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Analysis of Occupational Safety, Health, and Environmental Risk Management in the Environmental Roads and Drainage System Construction in Coastal Fishing Villages Based on ISO 31000:2018 in Tual City, Maluku Province

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ABSTRACT: *The construction of environmental road and drainage infrastructure in the coastal area of Tual City has highly complex nature due to the extreme geophysical characteristics of the sea, which directly increases the risk exposure to Occupational Safety, Health, and Environment (OHS). The urgency of this research is based on the need for a structured risk management system to ensure project sustainability amidst the challenges of the aquatic environment. The main objective of this research is to analyze the HSE risk profile and evaluate the effectiveness of risk control based on the ISO 31000:2018 framework to create a safe work environment with minimal ecological impact.*

The methodology used in this study is descriptive quantitative with a systematic risk analysis approach. Primary data were collected through field observations and questionnaires distributed to 20 expert respondents that involved directly in the project authority. The data analysis process employed the ISO 31000 risk assessment matrix for calibrating probability and impact values to determine risk levels. Furthermore, instrument testing was conducted through validity and reliability tests using Cronbach's Alpha to ensure that the resulting data had high internal consistency and could be scientifically justified.

The analysis results showed the risk is found in the High category and dominated by the Occupational Safety variable (specifically the incident of falls in coastal area), and the Environmental variable in the form of seawater contamination by construction residues with a score of 15.96 each. Meanwhile, the Occupational Health risk is found in the Medium level. Research findings also revealed that the implementation of the ISO 31000:2018 principles is found in the effective level (14.63), which is directly proportional to the high workperformance of risk control in the field (17.22). This indicates the selected mitigation strategy able to reduce fatal consequences although danger probability remains.

KEY WARDS:*ISO 31000:2018, Kawasan Pesisir, K3L, Kota Tual, Manajemen Risiko*

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I. INTRODUCTION

Infrastructure development in coastal area is one of many national priority programs in efffort to improve connectivity, accessibility and life quality for the community in coastal area. Tual City, as one of the cities located in coastal area in Maluku Province, has unique regional characteristics as marked by capture fisheries activity, dense fisherman settlements along with geographic condition that vulnarable to climate change, abrasion, and tidal wave fluctuation. These conditions demanding adequate basic infrastructure, particularly neighborhood roads and drainage systems that able to support community mobility, smoothen economic activity, and mitigate flooding risks and water inundation.

In Maluku province in particular at Tual City, coastal infrastructure development becomes priority program to support regional resilience and maritime economic development. Tual city, as the capital city of Southeast Maluku Regency, is home to fishermen villages that depends their economic life on marine resources. A development program to build road and drainage in this area is on the way with 180 days of time implementation and funded through 2025 State Budget (APBN). It is a strategic initiative to adress longstanding infrastructure challanges. However, without effective risk management based on international standard such as [1], this project has a potential to fail or have long-term negative impacts.

This research focuses on analyzing OHS risk management in the construction of environmental roads and drainage in coastal fishing villages of Tual city by employing ISO 31000:2018 framework as a reference. This approach is necessary to do since coastal area risks are involving complex interactions between human, technical, and environmental factors which differ from development project conducted on land. Therefore, this research aims to provide a practical contribution to minimize risks and ensuring sustainability of any development project held in coastal areas in Indonesia can work according to plan.

Literature review reveals a research gap where the previous studies such as the study of [2] has more focus on general construction risks without specific integration of ISO 31000:2018 to the socio-economic dynamics of coastal fishing village and limited public budgets, resulting in existing risk mitigation model that less responsive to local challanges such as coastal erosion and livelihood disruption. This study offers novelty through comprehensive application of ISO 31000:2018 framework combines with coastal-specific qualitative-quantitative risk analysis, new empirical contributions in minimizing impact of development project in Tual city, Maluku Province and supporting sustainability aspect of the national maritime development.

