment

In the crane placement activity, it is divided into several activities, including parking the crane, placing outrigger pads, and installing outriggers. Of the total activities, there are five possible events that can affect the risk, including equipment being pinched, scratched/punctured, ergonomics, the crane hitting an existing station, and the possibility of workers being hit by equipment. The first possible event is the worker being pinched by a tool or equipment that may occur, especially during the outrigger installation process. The possibility of scratches and punctures is also very possible during the process of fitting the outriggers or when installing the outriggers because the work is done manually. The possibility of ergonomic errors during the process of placing outrigger pads is very likely to occur because the work is done manually and the weight of the outrigger pads is quite large. The crane parking process is very possible if the crane hits an existing station where the crane is placed close to the existing station so a good distance estimate is needed when placing the crane. The possibility of workers being hit by equipment may happen. This has happened to workers in Hong Kong who died because they were hit by a gentry crane (Cheng, 2023).

In lifting activities, there are seven possible events that can affect the risk, including being crushed by material, being hit by a crane swing, being entangled in taglines, heavy equipment being overturned, exploding, catching fire, and instruments falling on existing stations. These possibilities make it possible to occur simultaneously or have a relationship between one another like a domino effect. Like heavy equipment that is overturned, this can cause the material on it to fall on workers and the surrounding environment where in this project work there is an existing station, and if the material or heavy equipment that is overturned hits the existing gas station, it is possible for an explosion to occur and the explosion can result in a fire (OSHA, 2021). Occupational accidents due to being entangled in a crane tagline have the possibility of occurring and the incident of workers getting entangled in a crane tagline has occurred in construction work in Toronto, where a rigger who is responsible for ensuring the material load is securely tied before being lifted hangs high in the air for quite a long time, this is because The worker was entangled in the crane's tagline rope, resulting in the worker suffering injuries (Houghton, 2022).

Based on the 15 existing risk events, there are 36 risk triggers (risk agents), there are 9 risk agents in mobilization activities, 11 risk agents in caren placement activities, and 14 risk agents in appointment activities. The details of the risk agent description are in Table 2.

**Table 2. Risk Agent**

| No | Activity | Risk Agent | Code |
|---|---|---|---|
| 1 | Mobilization | Drivers drive more than the specified speed limit | A1 |
| 2 | | Drivers lose concentration due to fatigue/drowsiness | A2 |
| 3 | | Driving duration is not proportional to the driver's ability | A3 |
| 4 | | Driver driving drunk | A4 |
| 5 | | Bad weather | A5 |
| 6 | | Heavy traffic conditions | A6 |

| No | Activity | Risk Agent | Code |
|---|---|---|---|
| 7 | | The worker who will make the delivery does not work on time | A7 |
| 8 | | There is material that is not suitable/damaged so that it requires replacement/additional material | A8 |
| 9 | | Delivery does not use escort | A9 |
| 10 | | Operators lose concentration due to fatigue/drowsiness | A10 |
| 11 | | The duration of work is not proportional to the operator's abilities | A11 |
| 12 | | Operators/workers work in a drunken state | A12 |
| 13 | Placement of Cranes | Bad weather | A13 |
| 14 | | Operators/workers are not skilled in installing outrigger beams | A14 |
| 15 | | The operator did not implement the SOP for installing the outgerbeam | A15 |
| 16 | | Workers do not use PPE (gloves) | A16 |
| 17 | | Workers do not pay attention to posture when lifting/installing the steel plate/crane mate | A17 |
| 18 | | The parking process is carried out backwards so that the driver cannot see and calculate the distance | A18 |
| 19 | | There is no area limit | A19 |
| 20 | | Crane maneuvering too fast/hard | A20 |
| 21 | | The road to be traversed is small/narrow | A21 |
| 22 | Material Lift | Operators lose concentration due to fatigue/drowsiness | A22 |
| 23 | | The duration of work is not commensurate with the ability of the operator/reager | A23 |
| 24 | | Operator/Reager working drunk | A24 |
| 25 | | Bad weather | A25 |
| 26 | | Crane maneuvering too fast/hard | A26 |
| 27 | | Lifting work does not comply with the SOP/lifting plan | A27 |
| 28 | | The binding work is not in accordance with the SOP | A28 |
| 29 | | One of the operators misinterpreted the signalman's sign | A29 |
| 30 | | The speed of raising/lowering the sling is not the same | A30 |
| 31 | | Cargo load exceeds capacity | A31 |
| 32 | | Poor sling/tagline quality | A32 |
| 33 | | Ragers/workers are not aware of the tagline behind workers | A33 |
| 34 | | Slanted platforms | A34 |
| 35 | | The platform collapsed | A35 |
| 36 | | Sparks from friction between iron (material and existing pipes) | A36 |

