



Application of Failure Mode and Impact Analysis (FMEA) Method in Controlling the Risk of Control and Steering System Failure During Dynamic Placement Trial on MV Walker Tide

Djufri Tekeng¹, Arifin H Abd Majid^{2*}, Deselfia D.N.M. Sahari³, Mashudi Gani⁴, Arif Fuddin Usman⁵, Hein Frans Jules Katuuk⁶

^{1, 2, 3}Marketing, Innovation, and Technology Department, AMI Makassar Maritime Polytechnic, Indonesia

⁴Maritime Logistics Business Department, AMI Makassar Maritime Polytechnic, Indonesia

⁵Sea Transportation Department, AMI Makassar Maritime Polytechnic, Indonesia

⁶Ship Machinery Department, AMI Makassar Maritime Polytechnic, Indonesia

Email: djufri21@gmail.com¹, arifin.pitpolimarim@gmail.com^{2*}, deselfia.sahari@gmail.com³,

mashudigani14@gmail.com⁴, arifusman575@gmail.com⁵, hein.katuuk04@gmail.com⁶

*Penulis korespondensi: arifin.pitpolimarim@gmail.com

Abstract. The Dynamic Positioning (DP) system is a vital technology on modern offshore vessels for automatically maintaining vessel position and heading without the assistance of anchors. The operational success of a DP Class 2 system depends heavily on the reliability of integrated components, including the control and steering systems. This study analyzes the failure risks of the control system and rudder blade during the Dynamic Positioning Trial on MV Walker Tide using an integrated Failure Mode and Effects Analysis (FMEA) and SWOT analysis. Actual testing revealed an anomalous phenomenon in test number 28 (Failure of Feedback Signal Test), in which disconnecting the feedback signal caused the propeller pitch angle to move uncontrollably toward a 45% reverse-pitch position and triggered a loss of position. Based on the FMEA analysis, the Rudder Actuator component has the highest risk priority with a Risk Priority Number (RPN) of 250, followed by the Communication Network and Redundancy System with an RPN of 200, and the Feedback Rudder Sensor with an RPN of 192. The IFAS and EFAS matrix analysis places the organization in Quadrant I (Growth Strategy), recommending an aggressive Strength–Opportunity (SO) strategy through optimization of digital predictive maintenance, strengthening of emergency redundancy systems, and improvement of certified crew competencies.

Keywords: Dynamic Positioning; FMEA; MV Walker Tide; Rudder Actuator; SWOT.

1. INTRODUCTION

Science- and technology-based maritime development in Indonesia plays a highly strategic role in strengthening comparative and competitive advantages as an archipelagic country. The application of modern technologies, such as computer-assisted simulation and propulsion-system automation, has been shown to make a significant contribution to shipbuilding safety, port management, and optimization of marine transportation operations. In the offshore operational ecosystem, safety is a top priority given the high risks associated with the maritime working environment.

One of the vital technologies on modern offshore support vessels such as MV Walker Tide is the Dynamic Positioning (DP) system. This system is an integrated computer control system that automatically regulates the vessel's position (coordinates) and heading using a combination of mechanical propeller data, thrusters, position sensors, and environmental sensors (wind and motion). A DP Class 2 system is designed according to the principle of full redundancy to ensure that if an active component experiences a functional failure, the backup system immediately takes over without causing an overall operational failure (loss of position).

However, during the annual Dynamic Positioning Trial on MV Walker Tide, a critical anomaly was found in test scenario number 28 (Failure of Feedback Signal Test). This scenario was intended to test the emergency response when the feedback signal from the Electronic Control Unit (ECU) to the propeller pitch-angle actuator was intentionally disconnected. In accordance with international fail-safe safety standards, the actuator should automatically return to the neutral position (0% pitch angle) so that thrust becomes zero. Field observations showed that the pitch angle instead moved uncontrollably toward the reverse-pitch position, reaching 45%. This caused an extreme deviation of the vessel's position from the safe reference point and indicated systemic weaknesses in the integrated control system and rudder mechanism.