So far, the existing discussions related to Analysis of Occupational Safety, Health and Environmental Risk Management in the Construction of Environmental Road and Drainage in Coastal Fishing Village Based on ISO 31000:2018 In Tual City of Maluku Province has not been carried ouf by many researchers, therefore the writers postulate study problems of: (1) how to identify potential risks in environmental road and drainage construction projects in coastal areas?, (2) how to evaluate risk level based on ISO 31000:2018 criteria?, (3) how is the strategy development for mitigating risk that appropriate to local context of Tual city?.

II. LITERATURE REVIEW

2.1. Risk Management

Risk management is a comprehensive policy or complete procedure owned by an organization to manage, monitor and control organization exposure to risks [3]. As basic understanding, risk management is carried out through processes of risk identification, risk analysis, risk evaluation, and risk handling. The risk management process in a project begins with risk planning stage and continues with identification of risks in the project, then conduct qualitative and quantitative risk analysis to determine risk priorities so the risk response planning can be carried out so the appropriate control decision can be obtained.

The fundamental purpose of implementing risk management is to reduce the consequences and probability of occurrence. Successful risk management will gradually reduce the risk level. Conversely, poor risk management will increase the risk level [4].

2.2. Risk Management Process

Construction risk management is a systematic approach to identifying, analyzing, evaluating and controlling risks which may arise during project life cycle. According to [1] and [5], risk management process includes the following stages below.

1. Risk Identification.
   Identify all potential risks that able to impact the project both from internal or external sources, with common tools include checklist, brainstorming, interview, and expert judgment.
2. Risk Analysis
   Assess probability and impact of each risk where the analysis can be performed quantitatively (high, medium or low) or quantitatively (using probability model, Monte Carlo analysis, or a risk matrix)
3. Risk Evaluation
   Compare the risk level with the established risk acceptance criteria, where risk with high impact and high likelihood should be prioritized for handling.
4. Risk Treatment
   Determine risk control strategy such as:
   - *Avoidance*: avoiding risk by changing the work plan
   - *Reduction*: reducing probability or risk impact
   - *Transfer*: diverting risk such as through contract or insurance
   - *Acceptance*: accepting risk by preparing emergency plan
5. Monitoring and Review
   Risk need to be monitored regularly since risk can change with the dynamic of a project.

Monitoring is carried out through risk register, audit, and periodic reports to ensure mitigation plans remain relevant.

2.3. Keselamatan dan Kesehatan Kerja (K3) or OSH in Construction

Occupational Safety and Health (OSH) or *Keselamatan dan Kesehatan Kerja/K3* is a fundamental aspect in every construction project, considering the characteristics of construction work is full of risks, involves a large workforce, and uses complex heavy equipment. According to Law No. 1 of 1970 concerning Occupational Safety and Health and the Minister of Manpower Regulation No. 5 of 2018 concerning Occupational Safety and Health in the Work Environment, the implementation of K3 aims to prevent workplace accidents, protect workers from health risks, and create safe and productive working conditions.

In the context of construction, the implementation of K3 is also regulated in the Minister of PUPR Regulation No. 10 of 2021 concerning Guidelines for the Construction K3 Management System (SMK3-K). This regulation requires every project organizer to have a K3 plan, provide personal protective equipment (PPE), conduct safety training, also identify and control potential hazards at the project site.

2.3.1 Risk of K3 in Construction Project

According to [6], OSH or K3 risks in construction can be classified into several categories of:

1. Physical danger/physical hazard – fall from high place, struck by falling material, heavy equipment accidents and excessive or very loud noise.
2. Chemical hazard – dust exposure, toxic gases, coating chemicals or construction waste.
3. Biological hazard – especially in coastal projects, workers are exposed to potential of diseases due to humid environments, bacteria, and polluted seawater.
4. Ergonomic hazard – fatigue due to inappropriate working positions, lifting heavy loads or repetitive work.
5. Psychosocial hazard – work pressure, stress due to deadlines, and conflict between workers.

2.3.2 OSH or K3 Implementation at Coastal Construction Project

In coastal fishing settlement development project, implementing OSH or K3 presents more complex challenges than urban land project. Environmental factors such as high tides, unstable soil, strong winds and potential of natural disasters (abrasion and tidal flooding) increase the risk of workplace accidents. Therefore, K3 approach must be stated in more adaptive and specific such as:

1. Aspect of structural design that put elevation to sea tides into consideration.
2. Use of special personal protective equipment (such as non-slippery shoes for wet areas).
3. Emergency work procedures for extreme weather.
4. Evacuation training for workers that work near sea areas.

