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Risk Analysis of Small Dam Projects in Lima Puluh Kota Area Using Failure Mode and Effect Analysis

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ABSTRACT

There is always a potential hazard that can cause losses to project constructions. Risk management is a way to accommodate risks that may occur during the construction period. The purpose of this study is to identify the dominant risk in construction activities and to recommend risk control measures. This study uses the Failure Mode and Effect Analysis method. The focus of risk identification was carried out during the construction phase and involved a total of 56 respondents. The research results showed that there were eight risk variables identified as dominant risks. The dominant risks were: (i) shortage of material landfills, (ii) labour negligence, (iii) lack of awareness of workers using PPE, (iv) heavy equipment accident, (v) unstable soil condition, (vi) groundwater level condition, (vii) unclean project environment, and (viii) noisy project environment. The risk that occurs in implementing construction projects have an impact on the project's productivity, directly or indirectly. Although there are different risks, some risks are recommended with the same handling method, especially consistency in doing work with SOPs, monitoring employee discipline and using appropriate work methods.

1 INTRODUCTION

Projects are dynamic and risky fields. Risk can affect the productivity, performance, quality and cost limitations of the project[1]. Risk is interpreted as a result that may occur unexpectedly. Even though a course of action has been planned as meticulously as possible, it still contains uncertainty that later can pull down the work that has been planned[1, 2]. Based on various experiences, risks in construction projects cannot be eliminated; however, they can be reduced or transferred from one party to another[3]. To reduce and prevent

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the risks, good risk management is needed. Risk management is a structured and systematic process of identifying, measuring, mapping, developing alternative risk management, monitoring, and controlling risk management[4].

Indonesia has many rivers, but some areas face problems with water availability when dry season comes. During the dry season, the surrounding area will encounter water shortage. To overcome this problem, the government has built 3462 small dams in 2021[5], which are expected to accommodate water reserves during the rainy season and be used during the dry season. For that, 90 of these water reserves were built in West Sumatra[5], and some of them in Lima Puluh area. The small dams were built to address the problems of local community agriculture, water supply storage, raw water reserves, and new tourist attractions that became a new economic source for the surrounding community[6]. Similar to dams, small dam construction is also considered a high-risk construction[7]. Due to that, strict supervision is required in order not to cause risks that have a bad impact during and after construction. Risks arising from the construction of small dams include force majeure risks, implementation risks and management risks, risks due to materials and equipment, labour risks, contractual risks, as well as design and technology risks[8]. Meanwhile, the risks that can arise after construction is completed, i.e., overtopping, external erosion, mass movement (slope instability)[7, 9], piping[9], erosion, cracking and seepage on the walls of buildings[10]. These risks can occur due to human or non-human actions.

This study used the Failure Mode and Effect Analysis (FMEA) method. Failure Mode and Effect Analysis (FMEA) is a structured procedure to identify and prevent as many potential failure modes as possible for each system/activity[11-13]. FMEA is a broad subject with a wide variety of standards, procedures and applications. There is no shortage of opinions and ideas from practitioners, both new and experienced. It is impossible to fully satisfy everyone[11]. The failure mode is the manner in which the activities or operation potentially fails to meet or deliver the intended function and associated requirements[11, 12].

Previously studies related to risk management have been conducted for Leuwigoong dam[14], Tugu dam[15] and Gerak Kanal dam project in Semarang and its impact on the environment[16]. On many occasions, this project is considered a high-risk project. In this research, a risk analysis needs to be carried out on each job to determine the potential risk in small dam construction, especially in Lima Puluh area - West Sumatra Province. This province has an agenda to build quite a lot of small dam construction ahead[17]. So, control measures can be recommended as part of risk management in order to reduce the possibility of risk at the small dam project. This study aims to identify risks in construction project activities, determine the most dominant risks, and establish its risk control measures for small dam construction, especially in West Sumatra.

2 METHODOLOGY

The research focused on risk identification during the construction phase and involved 56 respondents from small dam projects. This research is conducted using the Failure Mode and Effect Analysis (FMEA) method. To collect the data from respondents, risk variables from several previous research are provided. The potential risk variables used are force majeure, materials and equipment, labour, occupational safety and health (K3), implementation, and design[14-16, 18, 19]. There are several steps to be taken in this research:

1. Create a potential impact of failure (risks) in each work item.
2. Assess the severity of the risks.
3. Assess the occurrence of the risks.
4. Assess the detection of the risks.
5. Calculate the Risk Priority Number (RPN) values.

