

# Integrated Safety Risk Assessment and Accident Prevention In Scaffolding Operations Using Hirarc, Jsa and 5 Why Analysis: A Case Study At PT. AAA

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## **Abstract.**

Scaffolding work in the construction industry presents a high risk of occupational accidents, particularly during work at height. This study aims to identify hazards, assess risk levels, analyze work stages, and determine risk controls for scaffolding activities at PT. AAA. The study used Hazard Identification, Risk Assessment, and Risk Control (HIRARC) and Job Safety Analysis (JSA), with data obtained through field observations, interviews, and company documentation. HIRARC results showed that working at heights above 3 meters and dismantling bracing/ledgers had the highest risk score of 20, while standard post installation had a score of 16. JSA identified hazards including falling objects, structural imbalance, material transfer, and unfit components. An actual incident involving a dropped Explosion Proof CCTV unit on August 19, 2023 was also analyzed. The incident was associated with a damaged clamp and insufficient pre-work inspection. Recommended controls include inspection of scaffolding components and external equipment, engineering controls, SOP and TRA implementation, exclusion zones, HSE supervision, and Full Body Harness with 100% tie-off. Residual risk evaluation showed a reduction in risk levels after controls, although several activities remained in the High category.

**Keywords:** Scaffolding, Hazard Identification, Risk Assessment, and Risk Control (HIRARC), Job Safety Analysis (JSA), Occupational Health and Safety (OHS) and Risk Assessment

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## **I. INTRODUCTION**

The application of Occupational Health and Safety (OHS) to construction work is important to prevent accidents that can cause worker injuries, asset damage, and operational losses [1]. Construction work has dynamic activities and involves the use of equipment, materials, and working conditions with high potential hazards [2]. In scaffolding work, potential hazards can be in the form of falling from height, being hit by materials, structural instability, and scaffolding component failure [3].

Work at height requires special safety control. Regulation of the Minister of Manpower of the Republic of Indonesia Number 9 of 2016 regulates occupational safety and health at work at height, including requirements for labor competencies, protection systems, and safe work equipment [4]. This provision is in line with Law Number 1 of 1970 concerning Occupational Safety as the basis for the implementation of occupational safety in Indonesia. Scaffolding or scaffolding is a temporary structure used to support workers, materials, and equipment at work at height [5]. Risks need to be controlled from the stage of installation, use, to disassembly [6].

Previous research has shown that scaffolding work has a variety of potential hazards related to work at heights, the use of personal protective equipment, component conditions, and work procedures [7]. [8] analyze the risks to the installation and dismantling of scaffolding activities, while [9] implement HIRARC and JSA to analyze occupational safety and health risks in construction projects. [10] also shows that the HIRARC and JSA approaches can be used together to identify hazards and determine controls on construction work.

PT. AAA is a company engaged in construction services and labor provision that carries out scaffolding installation and dismantling work, including general construction work as well as mechanical and electrical services. In its operational activities, scaffolding work is carried out in the operational area of PT. Siam Maspion Terminal, Gresik, which includes installation, inspection, dismantling, and material removal.

One of the incidents that is of concern is the incident of the fall of the Explosion Proof CCTV unit at Jetty 1 PT. Siam Maspion Terminal on August 19, 2023 when the scaffolding team carried out dismantling work. A more detailed picture of the chronology, causes, and corrective actions taken is presented in table 1.

**Table 1.** Work Incident Data Summary (PT. AAA)

| No. | Remarks            | Description                                                                                                       |
|-----|--------------------|-------------------------------------------------------------------------------------------------------------------|
| 1   | Date of Occurrence | August 19, 2023                                                                                                   |
| 2   | Scene of Incident  | Jetty 1 PT. Siam Maspion Terminal                                                                                 |
| 3   | Types of Incidents | Falling equipment (CCTV)                                                                                          |
| 4   | Short description  | The fall of 1 CCTV Explosion Proof unit when the scaffolding team dismantled or dismantled the scaffolding        |
| 5   | Causes             | The CCTV camera clamp was broken/damaged before the incident, not due to the impact                               |
| 6   | Impact             | Damage to CCTV and its components (cameras, housings, adapters, connectors)                                       |
| 7   | Corrective Action  | Replacement of all CCTV components and reinstallation                                                             |
| 8   | Re-Prevention      | Revision of SOPs & TRAs, socialization of potential hazards, maintenance schedules and routine clamp replacements |
| 9   | PIC                | PT. AAA (Ega Ardjunika, Aldo, Afif)                                                                               |
| 10  | Status             | Completed (August–September 2023)                                                                                 |