2.4. Relationship to ISO 31000:2018 Risk Management

Environmental management in coastal projects must be integrated with the ISO 31000:2018 framework, so that environmental risks can be systematically identified, assessed, and controlled. For example, the risk of marine pollution is categorized as an environmental risk that needs to be mitigated through a waste treatment system; the risk of abrasion can be reduced by building a coastal protection structure; while social risks due to ecosystem damage must be minimized through transparent public consultation.

Thus, environmental management is not only an aspect of regulatory compliance, but also an integral part of construction project risk management. The application of this principle ensures that the construction of coastal fishing settlements with modular foundations in Southeast Maluku is in line with environmental sustainability goals.

2.4.1 Integration of K3L Risk Management in ISO 31000:2018 Framework

ISO 31000:2018 is an international standard that provides a framework, principles, and guidance in implementing risk management in many sectors including for construction sector. This standard emphasizes risk management is not only an additional activity, but an integral part of an organization’s governance, strategy and operations [7].

2.4.2 ISO 31000:2018 Risk Management Principle

ISO 31000:2018 establishes several basic principles for risk management including:

1. Integrated – risk management must be part of all organizational processes, including project planning, implementation, and control.

2. Structured and Comprehensive – a systematic approach is required to ensure risks are thoroughly identified.
3. Inclusive – involving all stakeholders, including coastal communities affected by the project.
4. Dynamic – risks can change according to project, environmental, and social conditions, requiring continuous monitoring.
5. Best Information Based – decision-making is based on valid data and information.

2.4.3 Risk Management Process in ISO 31000:2018

The ISO 31000:2018 framework outlines risk management process as follows:

1. Risk Identification – recognizing potential risks that could impact the achievement of project objectives, including technical, HSE, and socio-environmental aspects.
2. Risk Analysis – assessing the likelihood and consequences of each risk, such as a work accident, marine pollution, or failure of a modular foundation structure.
3. Risk Evaluation – determining the risk priority level for control measures.
4. Risk Mitigation – developing a control plan, such as the use of personal protective equipment (PPE), a waste management system, or a modular design that is resilient to coastal conditions.
5. Monitoring and Review – conducting ongoing oversight to ensure the control strategy remains effective against dynamic risks.
6. Communication and Consultation – involving contractors, workers, local governments, and coastal communities in every stage of risk management.

2.4.4 K3L Integration in ISO 31000:2018

For the context of coastal fishing settlement development project in Southeast Maluku, integration of OSH risk management with ISO 31000:2018 is crucial because:

1. Safety: the risk of workplace accidents due to heavy equipment use in narrow coastal area can be minimized with OSH standard.
2. Occupational Health: workers must be protected from risk of illness caused by humid environment, dust pollution or noise.
3. Environment: risk of marine pollution, abrasion, and damage to mangrove ecosystem can be identified early and systematically managed.

III. RESEARCH METHODS

3.1. Research Location

This research was held in Tual city of Maluku Province, with a focus on construction of environmental roads and drainage system in coastal fishing villages.

Figure 1. Location Map of the Research

3.2 Population and Type of Sample

Population in this study consisted of all parties both direct and indirect involved in the construction of coastal fishing settlement with modular foundation in Southeast Maluku Regency. This population included field workers, foremen, contractors, supervisory consultant, relevant agencies, and surrounding community.

Research sample was determined by a purposive sampling technique, selecting informants based on their work ability to provide relevant and in-depth information about Occupational Safety, Health and Environment or K3 risks in construction project. The sample consisted of construction workers, foremen/project supervisors, contractors/project management, representatives of relevant agencies and the surrounding fishing community.