All of the risk agents were identified and grouped into 4 risk factors including human error, work environment factors, mechanics and ergonomics. Based on the 36 existing risk triggers, of which 17 risk triggers are based on human error factors, 7 risk triggers are based on work environment factors, 11 are based on mechanics and 1 risk trigger is based on ergonomic attitudes. The detailed grouping of risk agents can be seen in Table 3.

**Table 3. Grouping Risk Agent**

| Factor | Risk Agent |
|---|---|
| Human error | A1, A2, A3, A4, A7, A10, A11, A12, A14, A15, A16 A22, A23, A24, A29, A30, A33 |
| Mechanic | A8, A9, A18, A20, A21, A26, A27, A28, A31, A32, A36 |
| Work environment | A5, A6, A13, A19, A25, A34, A35 |
| Ergonomics | A17 |

Based on the results of the questionnaires given to workers who are placed in offices and fields, there are differences of opinion between the two, this is in risk agent numbers A2, A4, A9, A10, A12, A21, A22, and A24. The difference in these assessments can be based on several factors such as minimal worker skills and knowledge, educational background, and previous work experience. This is in line with the domino theory that the social or genetic environment is a factor before an accident occurs, this theory was put forward by Heinrich (Handayani, 2020), and reinforced by the tripod theory that accidents are related to dangerous behavior, one example of which is high workload, excessive time constraints and inappropriate perception of danger, this theory was put forward by Reason in 1990 (Pratama, 2021).

### ***House of risk*** **Phase I**

*Aggregate Risk Potential* (ARP) is a calculation process from the HOR Phase I method where this ARP calculation will produce the most potential risks from lifting activities on the platform. The ARP calculation focuses on three factors, namely occurrence, severity and interrelationship. From the sum of the ARP values, cumulative frequency calculations are carried out using the Pareto diagram.