Based on company data, the incident was related to the condition of the CCTV clamp that had been broken or damaged before the incident. The incident caused damage to the CCTV unit and its components. Corrective actions taken include replacing CCTV components and reinstalling, while prevention is carried out through revision of SOPs and TRA, socialization of potential hazards, and scheduling maintenance and replacement of clamps periodically. The data shows that risk control not only needs to pay attention to the condition of the scaffolding structure, but also the condition of external equipment around the work area.

To systematically identify and determine risk priorities, the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method can be used[11]. HIRARC allows potential hazards to be identified and risk levels determined based on the likelihood of hazard occurrence and the severity of their impacts so that control can be prioritized based on the level of risk [12]. In addition to HIRARC, Job Safety Analysis (JSA) is used to analyze jobs in more detail based on work stages [13]. The JSA breaks down the work into steps so that hazards at each stage can be identified and control measures can be specified specifically [14].

HIRARC provides an overview of the level of risk to the overall work activity, while the JSA provides a more detailed analysis of the work steps that pose significant risks [15]. The use of both methods can help identify hazards, assess risk levels, and determine controls on construction work [15]. Once the control is determined, residual risk can be used to determine the level of remaining risk so that further control needs can be determined [16].

Although research on scaffolding risks and the implementation of HIRARC and JSA has been conducted, studies that integrate risk identification, work stage analysis, root cause analysis using Five Whys, and residual risk evaluation in certain scaffolding work conditions still need to be developed. Therefore, this study not only assesses the level of risk, but also analyzes the causes of occurrence and evaluates the remaining risks after the controls are established.

Based on these conditions, this study aims to identify potential hazards in scaffolding activities, assess the level of risk using HIRARC, analyze the stages of work using JSA, analyze the root cause of the incident using 5 Whys, and formulate control based on the results of identification and risk assessment. Furthermore, control is evaluated through residual risk assessment to determine changes in the level of risk after the control is established.

## II. METHODS

The research used a quantitative descriptive approach and was carried out in the operational area of PT. AAA at PGN Saka/Jetty 1 PT. Siam Maspion Terminal, Gresik, East Java, from July to August 2026. Research activities include installation, inspection, dismantling, and handling of scaffolding materials. The informants consisted of 10 scaffolders, 1 supervisor, and 1 HSSE. Primary data was obtained through direct

observation, interviews, and filling out HIRARC and JSA sheets. Secondary data included company SOPs, Task Risk Assessment (TRA), incident logbooks, and OHS regulations.

The analysis is carried out through two main stages. First, HIRARC is used to identify hazards and determine the level of risk based on the multiplication of Likelihood (L) in table 2 with Severity (S) in table 3[17]. Each uses a scale of 1–5. With the equation:

$$\text{Risk} = \text{Likelihood} \times \text{Severity}$$

**Table 2.** Scale Likelihood

| Value | Category       | Explanation                                                                            |
|-------|----------------|----------------------------------------------------------------------------------------|
| 1     | Rare           | Incidents almost never happen and the chances of them happening are very small.        |
| 2     | Unlikely       | Events are rare, but they are still possible under certain conditions.                 |
| 3     | Possible       | Events can occur under certain operational conditions and have a moderate possibility. |
| 4     | Likely         | Events are most likely to occur during work activities.                                |
| 5     | Almost Certain | Events are very likely to occur or can occur repeatedly during the activity.           |

**Table 3.** Scale Severity

| Value | Category      | Explanation                                                                                   |
|-------|---------------|-----------------------------------------------------------------------------------------------|
| 1     | Insignificant | Does not cause injury or only cause minor disturbances that do not require medical treatment. |
| 2     | Minor         | Inflicts minor injuries that require first aid or simple treatment.                           |
| 3     | Moderate      | Causes injuries that require medical treatment and may lead to loss of work time.             |
| 4     | Major         | Inflicts serious injury, temporary/permanent disability, or significant material damage.      |
| 5     | Catastrophic  | May cause death, permanent disability, or substantial loss.                                   |

After obtaining the risk value, it is then entered into the risk matrix to determine the risk level of the identified hazard. The risk matrix scale can be seen in table 4.

