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Risk Management Analysis of the Borarsi Public Open Space (RTP) Development Project, Manokwari Regency, West Papua Province

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ABSTRACT: *A construction of VVIP Football Grandstand in the Borarsi Public Open Space (RTP) in Manokwari Regency is a strategic facility to support the improvement of urban space quality. However, the construction process carries high risks due to workers' poor understanding of technical procedures also from suboptimal implementation of occupational safety and health or K3 in the work zone. This study aims to identify the dominant occupational accident risks, analyzes their causes and impact, then formulates risk control strategies to be applied. This study used a descriptive survey method with a case study. The primary data was obtained through interviews, observations, and questionnaires with 24 respondents from the government, contractors, consultants, workers and academicians. While the secondary data obtained from project documents.The risk assessment used HIRARC method through calculating the Frequency Index and Severity Index then mapped in a risk matrix. Extreme risks were further analyzed using Bowtie method to identify causes, consequences and control measures. Result of the study revealed two dominant extreme risks: uncontrolled material during lifting and workers falling from heights. The primary causes include improper rigging, ineffective communication, weather conditions, suboptimal use of PPE, and weak supervision. The conclusion of this study emphasizes on lifting material activities and work at heights require stricter control through improved lifting SOPs, rigging inspections, the use of full body harness and regular toolbox meetings.*

KEY WORDS: *Barrier, Bowtie, Hazard, Likelihood, Severity, Threat, Top Event.*

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I. INTRODUCTION

The construction of Borarsi Public Open Space (*Ruang Terbuka Publik/RTP)* in Manokwari Regency of West Papua Province is a strategic regional project that plays a significant role in improving urban spatial planning quality. As the provincial capital, Manokwari needs representative and functional public facility, in particular to support sports activity, recreation and social interaction. Then, football grandstands construction project at Borarsi Soccer Field is expected to become a city icon and a space for community interaction which able to improve life quality of its residents. The success of this project will reflect local government commitment to support sustainable and community-friendly public infrastructure development. In a construction project, risk is always a looming threat which able to delay progress that also imposed on construction of public open space, the Borarsi Football Grandstand. Field condition is showing workers' limited understanding of technical procedures and safety standards. For example, their lack of understanding of proper formwork installation procedures, or unfamiliar with the use of modern equipment like metal cutting machines or scaffolding also often neglecting safe work procedures due to their reliance on their manual practices. This situation is exacerbated by the ineffective implementation of the Occupational Health and Safety (K3) system as evident in the minimal provision and use of personal protective equipment such as helmets, gloves, and seat belts, the absence of routine safety briefings before work begins, and weak supervision in the field, resulting in violations of K3 regulations. Furthermore, risk identification and assessment are still carried out in a limited manner, usually only to fulfill administrative reports without in-depth technical studies, resulting in many potential hazards not being formally recorded, such as the risk of workers falling when installing grandstand structures, the danger of being crushed by materials stacked without safety measures, and ergonomic risks due to workers being forced to lift heavy loads manually. Combination of these conditions creates a real vulnerability to work accidents, delays in project completion, unexpected cost overrun, and a decline in work quality of the construction result and utimately reduces the quality and function of that public open space.

From these factors, this study raises hypothesis that construction of Borarsi Public Open Space (RTP) in particular at the VVIP Tribune contains significant risks that require a systematic analysis. A study by [1] on the Teladan Medan Stadium Supporting Facilities Project showed that most work accident risks were found in the moderate to high category, particularly during excavation and material lifting, thus confirming the vulnerability of stadium projects and similar public facilities to risks. However, risk management studies on public open space development projects in West Papua, particularly Manokwari Regency, are still very limited, as previous studies have focused more on high-rise building, road, and bridge projects. Therefore, this study offers novelty by examining the risks of the Borarsi Field VVIP Tribune Construction through the perspective of locality, workforce characteristics, geographical conditions and work culture of West Papua, as well as the application of OHS in eastern Indonesia. The results are expected to provide practical contributions for local governments, contractors, and stakeholders in formulating adaptive risk mitigation strategies for the development of public open spaces in eastern Indonesia.

So far, the existing discussions related to Risk Management Analysis in Borarsi Public Open Space (RTP) Development Project in Manokwari Regency of West Papua Province have not been widely conducted by researchers. Therefore, research questions for this study are: 1) what types of risks are the most prevalent during work implementation of VVIP Tribune/Football Grandstand Development Project, (2) what are the causal factors, also what impacts resulted from workplace accidents in the VVIP Tribune/Football Grandstand Development Project, and (3) what strategies are used to control workplace accident risks in the work implementation of VVIP Tribune/Football Grandstand Development Project?