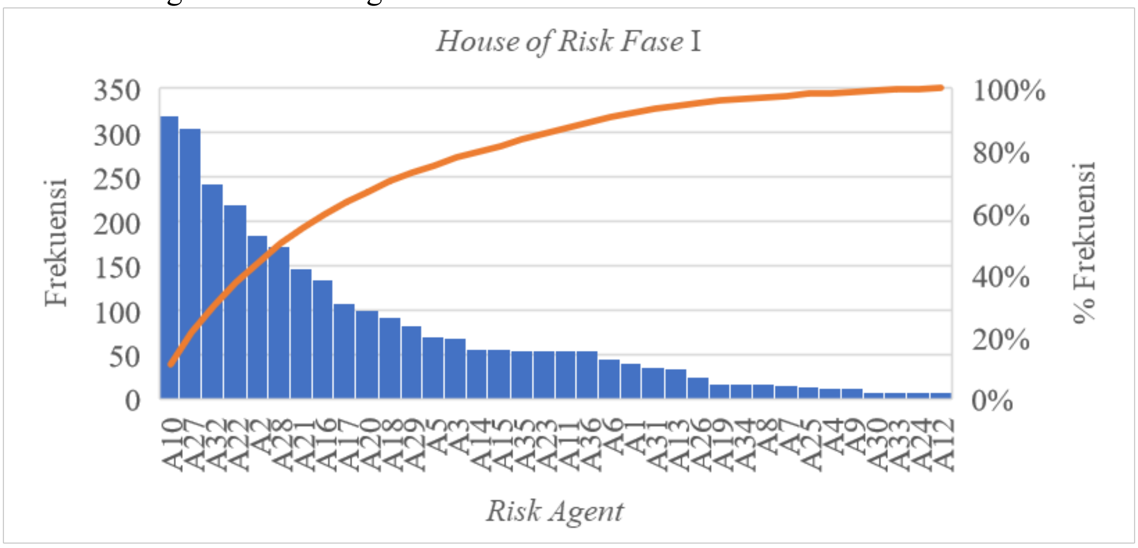


**Figure 1. Risk agent Priority Pareto Diagram**

Based on the Phase I HOR calculation, 16 potential risk agents were obtained as priority risks for risk mitigation. The 16 priority risk agents can be seen in Table 4

Based on the results of the potential risk agents obtained, 3 risk agents were found that could potentially occur in mobilization activities, namely A2, A3 and A5. There are 6 risk agents that have the potential to occur in crane placement activities, namely A10, A14, A15, A16, A17, A18 and there are 7 risk agents that have the potential to occur in material lifting activities, namely A20, A21, A22, A27, A28, A29 and A32.

**Table 4. The results of ranking the ARP value using a Pareto diagram**

| Code *risk agent* | Frequency (ARP Value) | Cumulative Frequency | % Cumulative Frequency |
|---|---|---|---|
| A10 | 319.0 | 319.0 | 11.0 |
| A27 | 305,2 | 624.2 | 21,6 |
| A32 | 243.1 | 867.2 | 30.0 |
| A22 | 218.6 | 1085.8 | 37.6 |
| A2 | 184.1 | 1269.9 | 43.9 |
| A28 | 171.4 | 1441.3 | 49.9 |
| A21 | 146.7 | 1588.0 | 54.9 |
| A16 | 134.8 | 1722.8 | 59.6 |
| A17 | 107,8 | 1830,5 | 63.3 |
| A20 | 99.5 | 1930.0 | 66,8 |
| A18 | 91.3 | 2021,4 | 69.9 |
| A29 | 83.0 | 2104.4 | 72.8 |

| | | | |
|---|---|---|---|
| A5 | 70.5 | 2174,9 | 75.3 |
| A3 | 69.1 | 2244.0 | 77.7 |
| A14 | 56,8 | 2300.8 | 79.6 |
| A15 | 55.5 | 2356,3 | 81.5 |

Based on the results of the potential risk agents obtained, 3 risk agents were found that could potentially occur in mobilization activities, namely A2, A3 and A5. There are 6 risk agents that have the potential to occur in crane placement activities, namely A10, A14, A15, A16, A17, A18 and there are 7 risk agents that have the potential to occur in material lifting activities, namely A20, A21, A22, A27, A28, A29 and A32. In general, the 16 potential risk agents said that crane accidents were caused by several factors, namely due to errors made by operators and/or riggers, especially related to: overloading the crane, collision/interaction between two cranes on the same construction site (A2 , A3, A10, A14, A20, A21, A22, A29), then crane accidents often occur due to errors in lifting, turning, or assembly/disassembly of large components (A15, A16, A17, A18, A27, and A28) and heavy tower crane structures, and crane accidents due to bad weather (A5). The results of the risk agent potential are in line with previous research that there are 6 factors that cause many crane accidents and 3 of them are due to weather and external factors, due to human or worker error, and due to method or technical errors in work, especially in lifting activities (Radlov & Ivanov, 2020).