**Table 4.** "Risk Matrix" scale in AS/NZS 4360 standard

| likelihood | Severity |   |   |   |   |
|------------|----------|---|---|---|---|
|            | 1        | 2 | 3 | 4 | 5 |
| 5          | H        | H | E | E | E |
| 4          | M        | H | H | E | E |
| 3          | L        | M | H | E | E |
| 2          | L        | L | M | H | E |
| 1          | L        | L | M | H | H |

The description of the matrix scale can be seen in table 5.

**Table 5.** Description of the Matrix Scale

| Color  | Category | Remarks                                                                                                                                             |
|--------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Orange | Low      | Risk is acceptable.<br>No additional controls required                                                                                              |
| Yellow | Medium   | Measures are needed to reduce risk, but the cost of prevention must be carefully calculated and limited                                             |
| Blue   | High     | Activities are not carried out until the risk has been reduced.<br>Risk management must be carried out immediately                                  |
| Red    | Extreme  | Activities should not be carried out until the risk has been reduced.<br>If it is not possible to reduce, then the work must be stopped immediately |

Risk control is arranged based on a control hierarchy, namely elimination, substitution, engineering control, administrative control, and PPE [19]. Then the JSA is used to describe the stages of scaffolding work in detail, identify hazards in activities that have extreme and high categories, possible impacts, and control actions. The results of HIRARC are used as a basis for determining activities that need to be further analyzed through JSA. After the control is determined, residual risk evaluation is carried out to see changes in the risk level [20].

### III. RESULT AND DISCUSSION

#### 3.1 Hazard Identification and Risk Assessment (HIRARC)

The results of the observation identified 10 main activities of scaffolding work with different levels of risk. The risk value was obtained from the multiplication of Likelihood and Severity which can be explained in table 6.

**Table 6.** Hazard Identification and Risk Assessment (HIRARC) Results

| No | Activities                 | Potential Hazards                                    | L | S | LxS | Category | Controlled Requirements                                                     |
|----|----------------------------|------------------------------------------------------|---|---|-----|----------|-----------------------------------------------------------------------------|
| 1  | Material transport         | Pinched when lifting pipes/ledgers                   | 4 | 1 | 4   | Medium   | SOP for appointment, gloves, daily briefing (Administrative Control)        |
| 2  | Pole mounting (standard)   | Temporary structures are unstable → collapse         | 2 | 2 | 4   | Medium   | Soil inspection, leveling, baseplate installation (Engineering control)     |
| 3  | Platform installation      | Unlocked and loose board                             | 1 | 2 | 2   | Low      | Toe board, double lock, inspection clamp (Engineering Control)              |
| 4  | Working at height          | Falling from a height of > 3 meters                  | 2 | 5 | 10  | Extreme  | Safety harness, anchor point, lifeline (Engineering Control dan APD)        |
| 5  | Scaffolding dismantling    | Falling objects hit bottom workers                   | 2 | 2 | 4   | Low      | Exclusion zone, lower area barrier (Engineering and Administrative Control) |
| 6  | Use of ratchet locks       | Scratched/pinched hand                               | 2 | 2 | 4   | Low      | Gloves, technique for using tools (Administrative Control and PPE)          |
| 7  | Environmental conditions   | Dehydration, tripping over scattered materials       | 3 | 3 | 9   | High     | Housekeeping, Provide drinks while working (Administrative Control)         |
| 8  | Use of safety harness      | The rope is not anchorage, it falls without any aids | 1 | 5 | 5   | Extreme  | Harness inspection, worker briefing (Administrative Control)                |
| 9  | Bracing/ledger disassembly | Imbalance → scaffolding collapse                     | 1 | 5 | 5   | Extreme  | Sequential dismantling, minimum of 2 workers (Administrative Control)       |

|    |                   |                                      |   |   |   |      |                                                                            |
|----|-------------------|--------------------------------------|---|---|---|------|----------------------------------------------------------------------------|
| 10 | Material transfer | Material falls when passed downwards | 1 | 4 | 4 | High | Use bucket rope, worker-helper communication (Engineering Control and PPE) |
|----|-------------------|--------------------------------------|---|---|---|------|----------------------------------------------------------------------------|

Overall, the most critical risks are related to work at height and changes in the stability of the structure when scaffolding is dismantled. These results form the basis for the selection of critical activities to be analyzed using JSA.

