International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 09 Sept. 2025, pp: 582-589 www.ijaem.net ISSN: 2395-5252

Bridging Traditional and Modern Reliability Approaches: Comparative Failure Mode Ranking of Subsea Distribution Units Using FMECA, Fuzzy TOPSIS, and PROMETHEE

Godstime U. Ugwulashi*, Ezebuchi Akandu, Charles U. Orji, Samson Nitonye
Department of Marine Engineering, Rivers State University, PMB 5080 Port-Harcourt

Date of Submission: 15-09-2025 Date of Acceptance: 25-09-2025

ABSTRACT: The reliability of subsea distribution units (SDUs) is pivotal to uninterrupted oil and gas production, particularly in deep and ultra-deep-water fields. This study presents an integrated framework that combines Failure Mode, Effects, and Criticality Analysis (FMECA), Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS), and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) to systematically evaluate SDU failure modes. FMECA establishes the baseline by identifying and ranking potential failures according to severity, occurrence, and detectability. Building on this, Fuzzy TOPSIS incorporates expert judgment and uncertainty, enabling the ranking of failures based on their relative closeness to the ideal solution. PROMETHEE complements the analysis through pairwise comparisons, generating a more robust prioritization of critical failure modes. The results demonstrate strong concordance between Fuzzy TOPSIS and PROMETHEE outcomes. Electrical Distribution Unit (EDU) failures—including transformer signal faults, junction box split-device defects, and manifold connector malfunctions—together with jumper short circuits, consistently ranked as the most critical vulnerabilities. This convergence reinforces the reliability of the findings and highlights key components that require targeted design improvements, redundancy strategies, and enhanced monitoring. By integrating classical reliability assessment with multi-criteria decision analysis, the study delivers a comprehensive and flexible framework for evaluating SDU performance under uncertainty. The proposed approach enhances reliability-focused decision-making, supports proactive maintenance planning, and contributes to risk mitigation in subsea production systems

KEYWORDS: PROMETHEE, Fuzzy -TOPSIS, FMECA,Closeness-Coefficient, Electrical Distribution Unit (EDU).

I. INTRODUCTION

The market size of the subsea business was valued at USD 13.2 billion in 2023, and it is projected to grow from USD 13.97 billion in 2024 to USD 20.7 billion in 2032.[1] These statistics highlight the prospects of the subsea industry as technological advancement unlocks the huge potentials in offshore ultra-deepwater and other harsh environments.

Extraction in these environments presents unique technical, operational, and environmental challenges. Wells in ultra-deepwater operate under extreme hydrostatic pressures and elevated temperatures, which complicate well-control design, casing, and blowout-prevention systems.[2] Long-term material degradation remains a pressing issue. Corrosion, fatigue, and stress-related damage to subsea pipelines, connectors, and umbilicals have been widely documented.[3] Flow assurance also poses risks, with hydrate, wax, and scale deposition complicating operations.[4] Subsea control systems—particularly power, signal, and fibre-optic umbilicals—pose significant reliability concerns.[5]

The risk of environmental disasters, such as hydrocarbon spills, is magnified by containment and remediation challenges in deepwater conditions.[6] Monitoring and interpretation difficulties are intensified by reliance on sensors, automation, and AI-driven diagnostics.[7] Recent research highlights Bayesian models, fuzzy expert systems, and probabilistic frameworks for subsea pipelines and risers.[8] Furthermore, failures in subsea infrastructure require systematic investigation to strengthen risk-mitigation strategies.[9] Collectively, these challenges underscore the need for advanced methodologies that integrate expert judgment and address uncertainty. This study responds by proposing an integrated framework combining FMECA, Fuzzy TOPSIS, and PROMETHEE to evaluate SDU reliability.[10]

II. MATERIALS AND METHODS

1. Materials

The materials required for conducting the reliability evaluation of the SDU include:

- (a) **System Description and Technical Data**: Engineering drawings, P&IDs (Piping and Instrumentation Diagrams), and operational manuals, as well as maintenance and operational history (failure logs, repair records).[23]
- (b) **Expert Knowledge**: Subject matter experts (SMEs) in subsea systems, including hardware and controls engineers.[15]
- (c) **Software Tools**: MATLAB and Microsoft Excel (commonly used for data processing, modelling, and reliability analysis).