*risk agent*The first potential is due to fatigue, namely A2, A10 and A22. This risk agent has a big possibility in every activity, where loss of concentration due to fatigue can be influenced by work shifts where before 5 am there are changes in cortisol, body temperature and melatonin levels which affect worker performance. This results in working at night, cortisol levels are higher in the afternoon (before work) than in the morning (after work). This difference in cortisol levels will affect work fatigue (Ihsan & Salami, 2012). Fatigue priority risk agent has continuity with other risk agents, namely workers who do not pay attention to posture or ergonomics (A17). This can occur in manual lifting work, namely crane mate lifting work, where working ergonomically can affect fatigue levels where the most important factor affecting blood pressure systolic and heart rate are risks related to ergonomics or posture at work, so the greater the risk of ergonomics, the more prone to fatigue (Muharmi & Ariesyady, 2012). The determining factor for body temperature is ambient temperature, so that the risk agent also has continuity with the priority risk agent for bad weather in this case which can be temperature, climate and wind speed and direction (A5, A13, and A25).

***House of risk* Phase II**

In the House of Risk Phase II, the priority risk agent results (the highest 80%) will carry out risk mitigation designs in order to reduce the possibility of these risks occurring. This stage focuses more on providing preventive action to priority risk agents and determining the correlation value between preventive action and risk agents. This correlation assessment is carried out by brainstorming and interviewing experts related to lifting activities on platforms. After knowing the correlation value and the possibility of its implementation, the effectiveness of the recommended preventive action will be calculated, then the effectiveness of the difficulty of the preventive action will be calculated and the ETD values will be ranked.

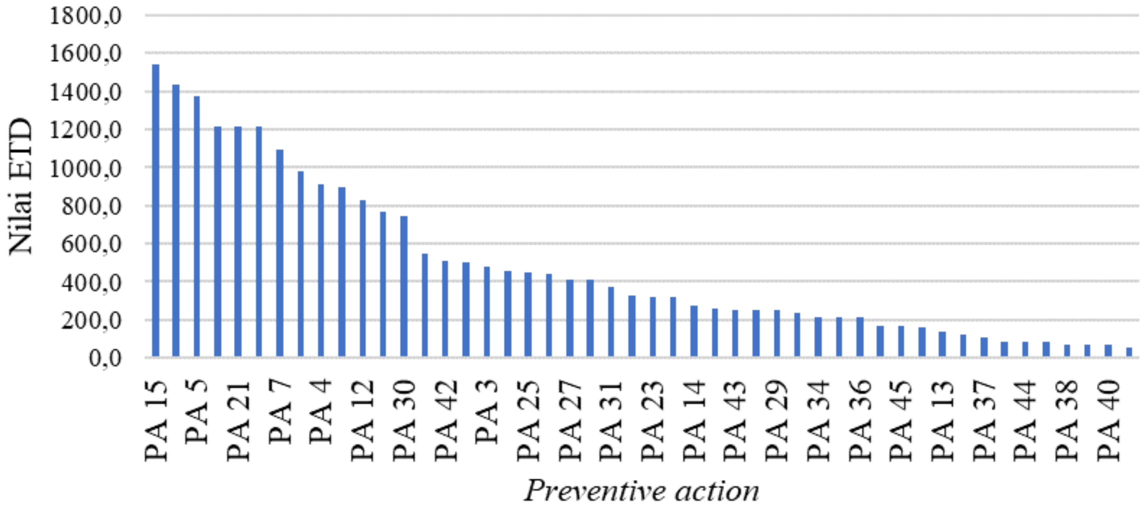


**Figure 2. Preventive Action**

Based on discussions and interviews with existing priority risk agents, 48 mitigation actions are suggested, out of the 48 suggested mitigation actions there is 1 preventive action that has a difficulty value of 5, there are 10 preventive actions that have a difficulty value of 4, and 37 preventive actions that have a value of 3. Making improvements by implementing preventive action certainly takes time in stages. This is based on several factors including the required resources, costs or costs required, and the time of application. Therefore, the preventive measures that have been prepared previously will prioritize preventive measures with the smallest probability value, namely 3, which means that the preventive measures are easy to implement.