II. LITERATURE REVIEW

2.1. Risk Identification

The primary objective of the risk identification process is to obtain a list of potential risks that could impact the achievement of objectives or the progress of a construction project. This stage involves collecting and identifying various risks and their characteristics, which may impact project implementation. According to [2], risk identification is the effort to know or identify risks that arise within a company's business processes. Risk identification is typically performed on all business processes within a company.

Several general methods used in risk identification process are:

a. *Brainstorming*

This method involves gathering various ideas and potential risks then categorizing them by type or source. Information on problems that have arisen and alternative solutions that have been implemented can also be included. According to [3], the brainstorming method is a teaching technique implemented by lecturers by presenting an issue to students.

b. *Interview*

This method involves interviewing stakeholders to obtain their perspectives and experiences regarding potential risks the project may face. According to [4], the interview method is one of the most widely used methods for identifying risks.

c. *Questionnaire*

This method aims to gather opinions from experts or specialists with expertise in project-related fields. Various ideas regarding potential risks are presented in a questionnaire, and respondents are then asked to provide assessments and comments on these risks. According to [5], a questionnaire is a data collection technique that makes it easier for researchers to gather data regarding beliefs, attitudes, behaviors, and characteristics.

2.2. Risk Assessment

Risk assessment is a systematic process used to identify work activities, estimate the likelihood of an action causing a fatal impact, and determine appropriate control measures to prevent injury, damage, or loss in the work environment [6]. Furthermore, risk assessment serves as a structured method for assessing whether an activity has the potential to generate acceptable risks or whether it poses a high risk and has the potential to cause serious consequences.

Risk assessment is used as a screening step to determine the level of risk based on the likelihood and severity of an event. The following table lists (Table 1) the likelihood and severity categories of a risk:

Table 1. The Likelihood Level

Level	Criteria	Explanation
0	Rarely	Able to occur under certain circumstances
1	Sometimes	Sometimes happen
2	Can happen	Can happen but not often
3	Frequent	Occurs several times in certain period of time
4	Almost certain to happen	Can occur at any time under normal condition

Tabel 2. The Severity Level

Level	Criteria	Explanation
0	Insignificant	The incident does not cause loss / no injuries to human
1	Small	Causes minor injury, first aid, and does not cause serious impact
2	Moderate	Injured and hospitalized, no permanent disability, moderate financial loss
3	High	Causing serious injury and permanent disability and major finansial losses also causing serious impact
4	Catastropic	Resulting death or fatality, the project can stop permanently

The Importance Index (IMPI) is a risk assessment approach based on two main components: the impact index and the frequency index of risk occurrence. The assessment of these two indexes is typically conducted by experts or stakeholders. The purpose of this method is to determine the priority or importance of each risk based on its frequency and severity. The formula used in this method is as follows [7]:

$$IMPI = FI\,x\,SI$$

Meanwhile, the frequency index is the percentage of the probability or frequency of occurrence of a risk calculated based on respondents' answers. The frequency index (FI) value is obtained using the following formula:

$$FI = \frac{\sum_{i=0}^{4} a_1 \cdot n_1}{4N} \times 100\%$$

The Severity Index produces an impact index of the severity of risk factors affecting contractor workperformance. The Severity Index (SI) formula is:

$$SI = \frac{\sum_{i=0}^{4} a_i \cdot n_i}{4N} \times 100\%$$

Where :

a = assessment constant (0 s/d 4)
ni = respondents' probability
i = 0,1,2,3,4, …n
N = total amount of respondents

The ranking classification of the severity assessment scale by adopting the Davis and Cosenza Risk Matrix approach in [8] is stated as follows:

0. Extremely Ineffective = 0% < SI ≤ 20%
1. Ineffective = 20% < SI ≤ 40%
2. Moderately Effective = 40% < SI ≤ 60%
3. Very Effective = 60% < SI ≤ 80%
4. Extremely Effective = 80% < SI ≤ 100%

Next, the results of the assessment of the possibilities and consequences obtained are entered into a risk matrix table as shown in following table (Table 3).

Table 3. Risk Assessment Matrix

Probability	**Severity**				
	0	1	2	3	4
4	T	T	E	E	E
3	S	T	T	E	E
2	R	S	T	E	E
1	R	R	S	T	E
0	R	R	S	T	T

Description:

- E = *Extreme risk*: the activity must not be carried out or continued until the risk has been reduce.
- T = *High risk*: the activity should not be carried out until the risk has been reduced.
- S = *Moderate risk:* requires action to reduce risks, but costs of necessary prevention measures must be carefully calculated dan must be put in limit.
- R = *Low risk:* the risk is acceptable and no additional controls are required.

2.3. Risk Control

Risk control measure is implemented for all potential hazards identified during the hazard analysis phase. This process considers the level or ranking of risks to determine priorities and the most appropriate control strategies. There are several alternatives can be implemented in risk control include:

a. Reduce likelihood of risk occurence.
b. Reduce severity of impact or reducing consequence
c. Partially or full risk transfer
d. Risk avoidance

When establishing risk control measures, it is important to consider the levels or hierarchy of hazard control, as shown in the following figure.