### 3.2 Job Safety Analysis (JSA)

The JSA is focused on five critical stages that have high and extreme categories, demolition work and scaffolding arrangement as shown in table 7.

**Table 7.** Job Safety Analysis (JSA) in Scaffolding Jobs

| No. | Working Steps                  | Potential Hazards                                       | Impact                         | Control                                                                                                |
|-----|--------------------------------|---------------------------------------------------------|--------------------------------|--------------------------------------------------------------------------------------------------------|
| 1   | Working at height              | Falls at a height of >3 meters                          | Head injuries, severe injuries | Safety harness must be clothed on strong pipes, anchor points, lifelines (Engineering Control and PPE) |
| 2   | Use of safety harness          | Falling from a height without aids                      | Head injuries, severe injuries | Harness inspection, worker briefing (Administrative Control)                                           |
| 3   | Bracing and ledger disassembly | Structural imbalances can cause scaffolding to collapse | Scaffolding collapsed          | Removed in order, minimum 2 workers (Administrative Control)                                           |
| 4   | Environmental conditions       | Dehydration and tripping over scattered materials       | Dizziness, falling             | Housekeeping, Provide drinks while working (Administrative Control)                                    |
| 5   | Material transfer              | Material falls when passed down                         | Minor injuries                 | Use bucket rope, worker-helper communication (Engineering Control and PPE)                             |

The JSA results show that the main hazards in scaffolding dismantling are falling objects, structural imbalances, risks during material transfer, and unsuitable component conditions. These findings reinforce HIRARC's findings that the dismantling process requires multi-layered control.

### 3.3 5 Why Analysis

From the JSA results, it was then analyzed using the 5 why method. Table 8 shows the analysis using the 5 why method of working activities at a height of >3 m.

**Table 8.** Analysis of the 5 why of working activities at a height of >3 m

| JSA Activities                        | Questions                                                | Answer                                                                                                                                           |
|---------------------------------------|----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Working at a height of &gt;3 m</b> | Why can workers fall from heights?                       | Because workers work at heights of more than 3 meters without hooking the hook from the safety harness and potentially lose their balance        |
|                                       | Why can workers lose their balance?                      | Because workers are in a work position that has a risk of falling and requires a fall protection system.                                         |
|                                       | Why is a fall protection system necessary?               | Because the work is carried out in areas with elevation differences that can cause serious injuries in the event of a fall.                      |
|                                       | Why can the risk of falling still occur?                 | Because the effectiveness of using harnesses, anchor points, and lifelines is highly dependent on their installation and use correctly.          |
|                                       | Why should the use of a protection system be controlled? | Because work control at height must ensure that workers are protected through anchor points, lifelines, and the correct use of safety harnesses. |

Then the stages of using the safety harness were analyzed using the 5 why method as shown in table 9.

**Table 9.** Analysis of the 5 why of the activity The use of safety harnesses

| JSA Activities        | Question Why                                                                          | Answer                                                                                                                                               |
|-----------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Use of Safety Harness | Why can workers fall from heights even if they use a safety harness?                  | Because the lanyard safety harness is not connected to the appropriate anchorage point.                                                              |
|                       | Why is the lanyard not connected to the anchorage point?                              | Because workers do not ensure the connection of the lanyard with the anchorage before starting work.                                                 |
|                       | Why is the connection of the lanyard with the anchorage not confirmed?                | Because the inspection of the use of safety harnesses before work has not been carried out optimally.                                                |
|                       | Why has the inspection of the use of safety harnesses not been carried out optimally? | Because the inspection and briefing regarding the use of the harness has not completely ensured that every worker checks the connection before work. |
|                       | Why should connection checks be ensured before work?                                  | Because lanyards that are not connected to the anchorage can cause the fall protection system to malfunction when workers lose their balance.        |

Then the bracing/ledger dismantling stage is analyzed using the 5 why method shown in table 10.