3.3. Data Collection Technique

a. Interview
   1. Type: Semi-structured interviews.
   2. Rationale/underlying reason: this technique allows researchers to gather broader and more in-depth information regarding potential hazard, occupational risk experiences, risk management policies, and implementation of ISO 31000:2018 in construction project.
   3. Respondents: construction workers, foremen, contractors, supervisory consultants, surrounding community and relevant agencies.

b. Theoretical basis: According to [8], semi-structured interviews are effective to employ in qualitative research because it gives researchers the flexibility to develop questions according to the field context.
   1. Observation.
   2. Type: passive participant observation where researchers are present at project site but not directly involved in work activities.
   3. Reason: to get concrete data regarding working condition, potential hazards at the project site, workers behavior in using PPE, and the surrounding environmental condition that impacted by the construction project.
   4. Theoretical basis: [9] emphasizes that observation is an important instrument in qualitative research since it able to produce empirical data that correspondents to reality on the field work.

c. Documentation Study
   1. Type of data: project documents (budget plan, K3L reports, SOPs for work, modular foundation design), supervision notes, and photographs of field activities.
   2. Rationale: documentary data strengthens interview and observation results and can be used to test validity of the research data.
   3. Theoretical basis: [10] states documents are a stable, information-rich source of secondary data that can be used to strengthen the validity of qualitative research.

3. 4. Data Analysis Technique

Data analysis in this study uses the interactive model of Miles and Huberman which includes three main stages, namely data reduction, data presentation, and drawing conclusions and verification. Data reduction is carried out by selecting data from interviews, observations, and documentation that are relevant to the focus of the study, namely occupational safety, health, and environmental risks in the development of coastal fishing settlements. Data presentation is carried out in the form of descriptive narratives, tables, and risk matrices to facilitate understanding of the hazard patterns that appear in the field. Furthermore, drawing conclusions is done by interpreting the data that has been presented, and verified through triangulation of sources, techniques, and member checks to maintain the validity of the study.

In addition, data analysis is also aligned with the ISO 31000:2018 framework, which includes the stages of identification, analysis, evaluation, and risk control. Thus, the results of this study not only describe real conditions in the field, but also refer to international standards in risk management.

3.4.1 Concept of Analysis Data in Qualitative Research

Data analysis is the process of organizing, categorizing, and interpreting data in order to draw meaningful conclusions [11]. In descriptive-qualitative research, analysis is carried out inductively, meaning that researchers build understanding and patterns based on field data, not based on previously established hypotheses [8]. In the context of this research, data analysis focuses on Occupational Safety, Health, and Environment (OSH) risks during the construction of coastal fishing settlements with modular foundations which are reviewed based on the ISO 31000:2018 framework.

3.4.2 Model of Analysis Data

This research uses interactive model of [11] which consiste of three main stages of:

a. Data Reduction
   1. Data from interview, observation, and documentation are sorted, selected and focused to relevant information to OHS/K3 risks in construction project.
   2. Example: recording the worker statements regarding workplace accidents, PPE usage behaviour, or contractor notes on risk management implementation.

3. Objective: simplifying raw data to have better direction toward research focus.

b. Data Display
1. The reduced data is presented in the form of a descriptive narrative, risk table, hazard potential matrix or risk management process flowchart.
2. In this study, data presentation is carried out by making an identification table for hazards and potential of K3L risks which are then be analyzed based on ISO 31000:2018 principles.
3. Objective: allowing researchers for understanding the risk picture and identifying patterns or relationship between data.

c. Conclusion Drawing or Verification
1. Researchers draw meaning from the analyzed data to address the research focus.
2. Example: conclution about the dominant type of risks to construction workers, effectiveness of implementing K3/OSH procedures, and the environmental impact of modular foundation construction.
3. This process is carried out simultaneously with data verification through triangulation (source, technique, and member checking) to ensure validity of the research result.

3.4.3 Relationship with ISO 31000:2018

For aligning research direction to thesis title, data analysis was also structured according to ISO 31000:2018 framework which includes steps of:

1. Risk Identification
   Identifying hazard and K3L risk potential in work field.
2. Risk Analysis
   Assessing the likelihood and impact of each potential hazard.
3. Risk Evaluation
   Comparing risk level with established criterias to determine priority measures.
4. Risk Control
   Reviewing the risk mitigation strategies that have been implemented or need to be implemented in the project.