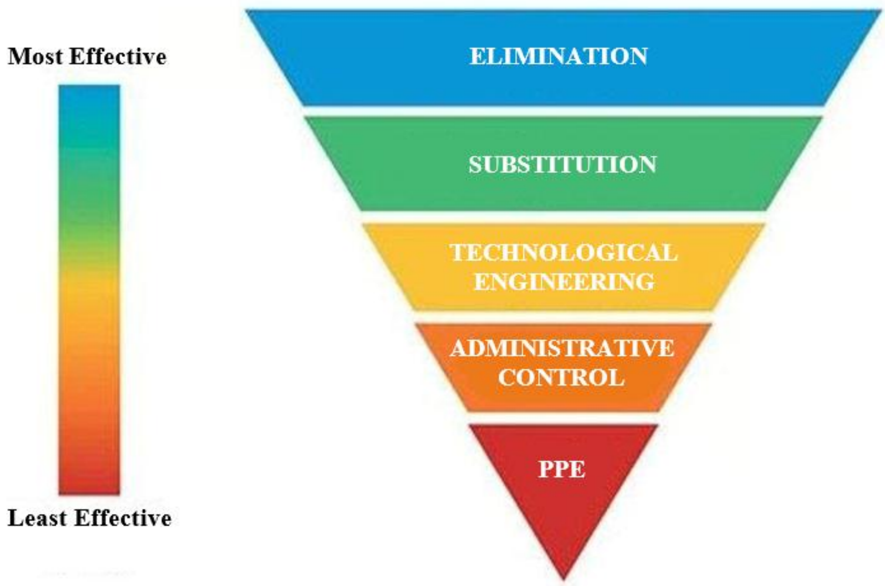

Figure 1. Hierarchy of Control

Description:

1. Elimination is a control method implemented by directly removing or eliminating the source of the hazard from the workplace.
2. Substitution is a control method implemented by replacing high-risk equipment, materials, systems, or procedures with safer or lower-risk alternatives.
3. Engineering Control is implemented through the implementation of equipment or technical means designed to minimize exposure to hazards in the work environment.
4. Administrative Control includes regulatory efforts such as adjusting work schedules and rest periods,

implementing safer work procedures, rotating workers, and regular health checks.

5. The use of Personal Protective Equipment (PPE) is a final form of control implemented by utilizing protective equipment, such as safety helmets, gloves, respiratory protection, seat belts, and protective footwear, to reduce the risk of injury from exposure to hazards.

III. RESEARCH METHODS

3.1. Data Collection Technique

3.1.1. Interview

Structured interviews were conducted with experts. The interviewees were those involved in the risk of workplace accidents (the project's K3 team).

3.1.2. Questionnaire Distribution

The questionnaire distribution was carried out in two stages:

1. Risk Identification Survey Questionnaire
   A risk identification survey questionnaire was administered to respondents, containing information about possible work accident risk variables. This risk identification survey aimed to validate whether these risk variables were relevant to the situation in the field or not.
2. Risk Assessment Survey Questionnaire
   A risk assessment survey questionnaire was administered to respondents to identify and assess likelihood and severity aspects.

3.2. Respondents and Research Object

Respondents in this project were used to obtain information on workplace accident risks, both through interviews and questionnaires. A sample was drawn from the project population to determine the respondents for the questionnaire. The selection of informants was carried out through purposive sampling, with the aim of only selecting those truly competent and relevant to the construction project context as sources of information.

Table 4. List of Potential Respondents

No	Source of Information	Work Position	Total
1.	PUPR Agency of Manokwari Regency	PPK, PPTK, and Technical Board	3 individuals
2.	Implementer Contractor	Project Manajer, Implementer, and K3 Expert	3 individuals
3	Supervisory Consultant	*Site Engineer,* Expert, and *Inspector*	3 individuals
4	Heavy Equipment Operator	Heavy Equipment Operators	3 individuals
5	Dump Truck Driver	Dump Truck Drivers	3 individuals
6	Foremen	Foremen	3 individuals
7	Worker / Labor	Workers / Labors	3 individuals
8	Academician	UNIPA Lecturers	3 individuals

3.3. Data Analysis

In this study, the data analysis technique used the Bowtie technique based on data from interviews or questionnaires with parties directly involved in the project, such as the PUPR Agency, implementing contractors, supervisory consultants, K3 officers, foremen, and laborers or workers. The information obtained will be used to identify potential hazards in each type of work in the construction project. Next, researchers will assess the level of risk based on the likelihood of occurrence and its impact, then compile it in the form of a risk table. Based on these results, the most appropriate and realistic control measures will be formulated to be implemented in the field, with the aim of improving overall work safety.