2. Methods

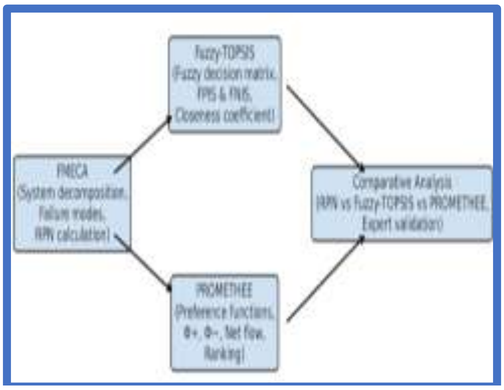

Figure 1: Workflow of Failure Mode Analysis om SDU

Failure Mode, Effects, and Criticality Analysis (FMECA)

1. System Breakdown
2. Identification of Failure Modes
3. Each component is assessed for possible failure mechanisms (e.g., leakage, insulation failure, signal loss).
4. Criticality Assessment [1314]

$$\mathrm{RPN} = \mathrm{S} \times \mathrm{O} \times \mathrm{D} \qquad (1)$$

$$\text{Risk Value} = \mathrm{S} \times \mathrm{O} \qquad (2)$$

$$\mathrm{Ci} = \beta \times \alpha \times \lambda\mathrm{p} \times \mathrm{t} \qquad (3)$$

$$FMD\ A_t = \sum_{i=1}^{n} RPN_i \qquad (4)$$

S : Severity
O: Occurrence.
D: Detection
Ci: Criticality Index
β = Conditional probability of the failure effect
α = Failure mode ratio
λp = Part failure rate
t = operating time.

Fuzzy TOPSIS

1. Definition of Criteria
2. Normalization of Data: Transform ratings into a normalized fuzzy decision matrix.
3. Weight Assignment

Aggregate the weight of criteria to get the aggregated fuzzy weight of criterion, and obtain the aggregated fuzzy rating of alternative under criterion evaluated by experts.

$$\boldsymbol{\tilde{X}_{\mathrm{ij}}} = \frac{\mathbf{1}}{\boldsymbol{k}}\left[\boldsymbol{\tilde{X}_{\mathrm{ij}}^{1}} + \boldsymbol{\tilde{X}_{\mathrm{ij}}^{2}} + \cdots + \boldsymbol{\tilde{X}_{\mathrm{ij}}^{k}}\right] \qquad (5)$$

$$\boldsymbol{\widetilde{W}_{j}} = \frac{\mathbf{1}}{\boldsymbol{k}}\left[\boldsymbol{\widetilde{W}_{j}^{1}} + \boldsymbol{\widetilde{W}_{j}^{2}} + \cdots + \boldsymbol{\widetilde{W}_{j}^{k}}\right] \qquad (6)$$

The fuzzy decision matrix is given in equation (7)

$$\widetilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \cdot \\ \cdot \\ \cdot \\ A_m \end{array} \begin{bmatrix} C_1 & C_2 & \cdot & \cdot & \cdot & C_n \\ \tilde{x}_{11} & \tilde{x}_{12} & \cdot & \cdot & \cdot & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdot & \cdot & \cdot & \tilde{x}_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot\cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdot & \cdot & \cdot & \tilde{x}_{mn} \end{bmatrix} \qquad (7)$$

$$\widetilde{W} = \left[\widetilde{W}_{1,} \quad \widetilde{W}_{2,} \quad \ldots. \quad \widetilde{W}_{n}\right]$$

The normalized fuzzy decision matrix denoted by $\tilde{R}$ is given in equation (8)

$$\boldsymbol{\widetilde{R}} = \left[\boldsymbol{\tilde{r}_{\mathrm{ij}}}\right]_{\boldsymbol{mxn}} \qquad (8)$$

Where B and C represent the set of benefit and cost criteria, respectively, and

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \qquad j \in B; \qquad (9)$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \qquad j \in C; \qquad (10)$$

$c_j^* = max_i c_{ij}$ if $j \in B$;
$a_j^- = min_i c_{ij}$ if $j \in C$.