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6. Determining the risk and recommendations of its control.

The FMEA failure process is carried out using three criteria, namely severity (S), occurrence (O), and detection (D). These three criteria are rated using a numerical scale, varying from 1 to 5. This 5-point scale format has a good average score and is more accessible for the respondent to understand[20], and has a better index of reliability, validity and strength of discrimination compared to 2, 3 or 4-point scale[21, 22]. Related to this research, the definition of each scale depends on the definition of the FMEA criteria used. Generally, a high value represents a poor score for all standards[23]. The severity, occurrence and detection scales and criteria are shown in Table 1.

Table 1. Severity, occurrence and detection scale for FMEA

Severity		Occurrence		Detection	
Scale	Criteria	Scale	Criteria	Scale	Criteria
5 Catastrophic	Hight severe effects of failure (lethal)	5 Very high/ often	Inevitable failures	5 Very Low	undetected/ almost impossible to detect failure earlier
4 Major	Severe effects of failure	4 High	Failures often occur repeatedly (frequent occurrences)	4 Low	low chance to detect failure earlier
3 Moderate	Rarely severe effects of failure	3 Moderate	The usual failures/ commonplace	3 Moderate	Moderate chance to detect failure earlier
2 Minor	Slightly severe effects of failure	2 Low/ rare	Failures occur only a few times (rare)	2 High	High chance to detect failure earlier
1 Insignificant/ no effect	not give severe effect of failure	1 Very Low	Very rare failures	1 Very high	Very high chance to detect failure earlier

The Severity Index (SI) of each criterion (S, O, D) is then calculated using Equation 1. The severity index (SI) is the percentage value of the impact and severity caused by risk factors.

$$SI=\frac{\sum_{i=0}^{4} a_i x_i}{4\sum_{i=0}^{4} x_i}100\% \tag{1}$$

In Equation 1, a is defined as constant (0 to 4), x_i as probability, and i as number 0, 1, 2, 3, 4, …, n. The score of SI result is then determined by its scale (Table 2). The scale values of these three criteria (S, 0 and D) are finally multiplied using Equation 2 to get the Risk Priority Number (RPN)[24].

Table 2. The category of Severity Index value[11]

Category	Severity index (SI)	Scale
Very low/ Rare	$0.00 \le SI \le 12.5$	1
Low	$12.5 \le SI \le 37.5$	2
Medium	$37.5 \le SI \le 62.5$	3
High	$62.5 \le SI \le 87.5$	4
Very high	$87.5 \le SI \le 100$	5

The SI value will affect the RPN score. The risk priority number (RPN) is a function of the three parameters: the severity of the effect of failure, the probability of occurrence, and the ease of detection for each failure mode[25] as given by Equation 2. The RPN becomes the basis for determining the focus of the risk priority and its handling. It means a failure mode with a high RPN number should be given the highest priority in the analysis and corrective action.

$$RPN = Occurrence \times Severity \times Detection \tag{2}$$

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3 RESULTS AND DISCUSSION

The result showed that all respondents agreed that 6 (six) variables with 29 risk factors had been identified throughout the construction phase of the small dam. The dominant risks were identified by calculating the Risk Priority Number (RPN) value using Equation 1. The risk factors, failure mode, effect, and the value of each risk RPN can be seen in Table 3 and described in Fig. 1.