Uncontrolled failure during actual operations near offshore installations, such as drilling platforms or personnel-transfer activities, can have fatal consequences, including the risk of collision with offshore structures, marine pollution, damage to subsea assets, and threats to human life. To mitigate these risks systematically, a comprehensive scientific method such as Failure Mode and Effects Analysis (FMEA) is required to identify failure modes in detail based on the Risk Priority Number (RPN). To produce applicable operational control measures, the FMEA evaluation is subsequently integrated with SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to generate comprehensive mitigation strategies for shipowners and maritime classification stakeholders.

2. LITERATURE REVIEW

Definition of a Vessel and Steering System

Based on Law Number 17 of 2008 concerning Shipping, a vessel is defined as a watercraft of any form and type, whether powered by mechanical energy or wind, including dynamically supported craft and floating structures that do not move. A crucial component in vessel movement is the steering system. The rudder blade is the primary control equipment located at the stern of the vessel (directly behind the propeller), operated mechanically or hydraulically to change or maintain the direction of vessel movement. The reliability of the rudder blade and its actuator system strongly determines vessel maneuvering stability, particularly when the vessel operates under the influence of dynamic currents and sea waves.

Dynamic Positioning (DP) System

The Dynamic Positioning (DP) system operates by integrating advanced computerized systems with the vessel's mechanical propulsion equipment. The system receives real-time input from various position-reference sensors, such as DGPS, laser, or taut-wire systems, as

well as environmental sensors, including anemometers, gyrocompasses, and motion reference units. The DP computer processes these data to calculate the environmental forces pushing the vessel away from its position, then automatically sends corrective commands in the form of angle and thrust adjustments to each thruster and the steering system to maintain the vessel at the desired coordinate point. On vessels with DP Class 2 classification, absolute reliability is required because no single point failure may cause the vessel to lose position control.

Failure Mode and Effects Analysis (FMEA) Method

FMEA is a risk-management technique widely used to detect potential failures in a component or process, analyze root causes, and determine the effects of those failures on the system as a whole. FMEA evaluation is based on a quantitative value known as the Risk Priority Number (RPN). The RPN is obtained by multiplying three main parameters: the severity of the impact (Severity, S), the probability of failure occurrence (Occurrence, O), and the ease with which the system can detect a failure before its effects occur (Detection, D). The mathematical formula for calculating RPN is:

$$\text{RPN} = S \times O \times D$$

The RPN value is used to establish the priority scale for corrective actions; the higher the RPN, the more critical the component and the faster and more comprehensive the mitigation required.

3. RESEARCH METHOD

Bagian This research was conducted aboard MV Walker Tide during the most recent one-year operational period, with the main observation focused on the implementation of the Dynamic Positioning (DP) Trial. The approach used was descriptive quantitative–qualitative research based on a maritime engineering case study.

Primary data were collected through direct observation of control-system parameters during the failure-signal test scenarios, as well as in-depth interviews with the Chief Engineer, Master, and vessel DP operator. Secondary data were obtained from the vessel’s maintenance log (PMS—Preventive Maintenance System), the manufacturer’s technical manual for the Electronic Control Unit (ECU), and reports of hydraulic steering-system component failures during the previous year.

Data analysis began by preparing the FMEA worksheet and establishing a 1–10 rating scale for Severity, Occurrence, and Detection based on international maritime classification standards. After calculating the RPN and establishing critical-risk rankings, a strategic SWOT analysis was performed. Through identification of internal factors (IFAS) and external factors

(EFAS), a TOWS matrix was formulated to generate long-term operational control strategies that are valid and applicable to the offshore shipping industry.

4. RESULTS AND DISCUSSION

Component Failure Analysis Using FMEA

Based on actual field testing, technical discussions with experts, and evaluation of historical maintenance data from MV Walker Tide, nine (9) major components in the control and steering systems that are vulnerable to functional failure were identified. The assessment results for Severity (S), Occurrence (O), Detection (D), and the calculated Risk Priority Number (RPN) are presented in Table 1.