3.4. Research Variables

Hazard variables and occupational accident risks were obtained based on initial risk identification by brainstorming/collecting ideas for risk variables, studying previous research literature (on chapter 2) and then conducting discussions with the K3 team of the Borarsi Public Open Space Development Project to obtain occupational accident risk variables which later be used as material/content for the risk identification survey questionnaire and the risk assessment survey questionnaire. The following is a table of occupational accident risk variables (Table 5).

Table 5. Risk Variable of Work Accident

RELEVANT RISK VARIABLES			
NO	**WORK ACTIVITIES**	**RISK**	**REFERENCES**
1	Excavation and Foundation work	Excavation landslide, worker falling, being hit by soil or heavy equipment	[9]
2	Concrete work	Formwork collapse, worker falling, pierced by formstructure, equipment vibration	[10]
3	Roofing and steel framing work	Fall from high places, lifting equipment failed, hit by steel frame	[11]
4	Wall/stone installment	Falling material, cement dust irritation, structural collapse	[12]
5	Lifting and shifting heavy materials	Sling broke, crane overturned, workers get hit by falling material	[13]
6	Electrical installation and grounding	Electric shock, short circuit, fire due to leakage electric current	[14]
7	Wall finishing (plastering & paint)	Strong paint odor, skin irritation, falls from scaffolding	[15]

IV. RESULTS AND DISCUSSIONS

4.1. Risk Analysis on 6d Variable (Uncontrolled Material when Lifted (*Lifting Risk)*

The Borarsi Public Open Space (RTP) Development Project uses a Kato brand mobile crane with a 25-ton lifting capacity as the primary equipment for material lifting. Based on visuals at the site, this crane is a hydraulic mobile crane with a telescopic boom that can be extended gradually to achieve the required height and reach in the project work area. The crane is also equipped with a hydraulic outrigger system to maintain stability when lifting loads, as well as a hook block connected to a wire rope as a medium for lifting construction materials.

In general, the Kato 25-ton mobile crane has a main boom length of approximately 30 meters, with 360° rotation capability, making it easy to maneuver in confined work areas. Its operating system is equipped with a Load Moment Indicator (LMI) to ensure lifting remains within safe capacity limits. This crane is used to lift and move various structural materials on the Borarsi Public Open Space (RTP) project, including steel frames and modular components visible in the work area. The following figures are documentation of the situation when lifting work was carried out using a mobile crane on the Borarsi Public Open Space (RTP) Development Project:

Figure 2. Situation at Lifting Work

4.1.1. Causal Factors for Uncontrollable Materials when Lifted (*LiftingRisk)*

1. Strong Wind during lifting process.

To anticipate the occurrence of uncontrolled material when being lifted due to strong winds, the following preventive measures are putting into effect:

a. Anemometer installation to the Crane

This device measures wind speed in real time and provides data to the operator. If the wind approaches a safe limit, the anemometer will show an increasing value. If it exceeds the limit, the system typically provides a visual or audible alarm. This prevents the operator from lifting in dangerous conditions.

b. SOP for lifting activity in relation to maximum wind speed limit.
The SOP establishes maximum wind speed limits for lifting, for example, no lifting is permitted when winds are greater than 10–12 m/s. The SOP also stipulates work operation suspension if weather conditions change suddenly. This guideline ensures consistency of field decisions.

c. Operator must verify weather condition before and during lifting activity.
Conducting manual weather checks, for example by observing cloud movements, field conditions, and checking weather forecast data. Decisions to halt operations are made based on observations and indicators on the crane.

2. *Sling/Ringging*is not suitable for the capacity or is damaged
To prevent uncontrolled material during lifting activity due to slings or rigging that are not ready or unable to carry up to the capacity or these equipments are damaged, then the following preventive measures are taken:
   a. Put a clear label about capacity or working load limit on the sling.
   Every sling, shackle, hook, and rigging gear has a Working Load Limit (WLL) printed on the label. This label is engraved or permanently printed to ensure the operator knows the safe load capacity.
   b. Inspection to the Rigging Checklist before use.
   Rigger must inspect the sling before use, checking for damage such as broken wires, deformation, corrosion, and looseness. The checklist ensures no inspection steps are missed.
   c. Competent rigger ensures the rigging is properly installed.
   Trained riggers understand tying techniques, sling angles, appropriate sling types, and load calculations. Human intervention is crucial because rigging relies heavily on visual expertise and experience.