**Table 10.** Analysis of the 5 reasons for the bracing/ledger dismantling activity

| KSA Activities             | Question Why                                                        | Answer                                                                                                                 |
|----------------------------|---------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Bracing/ledger disassembly | Why can scaffolding collapse during demolition?                     | Because the release of bracing or ledger can lead to structural imbalances.                                            |
|                            | Why can bracing/ledger discharge cause imbalance?                   | Because these components still play a role in maintaining the stability of the scaffolding.                            |
|                            | Why can components be removed when the structure is not yet stable? | Because the dismantling can be carried out not according to the set work order.                                        |
|                            | Why should the sequence of disassembly be controlled?               | Because the disjointed removal of components can reduce the stability of the structure.                                |
|                            | Why should the demolition be done sequentially?                     | Because the stability of the scaffolding must be maintained until the necessary support components are safely removed. |

Then the stage of environmental conditions was analyzed using the 5 why method which is presented in table 11.

**Table 11.** Analysis of the 5 whys of environmental conditions

| JSA Activities           | Question Why                                     | Answer                                                                                                          |
|--------------------------|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Environmental conditions | Why can workers trip or become dehydrated?       | Because there are materials scattered and workers are exposed to working conditions that can cause dehydration. |
|                          | Why can materials be scattered in the work area? | Because material arrangement and housekeeping have not been fully controlled during the work.                   |
|                          | Why does housekeeping need to be handled?        | Because scattered materials can interfere with the worker's path and increase the risk of tripping.             |

|                                                        |                                                                                                             |
|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Why can workers become dehydrated?                     | Because physical work can increase fluid needs during activities.                                           |
| Why do environmental conditions need to be controlled? | Due to the unorganized work area and lack of drinking water supply can increase the safety risk of workers. |

Then the material transfer stage was analyzed using the 5 why method which is presented in table 12.

**Table 12.** Analysis of the 5 reasons for material transfer activity

| JSA Activities    | Question Why                                           | Answer                                                                                                          |
|-------------------|--------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Material transfer | Why can workers trip or become dehydrated?             | Because there are materials scattered and workers are exposed to working conditions that can cause dehydration. |
|                   | Why can materials be scattered in the work area?       | Because material arrangement and housekeeping have not been fully controlled during the work.                   |
|                   | Why does housekeeping need to be handled?              | Because scattered materials can interfere with the worker's path and increase the risk of tripping.             |
|                   | Why can workers become dehydrated?                     | Because physical work can increase fluid needs during activities.                                               |
|                   | Why do environmental conditions need to be controlled? | Due to the unorganized work area and lack of drinking water supply can increase the safety risk of workers.     |

### 3.4 Formulation of Risk Control Measures

Controls are arranged based on a hierarchy of controls [21]. In work at height, work from ground level is carried out whenever possible. If the work is still carried out at height, engineering control is applied through guardrails, toe boards, lifeline, and anchorage points. Administrative control includes SOPs, inspections, Toolbox Meetings, TRA, and HSE supervision. The PPE used includes Full Body Harness with double lanyards, safety helmet with chin strap, safety shoes, and gloves.

In the use of safety harnesses, administrative control is implemented through harness inspections that must be carried out in several periods, worker briefings must also be carried out every day to remind workers not to forget to hook hooks.

The dismantling of the bracing and ledger is carried out in stages according to the working order by maintaining the main supporting components until the structure is safe. Administrative control is applied in the Work is carried out by a minimum of two workers and follows the SOP and JSA. For risks due to tools, tools must be inspected before use and damaged tools must not be used.

Environmental conditions also need to be watched out for due to uncertain weather and also material neatness. Administrative control is applied in a Housekeeping manner to remove materials that interfere with the path of workers, while the risk of dehydration is controlled through the regulation of rest times and the provision of drinking water.

Material transfer is carried out almost every work, whether installing or dismantling scaffolding. Engineering control is applied by using bucket ropes when transferring materials, as well as PPE is applied in worker communication.