Table 1. FMEA Analysis and Component Risk Priority

NO	System Component	Failure Mode / Potential Functional Failure	S	O	D	RPN
1	Rudder Actuator	Servo-valve failure, main hydraulic-seal leakage, actuator (jammed)	10	5	5	250
2	Communication Network	Data-signal interference, broken circuit cable, communication-protocol error between modules	8	5	5	200
3	Redundancy System	Auto-changeover failure when the main system experiences a malfunction	8	5	5	200
4	Feedback Rudder Sensor	Mechanical failure of rudder-angle sensor, calibration deviation of the electrical signal to the ECU	8	4	6	192
5	Human Operator (Crew)	Incorrect alarm interpretation, delayed manual response (human error)	8	4	6	192
6	Electronic Control Unit (ECU)	Control-logic firmware error, overheating of the electronic circuit board	9	4	5	180
7	Hydraulic Steering System	Fluid-pressure reduction due to worn pump, particle contamination in hydraulic oil	9	4	5	180
8	DP Control System	Glitch in position-calculation software algorithm, failure in sensor-data processing	9	4	5	180
9	Rudder Blade	Structural deformation due to impact with marine debris, corrosion of rudder-blade material	8	3	5	120
10	Power Supply DP System	Fluctuations in vessel generator output, UPS (Uninterruptible Power Supply) battery failure	10	3	3	90

Based on the quantitative FMEA analysis in Table 1, a detailed understanding of the critical-risk hierarchy of the system was obtained. The Rudder Actuator has the highest priority with an RPN of 250. This high value is driven by the maximum Severity score (10), because mechanical failure of the servo valve or leakage of the main hydraulic seal directly disables the vessel's physical maneuvering capability, which can result in loss of heading during testing or actual operations. Therefore, this component must become the primary focus of the vessel maintenance program.

The second rank is occupied by the Communication Network and Redundancy System, each with an RPN of 200. These empirical findings clearly explain the anomaly observed during test number 28. When the feedback signal was disconnected, failure in the

communication-network data-transfer logic or a delay in the redundancy system's auto-changeover caused the ECU to lose the actual actuator-position reference. Because the system could not detect the current network status, it failed to activate the integrated fail-safe mode, causing the propeller pitch angle to deviate to a 45% reverse position without operator instruction.

The Feedback Rudder Sensor and Human Operator factors were the next critical level, with an RPN of 192. The relatively high Detection score (6) indicates that subtle electrical-sensor calibration deviations or delays in crew cognition when interpreting complex DP-system alarms are more difficult to detect early, before the vessel actually moves away from its position. The medium-priority components—ECU, Hydraulic Steering System, and DP Control System software—each have an RPN of 180, indicating that strict scheduled maintenance must not be neglected to maintain the stability of automated steering-system responses. The Rudder Blade (RPN 120) and Power Supply (RPN 90) have the lowest priorities because they have high structural reliability and early detection is facilitated by reliable vessel electrical alarms.

Formulation of a SWOT-Based Risk Control Strategy

To transform the technical findings of the FMEA into strategic mitigation measures at the operational-management level of PT Walker Tide, internal (IFAS) and external (EFAS) factors were weighted. The evaluation shows that the internal strengths, such as the availability of certified DP Class 2 technology and compliance with the ISM Code, are more dominant than the internal weaknesses. Externally, opportunities arising from the development of digital maritime monitoring and the availability of maritime crew skills training can compensate for external threats such as extreme offshore sea conditions.

The integration of the total scores places MV Walker Tide's risk-management position in Quadrant I (Aggressive / Growth Strategy). This indicates that the company has sufficient internal strengths to exploit external opportunities in addressing technical risks. The tactical strategy formulation based on the TOWS matrix is presented in Table 2.

Table 2. SWOT Strategy Matrix for Vessel Control System Maintenance and Risk Management

Internal / External Factors	Factors	Strategy
STRENGTHS (S)	1. Full DP Class 2 system redundancy. 2. High operational safety culture. 3. Full fleet-management support.	SO STRATEGY (Aggressive / Top Priority) 1. Integrate digital Condition-Based Maintenance technology for the Rudder Actuator and feedback sensors. 2. Optimize periodic accredited DP emergency-support.