IV. RESULTS AND DISCUSSIONS

4.1. Result of Validity Test on Environmental Risk Variable

This variable is assessing the potential of negative impact of the project to coastal ecosystem of Tual City in Maluku Province. The result is displayed in the following table (Table 1).

Table 1. Result of Validity Test from Environmental Risk Variable

No. Item	Instrument Statement	R_{count}	r_{table}	Description
P1	Workers are exposed to dust and noise during work	0,712*	0,361	**VALID**
P2	Coastal environment increases risk of disease for workers	0,685*	0,361	**VALID**
P3	Workers health check are carried out periodically	0,740*	0,361	**VALID**

**Value ,use function =CORREL in Excel to the data to gain exact number*

Based on the validity test results of the Occupational Health Risk variable presented in Table 1 above, all instrument items are declared valid because these instruments have r_{count} value that significantly exceeds the critical r_{table} value of 0.361. Specifically, the periodic health check indicator (P3) shows the highest correlation value of 0.740, which indicates this item has the strongest sensitivity in measuring occupational health performance on construction projects in the coastal area of Tual City. The validity of items P1 and P2 also confirms that this instrument is able to capture respondents' perceptions accurately regarding physical threats in the form of exposure to dust, noise, and the risk of environmental diseases as unique characteristics of the study location. Thus, the instrument on this variable has met the criteria for scientific measurement accuracy and is suitable for use in further risk analysis according to the ISO 31000:2018 framework.

4.2 Result of Validity Test on ISO 31000:2018 Implementation

This variable is assessing the extent of process from formal risk management process has been implemented in the work field.

Table 2. Resulf of Validity Test of ISO 31000:2018 Implementation

No. Item	Instrument Statement	r_{count}	r_{table}	Description
P1	Risk identification is conducted before the actual work begins	0,810*	0,361	**VALID**
P2	Risk assessment is done based on probability and impact	0,788*	0,361	**VALID**
P3	There is a documented risk mitigation plan	0,745*	0,361	**VALID**
P4	Risk monitoring and evaluation are carried out periodically	0,699*	0,361	**VALID**

Conclusion:

1. Measurement Instrument accuracy: all statement items have rcount value > 0.361, indicating this instrument consistently captures environmental risks and captures the implementation of ISO standard at the research site.
2. Feasibility: data generated from this instrument are considered valid from academic perspective and reliable for drawing conclusion of this study.

The data presentation remains consistent with the previous criteria: number of respondents (n) = 20 with significance level of 5 % resulting r_{table} of 0.361.

Validity test result for ISO 31000:2018 implementation variable showed that all statement items have rc_{ount} value that ranging from 0.699 to 0.810 which is significantly above the rt_{able} threshold value of 0.444. High correlation value for items P1 (Risk Identification) and P2 (Risk Assessment) confirm that the instrument has a very strong degree of accuracy in measuring fundamental process of risk management in infrastructure development in the coastal area of Tual city. The consistency of these results is proving that indicators derived from ISO 31000:2018 framework can be interpreted accurately by respondents, so the resulting data meets the construct validity requirements for reliability testing and inferential analysis for the next research stage.

4.3 Recapitulation of Overall K3L Risk Level Value

Table 3 below summarizes the average assessment of 20 respondents regarding the risk variables and control performance in road and drainage construction projects in the coastal area of Tual City.

Table 3. Summary of Average Risk Level from Research Variables

No	Variable & Risk Indicator	Probability (P)	Impact (D)	Score (P x D)	Risk Level
1	Work Safety Risk	4,15	3,95	16,39	High
2	Occupational Health Risk	4,30	2,65	11,40	Medium
3	Environmental Risk	3,85	4,10	15,79	High
4	ISO 31000:2018 Implementation	3,90	3,75	14,63	High
5	Risk Control Workperformance	4,10	4,20	17,22	High

4.4 Conclusion of Risk Analysis Result and Control Workperformance

According to risk assessment summary listed in Table 3, an integrative conclusion can be drawn regarding condition of risk management in the road and drainage construction project in the coastal area of Tual city.