Table 3. Risk priority number

Risk variable	Code	Failure mode	Effect	S	O	D	RPN
Force majeure							
Erratic weather conditions	R1	Workers' health problems, difficulty of project location to work on (example, with heavy equipment)	disrupting work schedules, lowering productivity, more cost	3	2	2	12
Natural disasters (earthquakes, floods, etc.)	R2	Landslide	disrupting work, serious injuries, more expenses	3	2	2	12
Materials and equipment							
Damage or loss of material	R3	insufficient of materials inventory	Work becomes late/ delay	2	2	2	8
Inflation affecting material prices	R4	Material prices become inaccurate or difficult to predict material prices	Need more cost	2	2	2	8
Disadvantages of material storage	R5	Storage is full, placement of material in an inappropriate/ improper place	Damaged the material, effecting the quality of material	3	2	2	12
Equipment damage or loss	R6	Incomplete or insufficient of equipment inventory	Work becomes late/ delay/needs more costs	2	2	2	8
Imprecise amount/ volume of material sent	R7	insufficient of materials inventory	Work becomes late/ delay	2	2	2	8
Shortage of material landfills	R8	material waste scattered at the project site	Dirty environment, air pollution, and soil pollution, workers' health problems	3	3	3	27
Workforce							
Labor negligence	R9	Slipped down from a height, hit by equipment and materials	Minor and severe injuries, die, interferes the works	4	3	2	24
Labor shortage	R10	Slow job progress	Work becomes late, disbursement of funds is hampered	2	2	2	8
Labor strike	R11	Interfere the work, labor shortages	Work becomes late/ delay	2	2	2	8
Communication problems between workers	R12	miscommunication	Hamper the work process, misunderstandings, and disputes	2	2	2	8
Low labor productivity	R13	Project not completed on time, error at work	late, need more costs, The results of the work do not meet the quality control standards	3	2	2	12
Lack awareness of workers to use Personal Protective Equipment	R14	Workers do not use Personal Protective Equipment	Slipped down from height, hit by equipment and materials, minor and severe injuries	4	2	2	16

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Lack of team control and coordination	R15	miscommunication	Misunderstandings, and disputes, delay	3	2	2	12
Occupational health and safety (OHS) risk							
The machine/heavy equipment does not work well	R16	accidents, clash between heavy equipment during operations, falling tools	minor and severe injuries, late	3	3	2	18
Workers not equipped with Personal Protective Equipment	R17	Workers do not use Personal Protective Equipment	hit by equipment and materials, minor and severe injuries	3	2	2	12
Poorly implemented safety regulations	R18	Workers do not use Personal Protective Equipment/ not using the Personal Protective Equipment perfectly	Slipped, hit by equipment and materials, minor and severe injuries	3	2	2	12
Health problems due to general working conditions	R19	Many workers fall ill (covid 19)	Labor shortage, work becomes late, workers are exhausted	3	2	2	12
Implementation risks							
Difficulties in transporting heavy equipment to the project site	R20	Work schedule becomes late	Late project progress	2	2	2	8
Unstable soil conditions	R21	Landslide excavations	mired; minor and seriously injuries	4	2	2	16
Groundwater level conditions	R22	Flood location	cannot work or work hampered	4	2	2	16
Unclean/ less clean the project environment	R23	Material waste and dust	workers' health problems	3	3	3	27
Noisy project environment	R24	Workers do not focus on work	minor injuries	3	3	2	18
machine not checked before operation	R25	Machine overturned or mired	Hamper the work process, late	3	2	2	12
Lack of tools and materials	R26	Workers cannot work optimally	Work becomes late/ delay	3	2	2	12
Lack of quality work	R27	The results of the work do not meet the quality control standards	Rework, more costs, late	3	2	2	12
Design							
Incomplete design data	R28	Affects the physical failure of the building	redesign, reworks, more costs, late	3	2	2	12
Inaccuracy and incompatibility of design specifications	R29	The results of the work do not meet the specified specifications and designs	redesign, reworks, more costs, late	3	2	2	12
Average RPN							13.2

Note: S = severity, O = occurrence, D = detection, RPN = risk priority number

Table 3 showed that the highest RPN reached 27 points, and the lowest RPS was at point 8. Materials and equipment, workforce, occupational health and safety (OHS), and implementation risks were the variables that consisted of risks with the RPN more than the average, and no risk factor with RPN more than the average in force majeure and design variables. It indicated that during the construction, design and force majeure did not significantly influence, even though all RPNs almost reached the average.