*Peptical action* that can be implemented in general include re-education regarding safety carried out periodically by the HSE, providing PPE, checking the completeness of PPE every day before workers enter the work area, providing education regarding ergonomics principles to all workers by the HSE, providing symbols/ reminder banners regarding ergonomics rules, checking worker certification, implementing/carrying out a health check system for all workers before doing work, holding toolbox meetings before work is done, checking/inspecting slings periodically, monitoring workers' working hours and rest hours, use a monitoring system by the Safety Man in the field, determine the maximum speed/angle of crane maneuvers on the platform in the lifting plan, limiting the area and steering route, making innovations/modifications to add cameras or parking alarms, using a type of crane whose boom parts/position can be adjusted (lengthened/ shortened).

**HIRADC**

HIRADC (Hazard Identification Risk Assessment and Determining Control) in this study uses the results of priority risk agents (80% highest) where the data is the result of the House of risk Phase I method. The HOR I data will be designed for risk mitigation in accordance with the House method of risk Phase II. By using data from the HOR phase I and HOR phase II methods, it is hoped that the HIRADC method can see a reduction in potential risk.

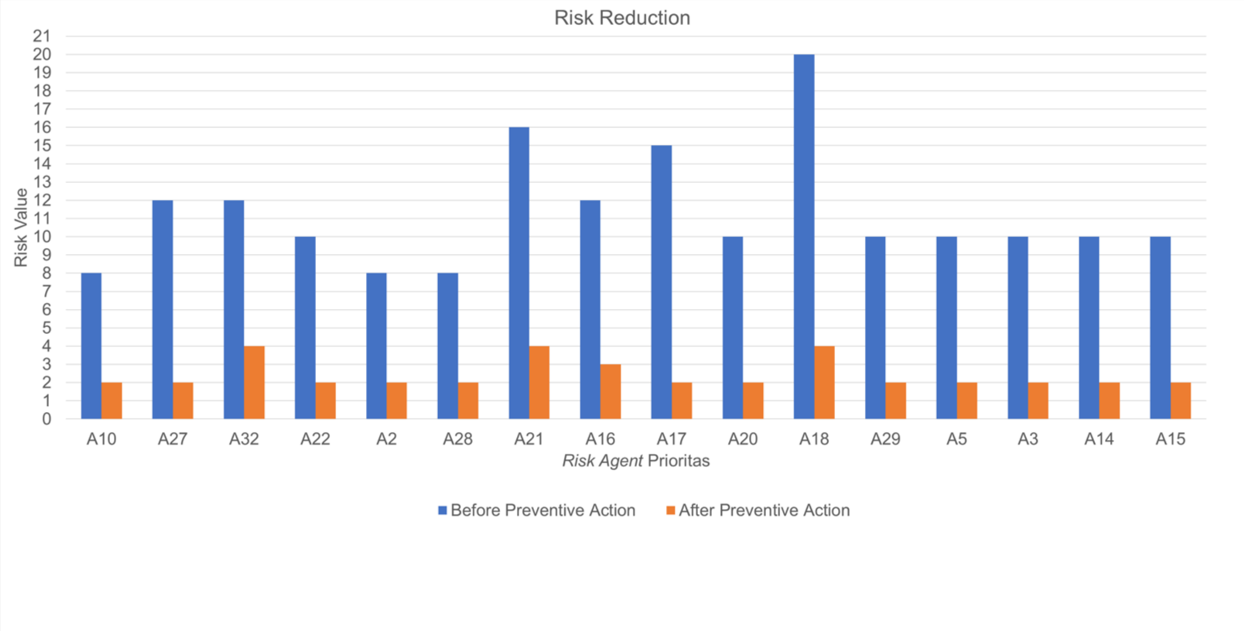


**Figure 3. Graph of Decrease in Potential Risk Value**

Based on the HIRADC method, potential risk agents are generated which are categorized into 2 levels of risk, namely extreme risk and high risk. Of the 16 potential risk agents, there are 3 risk agents in the extreme risk category and 13 in the high risk category. After being given preventive action there is a decrease in the level of risk, where there are 3 categories of moderate risk and 13 categories of low risk.