3. Bad Communication between rigger and crane operator
To prevent uncontrolled material loss during lifting due to poor communication between the rigger and the crane operator, the following preventive masures are taken:
   a. Two-way radio communication
   Radios enable clear communication even over long distances or in noisy conditions. Equipment is designed to withstand the project environment. If radio interference occurs, backup systems such as loudspeakers or signal lights can be used.
   b. Assigning one official signalman and establishing a standard signal code.
   This SOPs requires that only one signalman provide instructions to the operator. This prevents conflicting commands or confusion. All hand signals must comply with international standards (e.g., ISO or ASME).
   c. Training for Signalman and disciplinary in following signals.
   Signalmen must master hand signal codes, safe standing positions, and how to give easily understood instructions. Training improves nonverbal communication skills.

4. Material loads are not tied or inccorectringging method
To prevent uncontrolled material when lifted due to improperly secured or incorrect rigged loads, the following precautions should be taken:
   a. Must use a spreader bar, clamp, or special lifting frame.
   This equipment maintains load distribution, resulting in a more stable lift. The spreader bar reduces the sling angle, preventing the load from collapsing and causing instability.
   b. The chosen rigging method already has approval according to the lifting plan.
   The lifting plan describes the slinging scheme, center of gravity, and type of sling to be used. This document minimizes dangerous improvisation in the field.
   c. Conduct a balance check before lifting loads.
   The rigger ensures the load is not tilted, the slings are not loose, and the sling angle is correct. This is done before giving the "lift" signal. Human checks are essential to ensure the actual condition of the load.

5. Errors in calculating the crane capacity
To prevent uncontrolled material lifting due to errors in crane capacity calculations, the following preventative measures are taken:
   a. Installation of *Load Moment Indikator* (LMI) on the *crane*.

The LMI calculates the actual load being lifted, the crane radius, and the boom angle. The system issues an alarm if the crane approaches or exceeds capacity. Some cranes even automatically stop certain movements if the limits are exceeded.

b. *Lifting* plan containing the radius, load and crane configuration.
The document includes calculations for the radius, load weight, and boom configuration. These calculations are verified by an engineer to ensure the crane can lift the load safely.

c. Operator comply to LMI direction.
Operators not only rely on the automated system but also monitor the LMI indicator continuously. If an alarm occurs or the value approaches the limit, the operator is required to stop operation and report to a supervisor.

4.1.2. The Impact from Uncontrollable Material when lifted (*LiftingRisk)*

1. Material load fell on workers and causing injury or fatality.

To anticipate the possibility of uncontrolled material during lifted, impact control measures are implemented to minimize the risk of serious injury and fatalities through the following efforts:

a. Proper use of PPE (Personal Protective Equipment)
The following list are type of PPE for avoiding risk of getting hit by falling material from crane activity:

- Industrial Safety Helmet with Chip Strap
  Safety helmets are the most critical PPE because they protect the head from impact from falling materials, frame debris, or shifting crane loads. A chin strap ensures the helmet stays in place when workers move or are exposed to gusts of wind in open work areas.
- Safety Steel Toe Shoes
  Steel toe shoes provide protection against heavy materials that may fall onto the feet, including steel pipes, brackets, or roof truss parts that come loose during the lifting process.
- High Visibility Vest
  High-visibility vests help crane operators and riggers see workers' locations clearly, especially on large roof areas, thereby minimizing the risk of workers being struck by falling materials due to miscommunication or blind spots.
- Working Gloves
  Gloves protect hands from friction, sharp material edges, and impacts when workers hold or balance frame materials that are being positioned after being lowered by the crane.
- Safety Googles
  Goggles protect the eyes from metal chips, windblown dust, and small particles that may fall when lifting materials or when the frame is installed in a higher position.
- Safety Vest with Reflective Strip
  The use of reflective strips on vests increases worker visibility during material lifting, including in strong light conditions, shade, or when working in the morning/evening.
- Earplug or Earmuff (When Crane has disturbing noise)
  When cranes or metal construction equipment generate high levels of noise, ear protection helps maintain worker concentration and prevents hearing loss that can reduce alertness to potential falling materials.
- Full Body Harness(When worker must go to high altitude/high place).
  Although the focus of PPE is on the threat of falling materials, workers on the frame or roof must still use a harness to prevent falls due to the reflex to avoid falling materials.
- Mask or Light Respirator
  Masks are used if lifting materials generates dust, such as from roof membranes, insulation, or small particles carried by the wind when the crane lifts large materials.
- Face Shield if the material load is vulnerable or easy to brake
  For certain materials such as ACP or rigid membrane parts, a face shield can provide additional protection against flying fragments or debris resulting from impact during lifting.

b. Installation of retaining net at certain areas.
Retaining nets are installed in work areas to catch small loads or falling debris. While they cannot support very heavy loads, they prevent injury to workers below.

c. Establishment of Prohibited Zone Under Transportation Route
Standard operating procedures (SOPs) stipulate that the area below the lifting path must be clear of workers. The zone is marked with lines, signs, and sometimes physical barriers to prevent people from entering.