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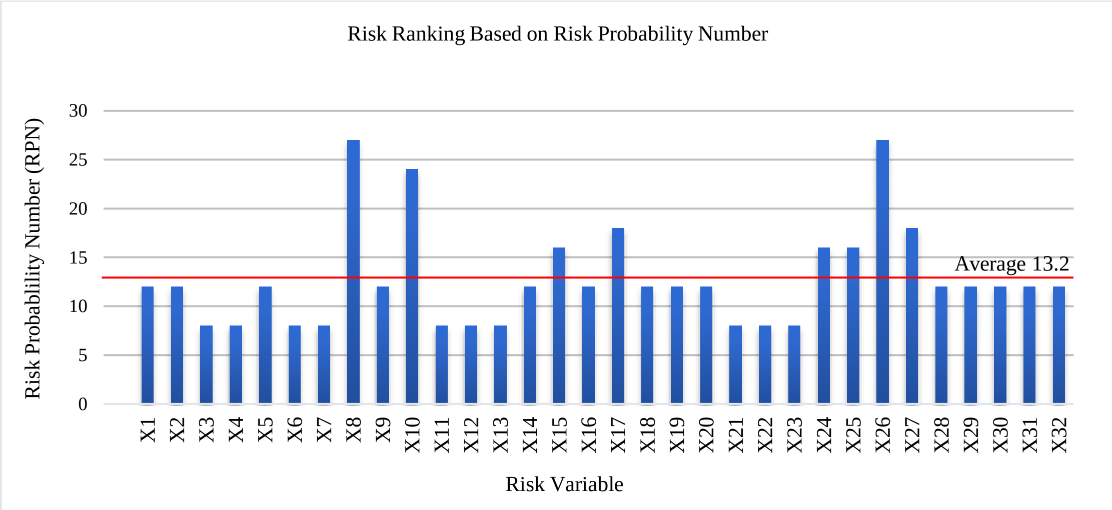

Fig. 1. The value of risk probability number for each risk variable.

Fig. 1 showed that among the 29 risk factors, there were 8 (eight) risks which have points more than the average of RPN, 13.2 and are considered as dominant risks. They are, i.e. (i) shortage of material landfills, (ii) labour negligence, (iii) lack of awareness of workers to use personal protective equipment, (iv) the machine/heavy equipment does not work well, (v) unstable soil conditions, (vi) groundwater level conditions, (vii) unclean/ less clean the project environment, and (viii) noisy project environment. These eight dominant risks are in the medium category, where the SI value of severity, occurrence and detection of each of them is between 37.5 and 62.5. The most dominant risk variable was the risk of implementation, where unclean/ less clean the project had the highest RPN. It was connected to the shortage of material landfills and had an impact on material waste scattered at the project site. These wastes were not only found at one time but almost throughout the implementation of the project. The implementation issues of further concern were unstable soil conditions, groundwater level conditions, and a noisy project environment. These three issues can have a direct impact on the worker. For example, unstable soil conditions can cause landslide excavations, and the impact is mired; minor and serious injuries (minor or major), hampered, late work progress, etc. All the dominant risks that have been identified require control measures to propose. Recommendations against the dominant risks are seen in Table 4.

Risks in Table 4 showed that there are several risks that have the same control recommendations, such as action to clean up material waste regularly, add more landfills, and ensure that the construction material is managed well in storage are the control in order to provide appropriate work. Besides area cleaning matter, the other risk was related to implementation, for example, the site/ area condition, material and the workforce. It was essential to manage the area because unstable area conditions could give several impacts on the construction process, especially when heavy equipment is used. The unset and unmanaged well of heavy equipment also could give influence the schedule and cost. The workforce risks such as negligence and lack of awareness to use Personal Protective Equipment could cause minor/major injuries, and if they occur, it will influence the productivity of the project (be delayed and late). Generally, the control for these risks also comes from supervision. The supervisor should ensure that the SOP or rules well implemented are important, so the supervisor's function is should maximal.

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Table 4. Risk control

Risk variable	Failure mode	Effect	Control
Materials and equipment			
Shortage of material landfills	material waste scattered at the project site	Dirty environment, air pollution, and soil pollution, workers' health problems	provide more landfill/trash bin, disposing (material waste) consistently and supervise its implementation
Workforce			
Labor negligence	Slipped down from a height, hit by equipment and materials	Minor and severe injuries, die, interferes the works	conducting briefings before starting work and warnings always to be alert and careful
Lack awareness of workers to use Personal Protective Equipment	Workers do not use Personal Protective Equipment	Slipped down from height, hit by equipment and materials, minor and severe injuries	strict supervision to ensure PPE is properly installed, prohibited the workers from working if not carried out according to SOP, provide punishment for those who violate, prepare PPE for the workers
Occupational health and safety (OHS) risk			
The machine/heavy equipment does not work well	accidents, clash between heavy equipment during operations, falling tools	minor and severe injuries, late	periodic checks on the heavy equipment and make sure to fix it immediately before using it
Implementation risks			
Unstable soil conditions	Landslide excavations	mired; minor and serve injuries	stabilizing the soil either mechanically or with additional materials, vacuum consolidation or maintaining soil slope with additional retaining structures/constructions
Groundwater level conditions	Flood location	cannot work/ work hampered	dewatering to reduce the high of the water level
Unclean/ less clean the project environment	Material waste and dust	workers' health problems	regular and consistent cleaning of the work area and gives warnings to workers
Noisy project environment	Workers do not focus on work	minor injuries	set the machine/ heavy equipment operation schedule and ensure the workers use hearing protection equipment.