Weighted normalized fuzzy decision matrix is given in equation (11)
Construct the weighted matrix in order of the different importance of each criterion as:

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn} \qquad (11)$$

$i = 1, 2, \ldots, m;$ $j = 1, 2, \ldots, n$
$Where\ \tilde{v}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j$, $i = 1, 2, \ldots, m;$ $j = 1, 2, \ldots, n$

The fuzzy positive-ideal solution S^+ (FPIS) and fuzzy negative-ideal solution S^- (FNIS) are given in equation (12) and (13)

$$S^+ = (\tilde{v}_1^+, \quad \tilde{v}_2^+, \ldots, \quad \tilde{v}_n^+) \qquad (12)$$

$$S^- = (\tilde{v}_1^-, \quad \tilde{v}_2^-, \ldots, \quad \tilde{v}_n^-) \qquad (13)$$

$Where\ \tilde{v}_j^+ = max\{v_{ij3}\}\ and\ \tilde{v}_j^- = min\{v_{ij1}\}\ since\ \tilde{v}_j\ is\ weighted\ normalized\ TFNs$
$i = 1, 2, \ldots, m;$ $j = 1, 2, \ldots, n$

The distance of each alternative from FPIS (d+) and FNIS (d-) with respect to each criterion are given in equation (15) and ((16):

$$d(A_1, A_2) = \sqrt{\frac{1}{3}[((l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2]} \quad (14)$$

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+) \quad , \quad i = 1, 2, \ldots \ldots, m \qquad (15)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \quad , \quad i = 1, 2, \ldots \ldots, m \qquad (16)$$

The closeness coefficient (CC_i) is given in equation (17).

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad , \quad i = 1, 2, \ldots\ldots, m \qquad (17)$$

(17)

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation)

(9)

(10)

The PROMETHEE technique was applied as a complementary multi-criteria decision-making (MCDM) approach [11 12]
Preference indices are given in equation (18)

$$\pi(a, b) = \sum_{j=1}^{k} w_j \ . P_j\left(f_j(a) - f_j(b)\right) \qquad (18)$$

Where:
w_j = Weight of criterion j.
$f_j(a)$, $f_j(b)$
= Scores of failure modes a and b on criterion j.

(11)

The Positive flow (ϕ^+) is given in equation (19)

$$\phi^+(a) = \frac{1}{n-1}\sum_{b \neq a} \pi(a, b) \qquad (19)$$

Negative flow (ϕ^-) is given in equation (20)

$$\phi^-(a) = \frac{1}{n-1}\sum_{b \neq a} \pi(b, a) \qquad (20)$$

(12)

(13)

i. Net flow (ϕ): Overall score

$$\phi(a) = \phi^+(a) - \phi^-(a) \qquad (21)$$

Comparative Analysis: Compare results from traditional FMECA (RPN), Fuzzy-TOPSIS, and PROMETHEE.

III. RESULTS & DISCUSSION

Results:
The top 10 ranked failure modes by Fuzzy TOPSIS method are shown 1n Table 1

The Fuzzy TOPSIS Closeness Coefficient (CCI) in a decision-making represents how close each failure mode is to the ideal solution.

i. High Closeness Coefficient (closer to 1) → Failure mode is more critical in the decision model (often meaning higher risk, priority for mitigation, or importance in decision ranking).
ii. Low Closeness Coefficient (closer to 0) → Failure mode is less critical in the ranking (lower immediate priority, or less impactful according to chosen criteria).

2: Top 10 Most Critical Failure Modes with PROMETHEE II

FMD ID	Failure Modes	Fuzzy TOPSIS Ranks
FMD 11	Hydraulic/Chemical jumper External leakage from burst hose	1
FMD 47	EDU Transformer Signal failure from failed connectors or switching units	2
FMD 36	Power/Signal Jumper Short circuit due to Structural damage to outer sheath	3
FMD 27	Power/Signal coupler Failure on demand from signal integrity issues	4
FMD 33	Power/Signal Jumper Signal failure from faulty conductors	5
FMD 42	EDU Electrical Junction Box Signal failure from faulty split devices	6
FMD 20	Power/Signal coupler Structural damage to outer sheath	7
FMD 31	Power/Signal coupler short circuit from insulation breakdown/diverted electrical path	8
FMD 34	Power/Signal Jumper Open circuit from broken conductors/water ingress	9
FMD 29	Power/Signal coupler Failure on demand from control logic faults	10