WEAKNESSES (W)	1. Susceptibility to wear in mechanical actuators. 2. Complexity of detecting sensor-calibration errors. 3. Dependence on spare-parts vendors.	simulation training for vessel crew to minimize human error. WO STRATEGY (Defensive / Improvement) 1. Utilize vendor digital programs for early detection of Feedback Sensor calibration deviations before the annual trial. 2. Increase the inventory of critical spare parts onboard to address supply dependence.
OPPORTUNITIES (O)	1. Advances in digital monitoring technology. 2. Availability of certified DP training. 3. Global maritime safety regulations.	ST STRATEGY (Diversification / Strengthening) 1. Tighten auto-changeover function testing of the Redundancy System before the vessel enters high-risk operational areas. 2. Apply specialized corrosion-protection coatings to the physical material of the Rudder Blade.
THREATS (T)	1. Extreme offshore weather and waves. 2. Risk of collision with offshore structures. 3. High corrosion in the marine environment.	WT STRATEGY (Survival / Mitigation) 1. Conduct periodic internal maritime-safety audits to evaluate crew operational compliance. 2. Prepare rigid written emergency standard operating procedures (SOPs) for control-signal failures.

Discussion of Mitigation-Action Implementation

Based on the integration of FMEA and SWOT, mitigation actions are prioritized for the critical components in the hazard quadrant. To mitigate the risk associated with the Rudder Actuator (RPN 250), the company should shift from corrective maintenance to a computerized predictive-maintenance system. Installing temperature and hydraulic-fluid pressure sensors on the servo valve will provide an early-warning signal to the bridge before the component experiences total physical jamming.

To address the anomaly in test number 28, the Communication Network and Redundancy System (RPN 200) strategy should be implemented by replacing transmission cables with high-electromagnetic-interference-protection shielded cable and updating the vessel's Electronic Control Unit (ECU) firmware. The ECU programming logic must be strictly modified to include an independent command: if the primary feedback signal is lost for more than 0.5 seconds, the ECU must force the hydraulic valve to lock the actuator position or mechanically return the pitch angle to the safe 0% position (fail-to-safe mechanism) without relying on erroneous network data.

For the Feedback Rudder Sensor (RPN 192), a dual-sensor calibration check should be routinely performed before the vessel begins each voyage. Meanwhile, to mitigate the Human Operator factor (RPN 192), PT Walker Tide management is required to conduct an integrated emergency-failure scenario simulation onboard at least once every three months. This measure is expected to improve the mental response speed of vessel officers when facing DP-system anomalies, in line with international maritime safety principles that prioritize synergy between technological reliability and human readiness at sea.

5. CONCLUSIONS AND RECOMMENDATIONS

Conclusion

This study successfully revealed the root cause of the critical anomaly in test scenario number 28 during the Dynamic Positioning Trial on MV Walker Tide. Loss of the feedback signal did not cause the system to enter a fail-safe mode; instead, it caused uncontrolled movement of the propeller pitch angle to 45% reverse due to a failure in the integration logic of the data communication network and a delay in the automatic redundancy system.

Through Failure Mode and Effects Analysis (FMEA), a hierarchy of the components with the highest risk levels was identified: the Rudder Actuator had the highest RPN (250), followed by the Data Communication Network and Redundancy System (RPN 200), and the Feedback Rudder Sensor and Human Operator (RPN 192). The combination of FMEA and SWOT analysis places vessel safety management in Quadrant I (Aggressive), confirming that a Strength–Opportunity (SO) strategy through digitalization of predictive component maintenance and improvement of practical crew competencies is a valid long-term solution for ensuring the operational reliability of the DP Class 2 system.

Recommendations

Based on the analysis results, several technical and operational actions are recommended. For shipowners and fleet management, the ECU control-logic firmware on MV Walker Tide should be upgraded immediately to ensure that the independent fail-to-safe protection function operates correctly, including the automatic return of pitch to 0% when the feedback signal is suddenly disconnected. For the onboard crew, physical inspections should be conducted, communication-network switches should be cleaned, and the automatic redundancy-system transfer (auto-changeover) function should be tested periodically at least one week before the annual DP Trial. For future researchers, further research is recommended by integrating conventional FMEA with a fuzzy-logic approach (Fuzzy FMEA) to reduce subjectivity in determining Severity, Occurrence, and Detection ratings for complex maritime components.