2. Damage to Building or Other Structures
   To anticipate the possibility of uncontrolled material being lifted, impact control measures are implemented to minimize the risk of damage to buildings or other structures through the following measures:
   a. Installation of physical barriers
      These are installed in specific areas to prevent swaying loads from contacting sensitive structures. Physical barriers can be made of wood, mild steel, or rubber pads.
   b. Determining a lifting path to avoid buildings
      The lifting path document ensures the load's path does not pass through high-risk areas. This path is coordinated with the building engineering team.
   c. Operator must perform the lifting activity with total focus and care
      The operator controls the crane smoothly to avoid load swing. The slow lifting technique helps stabilize the load before it reaches its full height.

3. The crane was unstable and fell over
   To anticipate the possibility of uncontrolled material during lifting, impact control measures are implemented to minimize the risk of crane instability and toppling through the following measures:
   a. Use of outrigger and ground mat to stabilize the crane.
      The outriggers increase the width of the crane's footprint, while the ground mats distribute pressure to the ground surface. This system technically improves the crane's stability.
   b. Check on the ground bearing capacity for crane's base.
      Before the crane is placed, the engineer checks whether the ground is strong enough to support the crane's weight. The results of the analysis are recorded in a soil bearing capacity report.
   c. The operator ensures the crane is stable before operations begin.
      The operator personally checks that all outriggers are locked, level, and stable before beginning operations. This is crucial to prevent the crane from tilting during lifting.

4. Work process is halt and the project is delayed
   To anticipate the possibility of uncontrolled material during lifting, impact control measures are implemented to minimize the risk of work interruptions and project delats through the following measures:
   a. Prepare backup equipment.
      Have additional cranes, spare rigging, or other equipment available to temporarily replace them in the event of damage. This ensures smooth work flow even during disruptions.
   b. Create a backup plan for preventive measures if the crane experiences problems
      This document outlines steps to take in the event of a delay, such as moving work to another location, adding a shift, or rescheduling the lifting activity.
   c. Making a quick coordination for rescheduling
      All stakeholders communicate and make quick decisions to adjust the work schedule, ensuring the project is not delayed for long.

4.2. Risk Analysis for Variable 6e (Workers fell from height/high place)

The roof installation work on the Borarsi Public Open Space (RTP) Development Project was carried out at a height of 7 to 10 meters above ground level, making it a high-risk project with the potential for falls. The roof structure consisted of a 5- to 8-inch-diameter steel pipe frame, assembled and positioned through erection stage using a mobile crane and a phased on-site work method.

Prior to the implementation, workers received a safety induction as a form of provision regarding the principles and obligations of implementing Occupational Safety and Health (K3). However, observations showed that some workers were still not using full body harness PPE completely and according to procedures. Furthermore, the work area was not equipped with a temporary working platform or safety net, so workers carried out installation activities by relying directly on the pipe frame elements being installed. This condition increases the potential risk of slipping, losing balance, or falling from a height.

This situation demonstrates the need for enhanced risk management, enforcement of PPE use, and the provision of additional safety equipment to ensure roof installation meets construction safety standards. The following is documentation of the installation of roof truss elements at height by workers at the Borarsi Public Open Space (RTP) Project.

Figure 3. Roof Truss Installation at Height

4.2.1. Causal factor of workers falling from height

1. Loss of Balance when walking on the steel pipe frame.
To anticipate workers falling from a height due to losing their balance when walking on a steel pipe frame, the following preventive measures are taken:
   a. Installation of Lifeline horizontal as a safety route
   A horizontal lifeline is a system of ropes or steel cables installed permanently or temporarily along the work path of a frame. This system provides a safety point for workers to attach their lanyards. The lifeline serves to catch workers if they slip on the curved surface of the steel pipe, which is naturally unstable to walk on. Lifeline installation must consider the strength of the anchor point, tension, and load capacity to withstand the force of the fall.
   b. SOP for mobilization and working on steel pipe frames
   The SOP defines technical measures such as safe crossing positions, the use of three points of contact, load limits, permitted access routes, and a prohibition on carrying large materials while walking on the frame. The SOP also stipulates that the area must be clean, dry, and oil-free, and that only trained workers are permitted to use the platform.
   c. Workers must be careful and maintain three points of contact when moving
   Workers are required to keep both hands and one foot, or both feet and one hand, attached to the structure at all times. This reduces the risk of slipping when walking on slippery or rounded steel pipes. This technique is crucial because the frame's curved shape can easily cause loss of balance.