The top 10 ranked failure modes by PROMETHEE II are shown in Table 2:

Table 2:Top 10 Most Critical Failure Modes with PROMETHEE II

FMD ID	Failure Modes	PROMETHEE Ranks
FMD 42	EDU Electrical Junction Box Signal failure from faulty split devices	1
FMD 47	EDU Transformer Signal failure from failed connectors or switching units	2
FMD 44	EDU manifold Signal failure from faulty connectors	3
FMD 36	Power/Signal Jumper Short circuit due to Structural damage to outer sheath	4
FMD 66	Subsea accumulator Signal failure from faulty pressure transmitter	5
FMD 62	Subsea accumulator Structural failure from failed relief valve	6
FMD 29	Power/Signal coupler Failure on demand from control logic faults	7
FMD 28	Power/Signal coupler Failure on demand caused by software problems	8
FMD 33	Power/Signal Jumper Signal failure from faulty conductors	9
FMD 20	Power/Signal coupler Structural damage to outer sheath	10

The Plots of the top 20 rankings are shown on Figure 2:

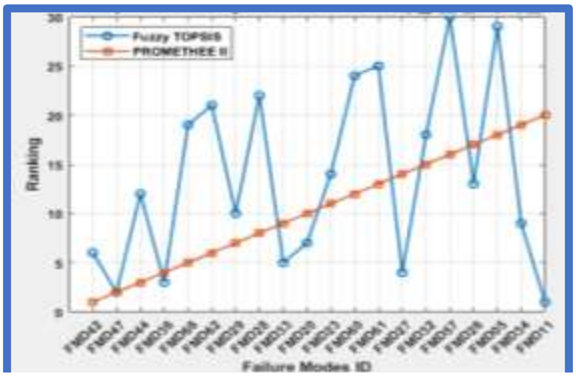

Figure 2: Comparison of Fuzzy TOPSIS vs PROMETHEE II, Top 20 Rankings

The Plot of the failure modes by SDU Sub-Systems is shown on Figure 3

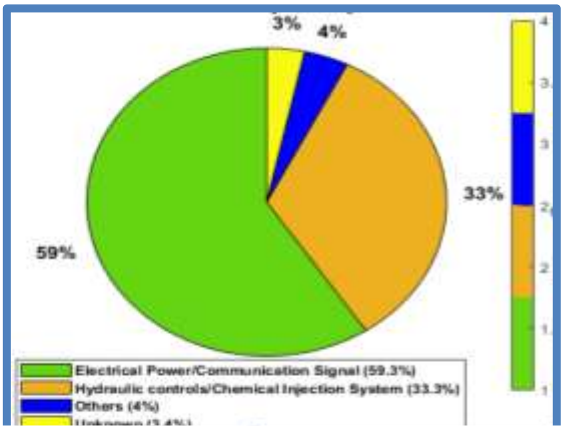

Figure 3: Failure Modes by Sub-Systems

The Plot of the failure modes by SDU System Components is shown in Figure 4

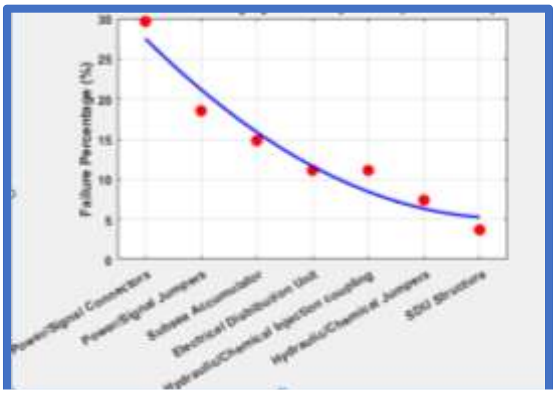

Figure 4: Failure Modes by System Components

Discussion:

As shown on Figure 2, there are convergent rankings, with several failure modes receiving highcriticality rankings across both methods:

FMD 47 (EDU Transformer– signal failure) → TOPSIS rank 2, PROMETHEE rank 2.

i. FMD 42 (EDU Junction Box – faulty split devices) → TOPSIS rank 6, PROMETHEE rank 1.
ii. FMD 44 (EDU manifold – faulty connectors) → TOPSIS rank 12, PROMETHEE rank 3.
iii. FMD 36 (Power/Signal Jumper short circuit due to sheath damage) → TOPSIS rank 3, PROMETHEE rank 4.