4 CONCLUSIONS

Risk will always have the potential to occur in project construction, including the small dam project. These risks will have an impact not only in the construction phase but also after the construction is completed. The unwell-built small dam could cause disaster when the small dam is operating. The dominant risk occurred mostly in implementation and will influence productivity, time, and cost. Although there are different risks, some risks can be recommended with the same handling method, for example, consistency in doing work with SOPs and monitoring employee discipline and using appropriate work methods.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest related to the work.

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AUTHORS' CONTRIBUTIONS

Conceptualization: Sapitri
Data curation: Sapitri, S. Afrilia
Methodology: Sapitri, S. Afrilia, & Harmiyati
Formal analysis: Sapitri, S. Afrilia, & Harmiyati
Visualisation: Harmiyati
Software: Sapitri, S. Afrilia
Writing (original draft): Sapitri, S. Afrilia, & Harmiyati
Writing (review and editing): Sapitri, S. Afrilia, & Harmiyati
Validation: Sapitri, S. Afrilia, & Harmiyati
Supervision: Sapitri
Funding acquisition: Sapitri
Project administration: S. Afrilia

REFERENCES

1. Labombang, M. (2011). Manajemen risiko dalam proyek konstruksi [Risk management in construction projects]. *Jurnal SMARTek, 9*(1), 39–46.

2. Salim, H. A. (2008). *Asuransi & manajemen resiko* [Insurance & risk management]. Rajagrafindo Persada.

3. Kangari, R. (1995). Risk management perceptions and trends of U.S. construction. *Journal of Construction Engineering and Management*, *121*(4), 422-429. https://doi.org/10.1061/(ASCE)0733-9364(1995)121:4(422)

4. Djohanputro, B. (2008). *Manajemen risiko korporat* [Corporate risk management]. Jakarta PPM.

5. Direktorat Jenderal Sumber Daya Air. (2021). *Embung* [Small dam]. https://data.pu.go.id/dataset/embung/resource/4fc63d7e-9ce6-4ae0-b66d-97a63468028a#{}

6. Połomski, M., & Wiatkowski, M. (2023). Impounding reservoirs, benefits and risks: A review of environmental and technical aspects of construction and operation. *Sustainability*, *15*(22), 16020. https://doi.org/10.3390/su152216020

7. Lima, D. A. de, Lima, G. T. N. P. de, Molina Júnior, V. E., & Fais, L. M. C. F. (2022). Application of a simplified methodology for classification of small dams in cascade. *Revista Ambiente & Água - An Interdisciplinary Journal of Applied Science*, *17*(1), e2790. https://doi.org/10.4136/ambi-agua.2790

8. Pratama, Y. B. (2018). *Analisa manajemen resiko pada proyek pembangunan embung di kawasan perkantoran Kota Pekanbaru* [Risk management analysis on the small dam project in Pekanbaru area]. *Universitas Islam Riau Repository*. https://library.uir.ac.id/skripsi/pdf/133110163/bab4.pdf

9. Andersen, G. R., Chouinard, L. E., Hover, W. H., & Cox, C. W. (2001). Risk indexing tool to assist in prioritizing improvements to embankment dam inventories. *Journal of Geotechnical and Geoenvironmental Engineering, 127*(4), 325-334. https://doi.org/10.1061/(ASCE)1090-0241(2001)127:4(325)

10. Indrawan, D., Tanjung, M. I., & Sadikin, N. (2013). Penilaian indeks resiko metode modifikasi Andersen dan modifikasi ICOLD untuk 12 bendungan di Pulau Jawa [Risk index assessment of Andersen and ICOLD modification method for 12 small dams in Java]. *Jurnal Sumber Daya Air, 9*(2), 93-104.