2. Roof frame is not stable or has not been braced
To anticipate workers falling from a height, due to the roof frame being unstable or not being braced, the following preventive measures are taken:
   a. Installation of temporary bracing to prevent the frame from moving
   Temporary bracing is a temporary stiffener installed to lock the position of frame elements so they don't move, shift, or twist when stepped on by workers. *Bracing* provides lateral stability and prevents the frame from distorting or deforming under human weight. Without bracing, long pipe frames can experience excessive flexure and potentially collapse under the weight of workers.
   b. Checking the stability of the frame before it is permitted to become a work access
   The inspection procedure includes checking the tightness of fastening bolts, the quality of welds, the installation of bracing, and ensuring that no elements are left hanging loose. This inspection ensures the frame is structurally safe to access before being used as a foothold.
   c. Make sure no workers climb up before the structure is declared stable.
   The field supervisor is responsible for conducting visual inspections and granting permission before workers can climb onto the frame. This active supervision prevents workers from climbing onto frames that are not secured or still under installation.

3. Roof membrane surface is slippery or unable to support the load.
To anticipate workers falling from a height, due to the roof membrane surface being slippery or unable to support the load, the following preventive measures are taken:
   a. Use of temporary walkways over the membrane.
   Temporary walkways consist of wooden planks or non-slip panels placed over the roof membrane. Blackout membranes are elastic, soft, and not designed to directly support the weight of workers. Walkways distribute the load and provide a safe, rough surface to walk on, reducing the risk of slipping or tearing the membrane.
   b. Prohibition on walking directly on the membrane without a foothold

This procedure emphasizes that workers must never perform work steps directly on the membrane without a foothold. This is crucial because the membrane is highly sensitive to pressure points and friction. The procedure also establishes a safe path to use to prevent workers from damaging the membrane or losing their steps.

c. Workers ensure safe footing before crossing

Workers are required to conduct a visual inspection before crossing, ensuring the walkway is secure, wet, and in the correct position. This intervention reduces the risk of missteps on slippery or elastic surfaces.

4. Working on the edge of the roof when installing ACP without edge protection.

To anticipate workers falling from a height, due to working on the edge of the roof when installing ACP without edge protection, the following preventive measures are taken:

a. Installation of temporary guardrail along the roof edges

A guardrail consists of a top rail, mid rail, and toe board installed at the edge of the roof. This structure prevents workers from falling directly if they lose their balance. The guardrail also serves as a physical barrier to prevent workers from getting too close to the edge when carrying ACP or other materials.

b. Restriction of certain roof edge areas through special work permit

The PTW stipulates that work on the edge of a roof must comply with additional safety procedures, such as installing guardrails, using harnesses, limiting the number of workers, and maintaining close supervision. These procedures ensure that work is not carried out without adequate safety controls.

c. Workers remain within the boundary of safe areas and follow the direction from the work supervisor.

Workers are obliged to remain within designated safety zones. They must follow supervisors' directions and not exceed protective boundaries. This intervention is crucial when workers are carrying ACP that could compromise balance.

4.2.2. Impact of Workers Falling from Height

1. Worker experiences serious injury or worst death/fatality.

To anticipate the possibility of workers falling from a height, impact control measures are implemented to minimize the risk of workers experiencing serious injury or even death through the following procedures:

a. Use of complete Personal Protective Equipment (PPE) designated for Roofing/Roof Frame Work at heights as stated below:

- *Full Body Harness*

  The harness serves as the primary fall arrest system that distributes the impact force to the strongest parts of the body, thus preventing fatal injuries when workers lose their balance on the frame or roof edge.
- *Lanyard* with *Shock Absorber*

  The lanyard keeps the worker attached to the anchor point, while the shock absorber dampens the impact force so that the body does not receive excessive shock impact when a fall is caught.
- *Double Lanyard (Y-Lanyard)*

  The use of a double lanyard allows workers to remain attached when moving anchor points on the steel frame, so there is no moment where workers are unprotected.
- *Safety Helmet withChin Strap*

  A helmet with a chin strap protects the head from impacts and falling objects, and remains securely in place when the worker moves, crawls, or receives sudden pulling forces.
- Anti-slip soles shoes

  Shoes with anti-slip soles provide better grip on slippery steel pipes and roof membranes, reducing the risk of slipping.
- Working Gloves

  Gloves help improve grip on steel pipes and ACP materials, as well as protect hands from scratches and hot surfaces.
- *Rope Grab* (For Vertical *Lifeline*)

  The rope grab automatically locks onto the rope when it detects a fall, providing protection when climbing up and down the frame.
- Auto Locking Carabiner

The carabiner serves as a secure connection in a fall arrest system and its locking mechanism prevents it from opening due to vibration or sudden pulls.