These results confirm that EDU-related electrical failures and jumper short circuits are consistently the most critical vulnerabilities in the SDU architecture. This convergence strengthens confidence in prioritizing these components for design improvement, redundancy, or enhanced monitoring.

Middle-Ranked Failures: Some modes cluster in the middle across both methods, such as:

i. FMD 29 (Control logic faults) → TOPSIS 10, PROMETHEE 7.
ii. FMD 33 (Signal failure – faulty conductors in jumper) → TOPSIS 5, PROMETHEE 9.
iii. FMD 20 (Outer sheath damage in coupler) → TOPSIS 7, PROMETHEE 10.

These “agreement zones” indicate consistent medium-level threats, important but secondary to top-ranked EDU/jumper failures.As shown on Figure 2. there are divergent rankings as certain failure modes are ranked very differently between methods, signaling sensitivity to evaluation criteria and methodology:

i. FMD 11 (Hydraulic/Chemical jumper – external leakage from burst hose)
ii. FMD 28 (Power/Signal coupler – software problems)
iii. FMD 66 (Subsea accumulator – faulty pressure transmitter)
iv. FMD 01 & FMD 02 (Hydraulic coupling leakages)

Strategic Implications

i. Design Focus: EDU components (junction box, manifold, transformer) and jumper short circuits emerge as primary redesign priorities given consistent criticality.
ii. Monitoring & Diagnostics: PROMETHEE’s elevation of software problems and transmitter failures indicates the need for stronger digital fault detection, system diagnostics, and redundancy in sensors/control logic.
iii. Maintenance Planning: Disagreement on hydraulic leakages shows they should not be ignored—even if PROMETHEE downplays them—since they may escalate into cascading system failures in practice.
iv. Methodological Complementarity:

a) FUZZY-TOPSIS tends to highlight direct, high-severity physical failures (burst hose, structural damage).
b) PROMETHEE tends to prioritize systemic, cascading, or control-related failures (software, transmitter faults, EDU components).
c) Using both in parallel provides a balanced risk perspective, capturing both local and systemic vulnerabilities.

From Figure 3 – The failure distribution across SDU Sub-Systems plot reveals the following:

The major failure modes contributors are Electrical & Hydraulic sub systems– (92.6%)

a) Electrical Power/Signal (59.3%) – Dominates failures, mainly from connectors, jumpers, and distribution units. Subsea electrical components face insulation breakdown, leakage, and water ingress, threatening monitoring, control, and actuation functions.
b) Hydraulic/Chemical Injection (33.3%) – The second-largest contributor, tied to couplings, accumulators, and injection lines. Failures arise from seal wear, structural damage, clogging, or corrosion. These affect flow assurance, valve control, and can raise environmental concerns.

c) Others (4.0%) – Covers miscellaneous structural or auxiliary issues. Small in share
d) but can expose critical parts or complicate repair.
e) Unknown (3.4%) – Failures without clear diagnostic attribution. Indicates monitoring/reporting gaps and emphasizes the need for better forensic analysis.

From Figure 4 – The failure distribution across SDU components plot reveals:
Connectors, Jumpers, Accumulators – 62.9% as the High-Risk components

a) Power/Signal Connectors (29.6%) – The most failure-prone component, highly exposed, crucial for both energy and signal transmission.
b) Power/Signal Jumpers (18.5%) – Next most vulnerable, affected by bending fatigue and insulation wear.
c) Subsea Accumulators (14.8%) – Critical for hydraulic energy storage; prone to fatigue, seal failure, and pressure-related issues.
d) Hydraulic/Chemical Couplings (11.1%) – Exposed to corrosion and seal leaks under high pressure.
e) Electrical Distribution Unit (11.1%) – Weaknesses in circuit integrity and protection systems.
f) Hydraulic/Chemical Jumpers (7.4%) – Susceptible to leakage and fatigue but less frequent overall.
g) SDU Structure (3.7%) – Least prone, but structural failures compromise all housed systems.