11. Carlson, C. S. (2012). Effective FMEAs: Achieving safe, reliable, and economical products and processes using failure mode and effect analysis. *John Wiley & Sons, Inc*. https://doi.org/10.1002/9781118312575

12. Ushakov, I. A., & Harrison, R. A. (1994). Handbook of reliability engineering. *John Wiley & Sons, Inc*. https://doi.org/10.1002/9780470172414

13. Sielaff, L. (2022). Maintenance strategy selection based on fmea/fmeca approach using time dependent failure probability. *Engineering Proceedings*, *24*(1), 21. https://doi.org/10.3390/IECMA2022-12893

14. Rustandi, T. (2017). Kajian risiko tahap pelaksanaan konstruksi proyek peningkatan jaringan irigasi bendung Leuwigoong [Risk assessment of the irrigation network conctruction project of Leuwigoong small dam]. *Jurnal Infrastruktur, 3*(1), 19-30.

15. Wibisana, D. A. (2016). Analisa risiko kecelakaan kerja proyek bendungan Tugu kabupaten Trenggalek menggunakan metode FMEA (Failure mode and effect analysis) dan metode domino [Risk analysis of work accidents of the Tugu dam project Trenggalek district using the FMEA (Failure mode and effect analysis) and domino method]. *ITS Repository Insititut Teknologi Sepuluh November*. https://repository.its.ac.id/41835/1/3113106010-Undergraduate-Theses.pdf

16. Fatchiyati, A., Rahmawati, D., & Anggraini, L. (2019). Analisis manajemen risiko pembangunan Bendung Gerak Kanal Banjir Barat Kota Semarang dan dampaknya terhadap lingkungan [Risk management analysis of dam construction Gerak Kanal Banjir Barat in Semarang City and its environmental impact]. *Teknika,14*(1), 1-10. https://doi.org/10.26623/teknika.v14i1.1518

17. Pemerintah Provinsi Sumatera Barat. (2021). Rencana pembangunan jangka menengah daerah tahun 2021-2026 [Regional medium-term development plan for 2021-2026]. *Database Peraturan JDIH BPK*. https://peraturan.bpk.go.id/Details/188803/perda-prov-sumatera-barat-no-6-tahun-2021

18. Meylani, R. (2018). Analisa risiko konstruksi pada proyek pembangunan Gedung. Studi kasus: Pembangunan rumah susun Medan [Analysis of construction risks on building projects. Case study: Construction of Medan flats]. *Repositori Institusi USU, Univsersitas Sumatera Utara.* https://repositori.usu.ac.id/handle/123456789/10068

19. Lisananda, A. A. (2021). Manajemen risiko konstruksi pada proyek pembangunan perpipaan air limbah berdasar konsep ISO 31000:2018 [Construction risk management in wastewater piping construction projects based on ISO 31000: 2018]. *Universitas Islam Indonesia*. https://dspace.uii.ac.id/handle/123456789/29558

20. Dawes, J. (2008). Do data characteristics change according to the number of scale points used? An experiment using 5-point, 7-point and 10-point scales. *International Journal of Market Research, 50*(1), 61-77. https://ssrn.com/abstract=2013613

21. Budiaji, W. (2013). Skala Pengukuran dan jumlah respon skala likert [Measurement scale and Likert scale response count]. *Jurnal Ilmu Pertanian dan Perikanan, 2*(2), 127-133. http://dx.doi.org/10.31227/osf.io/k7bgy

22. Chyung, S. Y., Roberts, K., Swanson, I. & Hankinson, A. (2017). Evidence-based survey design: The use of a midpoint on the Likert scale. *International Society for Performance Improvement, 56*(10), 15-23. https://doi.org/10.1002/pfi.21727

23. Díaz, H., & Soares, C. G. (2020). Failure mode identification and effect analysis of offshore wind turbines and substations. In G. Soares (Ed.), *Developments in renewable energies offshore* (pp. 444-460). Taylor & Francis. https://doi.org/10.1201/9781003134572-51

https://doi.org/10.24191/jsst.v4i1.67

24. Albasyouni, W., Abotaleb, I., & Nassar, K. (2023). Proposing the use of failure mode and effect analysis (FMEA) as risk assessment tool in construction. *International Journal of Innovative Technology and Exploring Engineering*, *12*(12), 6-14. https://doi.org/10.35940/ijitee.L9750.11121223

25. Kiran, D. R. (2017). Chapter 26 - Failure modes and effects analysis. In D. R. Kiran (Ed.), *Total quality management* (pp. 373-389). Elsevier Inc. https://doi.org/10.1016/B978-0-12-811035-5.00026-X

https://doi.org/10.24191/jsst.v4i1.67