**The impact of OSH risk management on work productivity and quality of construction projects**

K3 (Health, Safety and Security) risk management in construction projects has a broad impact on work productivity and project quality. The following is a more detailed description of these impacts:

***Increased Work Productivity***

Effective implementation of OHS risk management creates a safe and healthy work environment. Workers who feel secure tend to focus and concentrate more on their work, reduce distractions, and increase productivity. Reducing the potential risk of injury or accident means workers can work without the worry and worry of unexpected interruptions (Noviana et al., 2023).

***Reduction of Downtime and Interruptions***

Good K3 risk management helps reduce the frequency of work accidents or incidents. This leads to a reduction in downtime resulting from accidents or necessary repairs. Reduced downtime means projects can continue running without being hampered by preventable safety issues (Toyib, 2022).

***Project Quality Improvement***

Focusing on K3 can prevent injuries or damage that can damage the quality of work. Workers who work in a safe and orderly environment tend to produce better and better quality work. Avoiding defects or damage in the early stages of a project can reduce the need for later repairs, thereby improving the overall quality of the project (Sholihah, 2018).

***Cost and Time Savings***

The adverse impact of accidents or work incidents can cause project delays and additional costs for repairs. Effective OHS risk management can avoid the additional costs and time usually required to address the negative consequences of accidents or incidents (Irawan, 2023).

***Positive Image and Reputation***

Companies that implement strong OHS risk management demonstrate a commitment to worker welfare and a safe work environment. This positive image helps in building a good reputation among workers, clients, and the general public, which can ultimately help in getting new projects and maintaining good business relationships (Chaerudin et al., 2020).

***Regulatory Compliance***

Good OHS risk management ensures that the company complies with all regulations and rules related to work safety. This compliance can prevent legal sanctions and fines that may arise as a result of violations of K3 regulations. Effective K3 risk management has a significant positive impact on higher work productivity, reduced risk of downtime and disruption, increased project quality, cost and time savings, better company image, and better regulatory compliance (Hasibuan et al., 2023).

**Application of Technology and Innovation in OHS Risk Management**

Implementation of Occupational Safety and Health (K3) risk management has a significant impact on work productivity and project quality in the context of the construction of the Semarang - Batang Section of the Natural Gas Transmission Pipeline. With effective K3 risk management, work accidents and worker health risks can be minimized, paving the way for a sustainable increase in work productivity. Workers who work in safe environmental conditions and free from risk of injury can focus on their tasks without limitations. This contributes to increased worker efficiency and productivity, which can ultimately accelerate project progress (Mindhayani & Purnomo, 2016).

Not only that, implementing good K3 risk management also has a positive impact on overall project quality. Workers who are in optimal health conditions and equipped with adequate knowledge and skills will tend to carry out work more carefully and thoroughly (Khairina et al., 2020). The risk of defects or failures in the construction process of natural gas transmission pipelines can be reduced, so that the end result of the project has better quality. Repairs and modifications due to errors can be reduced, resulting in projects that are more reliable and comply with established standards (Martaningtyas & Ariesyady, 2018).

In addition, the implementation of OSH risk management also has positive implications for the reputation of the project and the company as a whole. Interested parties such as the government, community and other related parties will see this project as an example of the company's commitment to maintaining the safety and health of workers, as well as implementing ethical construction practices. This good reputation can open doors for wider business opportunities and strengthen cooperative relationships in the future. Thus, the positive impact of K3 risk management is not only limited to work productivity and project quality, but also forms a positive image of the company in the construction industry as a whole.

## CONCLUSION

The biggest risk that can arise in the natural gas transmission pipeline construction project area is during lifting operations in the natural gas reception area (ORF). The risk events found consisted of 3 risk events in mobilization activities, 5 in crane placement activities and 7 in material lifting. There are 36 risk factors (risk factors) of all activities namely. 9 in mobilization activities, 11 in crane placement activities and 14 in material lifting activities. Of the 16 existing risk factors, 48 preventive actions were obtained, but with limited resources, we prioritized preventive action with the lowest possible value, namely 3. The HOR method that has been carried out has 3 of the 16 possible risk factors in the extreme risk category and 13 in the high risk category. After taking preventive measures, the risk level decreased to 3 categories of moderate risk and 13 categories of low risk.

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