IV. CONCLUSION

This study highlights that the reliability of the Subsea Distribution Unit (SDU) is largely constrained by failures in the electrical power and communication signal subsystem (59.3%) and the hydraulic/chemical injection subsystem (33.3%). Within these, power/signal connectors (29.6%), jumpers (18.5%), and accumulators (14.8%) emerged as the most failure-prone components, reflecting their exposure to insulation degradation,

mechanical fatigue, seal leakage, and corrosion in harsh subsea environments. These failures pose significant risks to power delivery, signal transmission, valve actuation, and flow assurance—functions critical to the operability of subsea production systems. These results align with OREDA, 2015; As Electrical power/signal couplers and Jumpers accounts for 51.6% of SDU total failures and 45.5% of SDU critical failures.

While structural failures (3.7%) and unclassified incidents (3.4%) represent smaller proportions, they highlight the importance of maintaining SDU integrity and improving diagnostic systems. Overall, the findings emphasize the need for targeted design improvements, robust qualification testing, corrosion-resistant materials, enhanced sealing technologies, and real-time monitoring to mitigate high-risk failure modes. By prioritizing these measures, subsea operators can significantly reduce downtime, extend system service life, and strengthen overall system availability.

REFERENCES

[1]. Market Research Future, Subsea business market research report, 2024–2032 (Pune: Market Research Future, 2024).
[2]. Bureau of Safety and Environmental Enforcement (BSEE), Well control rule and deepwater operations (Washington, DC: US Department of the Interior, 2019).
[3]. Han, W, and Zhou, J, ‘Reliability analysis of corroded subsea pipeline’, Acta Petrolei Sinica, 36.4 (2015), 516–520.
[4]. Mahmoudi, A, Gao, Y, and Wang, J, ‘Reliability challenges of subsea pipelines and umbilicals: Degradation mechanisms and monitoring strategies’, Ocean Engineering, 234 (2021), 109270 https://doi.org/10.1016/j.oceaneng.2021.109270.
[5]. Abdelaty, I F, ‘Technology focus: Reliability challenges in subsea control systems’, Journal of Petroleum Technology, 2024.
[6]. Anderson, R, Cohen, M A, Macauley, M, Richardson, N, and Stern, A, Managing risk through liability, regulation, and innovation: Organisational design for spill containment in deepwater drilling operations (Washington, DC: Resources for the Future, 2011).
[7]. Cordes, E E, Jones, D O B, Schlacher, T A, Amon, D J, Bernardino, A F, Brooke, S, … Witte, U, ‘Environmental impacts of the deep-water oil and gas industry: A review to guide management strategies’, Frontiers in Environmental Science, 4 (2016), 58 https://doi.org/10.3389/fenvs.2016.00058.
[8]. Ratnayake, R M C, ‘Knowledge based engineering approach for subsea pipeline systems’ functional failure risk assessment: A fuzzy expert system’, The TQM Journal, 28.1 (2016), 40–61

https://doi.org/10.1108/TQM-12-2013-0148.

[9]. Zhou, J, Chen, X, Sun, Q, and Huang, Y, 'Investigation of subsea pipeline failure accidents in deepwater using fuzzy analytical hierarchy process', in Lecture Notes in Mechanical Engineering (Springer, 2023), 613–623 https://doi.org/10.1007/978-3-031-25252-5_52.

[10]. Zhang, Y, Liu, J, Chen, J, and Li, P, 'Reliability analysis of subsea control systems using FMEA and fuzzy fault tree approaches', Reliability Engineering & System Safety, 236 (2024), 109450 https://doi.org/10.1016/j.ress.2023.109450.

[11]. Brans, J P, and Vincke, P, 'A preference ranking organisation method: The PROMETHEE method for MCDM', Management Science, 31.6 (1985), 647–656 https://doi.org/10.1287/mnsc.31.6.647.