- *Body Positioning Belt*
  The positioning belt maintains body stability when workers have to work with both hands free, especially when installing ACP plank lists on the roof edge.
- *Safety Googles* or *Face Shield*
  Eye protection prevents exposure to dust, ACP debris, and fine particles carried by the wind so that the eyes remain safe and comfortable while working.
- *High Visibility Vest*
  High visibility vests help workers be clearly visible to coworkers and supervisors, especially in noisy areas or with a lot of material lifting activity.
- *Knee Pad*
  Knee pads help workers when they have to crawl or kneel on frame or membrane surfaces, reducing pressure and the risk of slipping.
- *Respiratory Mask*
  Masks protect the respiratory tract when working with materials that produce fine dust such as ACP or membrane pieces.
- *Lanyard Keeper*
  Lanyard guards ensure that the ends of the lanyards do not hang freely so that they do not get caught on structures or interfere with worker movement.

b. Emergency Handling Procedures and Evacuation of Fallen Workers
This procedure outlines technical steps such as assessing the workers condition, stopping work, and contacting a medical team. Prompt and appropriate evacuation prevents further injuries, such as shock, bleeding, or other complications.

c. Installation of Safety Net
Safety nets are installed below the work area to catch workers in the event of a fall. The net absorbs the energy of the fall and reduces the impact force, preventing serious injury. This system is particularly effective on roofing projects with ample clearance spaces below.

2. Other workers below also get impacted when the worker fell
To anticipate the possibility of workers falling from a height, impact control measures are implemented to minimize the risk of other workers below being hit when a worker falls through the following procedures:
   a. Use of *barricade* and no entry zone at below workers' working site
   Physical barriers are placed to block people's access to areas below work sites. Barricades prevent people from being in areas where they could potentially receive falling objects or be struck by falling workers.
   b. Controlling personnel access so not everyone able to pass under the work area.
   Procedures dictate that workers on lower floors must not be present or passing through the path under roofing work. Coordination with the supervisor ensures the area remains sterile during work.
   c. Make sure the lower area remains empty during the work.
   Spotters are responsible for monitoring the area below and ensuring that no one enters the danger zone. They alert anyone to potential hazards and halt work if the area becomes unsafe.

3. Damage to Structures or Other Materials when hit by falling workers
To anticipate the possibility of workers falling from a height, impact control measures are implemented to minimize the risk of damage to structures or other materials when struck by falling workers through the following efforts:
   a. Installation of safe work platform to hold materials and workers
   Temporary storage platforms or racks are placed to hold the material and prevent it from falling. This is important when transporting ACP or membranes that can easily blow away or slip off the frame.
   b. Procedures for arranging and securing materials to prevent them from falling
   Procedures for arranging materials so they are not near the edge, setting limits on the amount of material on the structure, and using safety ropes. These procedures prevent falling materials that could damage the structure.
   c. Workers must secure the materials before starting to work

Workers are responsible for ensuring that materials are not placed carelessly, are always secured during installation, and are not left in fall-risk areas. These interventions protect the structure and the safety of other workers.

V. CONCLUSIONS

According to analysis result of the risk management analysis on the Public Open Space Development Project under the name of Construction project of VVIP Tribune at Borarsi Football Field, Manokwari, West Papua, the researchers are able to withdraw conclusion as stated below:

1. The most dominant work accident risks are:

a. Roofing work with hazard of using cranes and chain blocks to lift materials. The risk of uncontrolled material when lifting (6d) obtained the following scoring: Frequency Index (FI) = 41 %, rank : 2, Severity Index (SI) = 63 %, rank : 3, category: extreme matrix.

b. Roofing work with hazard of installing roofs at height with the risk of workers falling from a height (6e) obtained the following scoring: Frequency Index (FI) = 42 %,rank : 2, Severity Index (SI) = 70 %, rank : 3, category: extreme matrix.

2. The causal factors and resulting impact are:

a. Factors causing material instability during lifting include strong winds, the use of slings/rigging that are not suitable for the lifting capacity, ineffective communication between the rigger and crane operator, errors in load lashing methods, and miscalculations of crane capacity. While the impacts include the potential for falling materials and able to cause serious injury or death to workers, structural damage, crane instability, and the risk of collapse, as well as work interruptions that can lead to project delays.

b. Factors that cause workers to fall from heights include loss of balance while moving on a steel frame, unstable roof structures, slippery or load-bearing roof surfaces, and working on the edge of a roof without edge protection. While the impacts include serious or fatal injuries to workers, the risk of other workers being struck in the event of a fall, and potential damage to materials or structural elements due to the impact.

3. Risk Control Strategy

Risk control strategy is applied through two primary approaches:

a. Preventive Barrier: ensuring the use of standard rigging, checking weather conditions, installing safety devices such as lifelines and guardrails, implementing SOPs for lifting and working at heights, installing temporary bracing, using safe footing, and strengthening communication through signalmen and communication devices.

b. Mitigation Barrier or impact mitigation: providing complete PPE, installing safety nets and barricades in hazardous areas, establishing prohibited zones under the lifting path and upper work areas, ensuring crane stability through outriggers and ground mats, and implementing emergency response also evacuation procedures to reduce the level of injury and the impact of damage if incident still occurs.

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