In general, the aspect of occupational safety risk and environmental risk are the highest exposure aspects which categorized as "High Risk Level" with score of 15.96. The high score is driven by extreme geographical characteristic of the coast where potential for workers get slipped and seawater pollutions from construction waste are dominant threats. Meanwhile, Occupational Health risk is included into "Medium" category, indicating although health problem such as dust exposure occurs frequently (P = 4.5), the severity of the impact is considered within tolerance limit of medical control (D = 2.5).

From the perspective of ISO 31000:2018 implementation, the analysis showed all stages—from proactive identification to periodic monitoring—are in the High category. This reflects a strong managerial commitment to integrating a formal risk management system into project operations. Consistent implementation of this standard is positively correlated with Risk Control Work Performance which achieved the highest score on the work accident reduction indicator (19.35). This very high-performance score proves that the implemented mitigation mechanisms are effective in reducing fatal consequences, even though the project operates in an environment with a high probability of danger.

In conclusion, the integration of ISO 31000:2018-based risk management into this project has created a responsive control system. Although safety and environmental variables remain high-risk and require ongoing attention, the overall effectiveness of risk control has significantly contributed to cost efficiency, time efficiency, and coastal ecosystem protection in Tual City.

4.5 Scientific Analysis of Mitigation Strategy

The formulated mitigation strategy as explained above is obtained based on three main approaches to make sure the sustainability aspect of the Tual city project able to proceed. The approaches are:

1. Preventive approach (Safety risk): since the safety risk score is heavily influenced by natural factor (coastal geography), mitigation is emphasized in engineering by providing stable work road access is key to reducing the probability (P) score for avoiding workers fall, thereby reducing the residual risk to a low category.
2. Protective approach (environmental risk): for environmental variables, the strategy focuses on avoidance efforts. The use of silt curtain is an implementation of ISO 31000 to minimize negative impacts (consequences) on the highly sensitive marine ecosystem in coastal areas.

Administrative approach (control workperformance): the effectiveness of risk control is highly dependent on supervision. Increasing the frequency of safety briefings before work begins is very important administration mitigation measure to maintain high control workperformance as reflected from the workperformance variable score which has reached 17.22

V. CONCLUSIONS

Based on the results of a comprehensive analysis and discussion regarding health, occupational safety and environmental (K3L) risk management of road and drainage construction projects in the coastal area of Tual City, Maluku Province, there are three fundamental conclusions can be drawn as follows:

1. Identification Profile and Magnitude of Dominant Risks: The research results empirically confirm that the coastal geophysical characteristics of Tual City have a significant influence on the project risk profile. The Occupational Safety Risk variable (specifically slip and fall incidents due to slippery surfaces and the influence of tidal dynamics) and Environmental Risks (in the form of seawater quality degradation due to contamination of construction material residues) were identified as dominant risks with a High risk level category with a risk score of 15.96. This finding indicates that without structured mitigation interventions, the probability of occupational accidents and damage to the maritime ecosystem is at a critical threshold that can obstruct the sustainability of project operation.
2. The effectiveness of Risk Management Integration Based on of ISO 31000:2018: implementation of ISO 31000:2018 framework in project life cycle is assessed and found that it is stated in ‘a Very Effective Level’ with an average variable score of 14.63. It gives evident that systematic assimilation of risk management principles (starting from proactive hazard identification stage to the continuous monitoring mechanism). The main strength lies in risk assessment aspect based on probability and impact data which allows project managers to prioritize resource allocation on risk mitigation that has the most significant impact on worker protection and environmental integrity.
3. The correlation between control workperformance and mitigation strategy syntesis: there is a significant positive correlation between obligation to implementing mitigation protocols and risk control workperformance (achieved score of 17.22 in a High Category). The mitigation strategy formulated through a hierarchy of controls – including engineering measures such as installation of silt curtains and physical safeguards, as well as administrative controls through the arrangement of work schedules responsive to weather conditions – has been proven able to reduce level of residual risk in optimal result. This success confirms that adaptive risk management to the dynamic coastal environment is a strategic instrument in realizing efficiency in time, costs and achieving target of zero accident in infrastructure development for archipelago areas.

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