[12]. Brans, J P, Vincke, P, and Mareschal, B, 'How to select and how to rank projects: The PROMETHEE method', European Journal of Operational Research, 24.2 (1986), 228–238 https://doi.org/10.1016/0377-2217(86)90044-5.

[13]. International Electrotechnical Commission, Failure modes and effects analysis (FMEA and FMECA), IEC 60812:2018, 3rd edn (Geneva: IEC, 2018).

[14]. US Department of Defense, Procedures for performing a failure mode, effects, and criticality analysis (FMECA), MIL-STD-1629A (Washington, DC: Department of Defense, 1980).

[15]. Chang, C L, Wei, C C, and Lee, Y H, 'Failure mode and effects analysis using fuzzy logic', Quality and Reliability Engineering International, 15.6 (1999), 447–455 <https://doi.org/10.1002/(SICI)1099-1638(199911/12)15:6<447::AID-QRE249>3.0.CO;2-Q>.

[16]. Xin, J, Zhang, Y, Zhong, C, Cheng, Z, and Jia, Z, 'Analysis of ultimate pressure of corroded subsea pipe repaired with composite considering temperature and material degradation', Journal of Marine Science and Technology, 25.2 (2019), 285–297 https://doi.org/10.1007/s00773-019-00647-y.

[17]. Du, F, Li, C, and Wang, W, 'Development of subsea pipeline buckling, corrosion and leakage monitoring', Journal of Marine Science and Engineering, 11.1 (2023), 188 https://doi.org/10.3390/jmse11010188.

[18]. Kakaie, A, Guedes Soares, C, Ariffin, A K, and Punurai, W, 'Fatigue reliability analysis of submarine pipelines using the Bayesian approach', Journal of Marine Science and Engineering, 11.3 (2023), 580 https://doi.org/10.3390/jmse11030580.

[19]. Xu, L, Hu, P, Li, Y, Qiu, N, Chen, G, and Liu, X, 'Improved fatigue reliability analysis of deepwater risers based on RSM and DBN', Journal of Marine Science and Engineering, 11.4 (2023), 688 https://doi.org/10.3390/jmse11040688.

[20]. Han, Z, Li, X, Zhang, R, Yang, M, and Ben Seghier, M E A, 'A dynamic condition assessment model of ageing subsea pipelines subject to corrosion-fatigue degradation', Applied Ocean Research, 139 (2023), 103717 https://doi.org/10.1016/j.apor.2023.103717.

[21]. 'Study on burst pressure of subsea pipelines with asymmetrical corrosion defects', Engineering Failure Analysis, 155 (2023), 107722 https://doi.org/10.1016/j.engfailanal.2023.107722.

[22]. Bhardwaj, U, Teixeira, A P, and Guedes Soares, C, 'Bayesian framework for reliability prediction of subsea processing systems accounting for influencing factors uncertainty', Reliability Engineering & System Safety, 218 (2022), 108181 https://doi.org/10.1016/j.ress.2021.108181.

[23]. Yasseri, S, Bahai, H, and Yasseri, R, 'Reliability assurance of subsea production systems: A systems engineering framework', Journal of Marine Science and Application, 17.1 (2018), 81–92 https://doi.org/10.1007/s11804-018-0014-9.

[24]. Idiapho, C A, and Jamaica, G T, 'Enhancing subsea pipeline reliability: A combined FAHP and SAW approach for multi-criteria decision-making', Asian Journal of Advanced Research and Reports, 18.12 (2024), 388–397 https://doi.org/10.9734/ajarr/2024/v18i123835.

[25]. Li, H, Chen, Q, Ren, H, and Wang, T, 'Advances in flow assurance for subsea oil and gas systems: A reliability perspective', Journal of Petroleum Science and Engineering, 236 (2024), 112345 https://doi.org/10.1016/j.petrol.2024.112345.

[26]. Olatunde, M, Sriramula, S, Siddiq, A, and Akisanya, A, 'Effect of widespread internal corrosion defects on collapse pressure of subsea pipelines', Ocean Engineering, 287 (2023), 115926 https://doi.org/10.1016/j.oceaneng.2023.115926.

[27]. OREDA, Offshore reliability data handbook, 6th edn (Trondheim: SINTEF, 2015).