### 3.5 Risk Evaluation After Control

Once the control was determined, a residual risk evaluation was carried out as shown in table 8. The results showed a decrease in the risk value in most activities. The risk of working at a height of >3 meters decreased from 20 to 10, while the dismantling of bracing and ledger decreased from 20 to 10. The installation of standard posts decreased from 16 to 8, the installation of platforms from 12 to 8, the use of ratchet wrenches from 6 to 2, and the risk of lanyards not connected to anchorage decreased from 10 to 5.

**Table 13.** Residual Risk Calculation

| No. | Activities                     | Initial Risk (L×S) | Initial Categories | L After Handling | S After Handling | Residual Risk Calculation | Category Residual |
|-----|--------------------------------|--------------------|--------------------|------------------|------------------|---------------------------|-------------------|
| 1   | Works at a height of >3 meters | 2×5 = 10           | Extreme            | 1                | 4                | 1×1 = 1                   | Low               |
| 2   | Use of safety harness          | 1×5 = 5            | Extreme            | 1                | 1                | 1×1 = 1                   | Low               |
| 3   | Bracing/ledger disassembly     | 1×5 = 5            | Extreme            | 1                | 1                | 1×1 = 1                   | Low               |
| 4   | Environmental conditions       | 3×3 = 9            | High               | 1                | 2                | 1×2 = 2                   | Low               |
| 5   | Material transfer              | 3×2 = 6            | High               | 1                | 2                | 1×2 = 1                   | Low               |

The decrease shows that the designed controls can reduce the level of risk. However, work at height and bracing/ledger dismantling still have a residual risk of 10 or the High category. Both activities still require strict supervision, 100% tie-off, scaffolding stability checks, exclusion zones, and adherence to the demolition order.

## IV. CONCLUSION

### 4.1 Conclusion

The results of HIRARC show that the highest risk is found in work at a height of more than 3 meters and the dismantling of bracing and ledgers with a risk value of 20 each, while the installation of standard posts has a value of 16. The results of JSA show that the dismantling of scaffolding has the main hazards in the form of falling objects, structural imbalances, material displacement, and improper components.

The case of the CCTV Explosion Proof crash shows that clamp damage and the lack of optimal initial inspection of external equipment can be a factor causing the incident. Priority controls include inspection of scaffolding and external equipment, guardrail, lifeline, anchorage point, sequential demolition, exclusion zone, SOPs and TRAs, Toolbox Meeting, HSE supervision, as well as the use of PPE and 100% tie-off.

Residual risk evaluation showed that the risk of working at height and the dismantling of bracing/ledger decreased from 20 to 10, the installation of standard posts from 16 to 8, the installation of platforms from 12 to 8, the use of ratchet wrenches from 6 to 2, and the risk of lanyards not connecting anchorages from 10 to 5. Thus, HIRARC and JSA can provide a systematic basis for determining risk prioritization and control on scaffolding work.

### 4.2 Suggestion

PT. AAA is advised to strengthen inspections before installation and dismantling using a checklist that includes scaffolding components as well as external equipment such as CCTV and clamps. The implementation of scaffolding feasibility tagging, 100% tie-off, exclusion zone, demolition in order of work, and HSE supervision needs to be strengthened.

SOPs and TRA need to be updated by including potential hazards of external equipment as well as lessons learned from CCTV incidents. Toolbox meetings and K3 scaffolding training need to be conducted periodically to improve worker compliance. Further research can quantitatively measure residual risk and evaluate the effectiveness of control after it is implemented.

The research was conducted in the operational area of PT. AAA from July to August 2026 so that the results of the assessment were influenced by the location and activity conditions in that period. Data was also

obtained through observations, interviews, and company documents so that the Likelihood and Severity assessment still had elements of subjectivity.

The research focuses on scaffolding activities and has not conducted quantitative measurements of environmental factors such as heat, noise, lighting, and ergonomics. In addition, the study has not measured the effectiveness of control in the long term after implementation. Therefore, the residual risk obtained is the result of evaluation based on the control designed and still needs to be verified through application in the field.

## V. ACKNOWLEDGMENTS

The author expresses his gratitude to PT. AAA for providing permission and support in this research process. The author also expresses his gratitude to all employees of PT. AAA, especially for scaffolding workers in the field who have played an active role in collecting data and providing the necessary information during the research. Thanks to this support, this research can be completed well and is expected to provide benefits for improving K3 control at PT. AAA.

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