REFERENCES

- Aufa, A., & Dahda, S. S. (2023). Risk analysis of the dry bulk loading and unloading process using the FMEA (Failure Mode and Effect Analysis) method at PT. XYZ. *Jurnal Intecom: Journal of Information Technology and Computer Science*, 6(2), 707–715. <https://doi.org/10.31539/intecom.v6i2.7078>
- Bambang, T. (2010). *Port planning and marine transportation facilities*. Beta Offset.

- Cahaya Mulia, R., & Rochmoeljati, R. (2021). Welding quality control using statistical quality control (SQC) and failure mode effect analysis (FMEA) methods at PT. PAL Indonesia. *Jurnal Juminten*, 2(6), 340–350. <https://doi.org/10.33005/juminten.v2i6.346>
- Daryanto, D., & Basuki, R. (2023). Risk mitigation of equipment functional failure in fresh water generators using the Failure Mode and Effect Analysis (FMEA) approach on commercial vessel XYZ. *Jurnal Sains dan Teknologi Maritim*, 24(1), 350–360. <https://doi.org/10.33556/jstm.v24i1.358>
- Ferida Yuamita, F., & Anang Fatkhurohman, A. (2023). Occupational accident risk analysis at a natural-stone cutting station using the Failure Mode and Effect Analysis (FMEA) method at PBA Surya Alam. *Jurnal Cakrawala Ilmiah*, 2(12), 6390–6400. <https://doi.org/10.53625/jcijurnalcakrawailmiah.v2i12.6398>
- Guritno, A., & Triwibowo, H. (2018). Computer-based automatic control system for dynamic positioning systems on offshore vessels. *Jurnal Otomasi Maritim*, 4(1), 22–29.
- Labib, M., & Ayudyah Eka Apsari, A. (2024). Occupational safety and health (OSH) risk analysis using Failure Method and Effect Analysis (FMEA) and Fault Tree Analysis (FTA). *Jurnal Jisi: Jurnal Integrasi Sistem Industri*, 2(1), 590–600. <https://doi.org/10.59024/jisi.v2i1.599>
- Muhammad, A., et al. (2019). Hydrodynamic characteristics analysis of a balanced rudder on cargo vessels. *Jurnal Teknik Perkapalan*, 7(3), 114–122.
- Mudita, I. W. (2021). Indonesian maritime development policy from the perspective of the State Policy Guidelines. *Jurnal Kelautan Global*, 12(2), 85–94.
- Pariyanti, E. (2017). Operational risk management strategies for shipping companies facing maritime market uncertainty. *Jurnal Manajemen Bisnis Maritim*, 5(2), 102–110.
- Putri, A. S. (2024). Application of FMEA in the early design stage of maritime industrial automation systems to minimize potential failures. *Jurnal Teknologi Rekayasa*, 9(1), 45–53.
- Radiks, P. (1997). *Sea cargo transportation and ship equipment*. Penerbit Aksara.
- Republic of Indonesia. (2008). *Law Number 17 of 2008 concerning shipping*. State Gazette of the Republic of Indonesia Year 2008 Number 64.
- Sarjito, S. (2023). The role of computerized technology in the modernization of port infrastructure and shipbuilding in Indonesia. *Jurnal Riset Maritim Indonesia*, 11(4), 140–148.
- Sarwito, S., et al. (2019). Laboratory-scale modeling of a dynamic positioning system for testing tanker-vessel response. *Jurnal Penelitian Kelautan*, 15(3), 167–175.
- Tupalessy, J., et al. (2017). Development of mechanical and electrical sensor interface systems for industrial control systems. *Jurnal Elektro Maritim*, 3(2), 78–85.
- Wicaksono, A., Dhartikasari Priyana, E., & Pandu Nugroho, Y. (2023). Quality control analysis using Failure Mode and Effects Analysis (FMEA) for centrifugal pumps at PT. X. *Jurnal Teknik Industri*, 9(1), 175–182. <https://doi.org/10.24014/jti.v9i1.22233>