

Comprehensive Assessment of Factors Affecting Occupational Health and Safety in Dynamic Positioning (DP) Vessel Operations

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Abstract— Background: Dynamic Positioning (DP) systems have become indispensable to modern offshore operations, enabling vessels to maintain precise station-keeping in drilling, diving support, subsea construction, and renewable energy installations without traditional anchoring. Despite their technological sophistication, DP-equipped vessels present a unique constellation of Occupational Health and Safety (OHS) risks that span technical, human, organisational, and psychosocial dimensions (IMO, 1994; IMCA, M182). Methods: This paper employs a multi-method analytical approach drawing on IMCA incident databases, regulatory documentary analysis, FMEA synthesis, Bowtie risk analysis, human factors assessment using HFACS, and thematic synthesis of peer-reviewed occupational health and safety literature (Reason, 1997; Wiegmann & Shappell, 2003; Endsley, 1995). Results: Human error — amplified by fatigue, cognitive overload, and poor Human-Machine Interface (HMI) design — contributes to approximately 30% of DP-related incidents (IMCA, M182). Psychosocial stressors including isolation, shift-work disruption, alarm fatigue, and under-resourced mental health support remain substantially under-addressed within existing regulatory frameworks (Endsley, 1995; NIOSH, 2021). Conclusions: An integrated, human-centred approach to DP safety management is essential. Recommendations are presented for shipowners, training institutions, regulators, and technology developers.

Keywords— Alarm Management, Dynamic Positioning, Fatigue Risk Management, Human Factors, Marine Engineering, Occupational Health and Safety, Safety Management Systems, Situational Awareness

I. INTRODUCTION

The offshore marine industry has undergone a fundamental transformation over the past six decades, driven by escalating demand for oil, gas, and renewable energy resources in increasingly remote and deepwater environments (IMO, MSC/Circ.645, 1994). Dynamic Positioning (DP) technology stands as one of the most significant advancements in vessel control and station-keeping (IMCA, M103, current edition), enabling vessels to maintain precise position automatically.

DP systems are deployed across a broad range of offshore vessels — drilling rigs, dive support vessels (DSVs), floating production storage and offloading (FPSO) units, cable-laying vessels, and offshore wind farm installation craft. This widespread adoption has brought with it a growing body of evidence documenting the serious OHS risks associated with these operations (IMCA, M182, current edition).

DP-related incidents encompass vessel drift-offs, subsea equipment damage, diver endangerment, power blackouts, and catastrophic position loss. Analyses by IMCA and classification societies consistently reveal that a significant proportion of these incidents arise from the complex interplay of human factors, organisational deficiencies, and inadequate integration of safety management systems (Reason, 1997; Wiegmann & Shappell, 2003).

A. Research Aim and Objectives

This paper aims to provide a comprehensive, multidimensional assessment of the factors affecting OHS in DP vessel operations, with the objective of informing practical safety improvements across the industry (ISO 45001:2018). The specific objectives are: (1) to map technical, human, organisational, regulatory, and psychosocial OHS risk factors; (2) to evaluate incident data and case study evidence; (3) to critically assess existing regulatory and safety management frameworks (IMO, ISM Code, 2018); and (4) to present evidence-based recommendations for improving OHS outcomes on DP vessels.

B. Scope and Structure

This paper encompasses DP vessels classified under DP1, DP2, and DP3 engaged in offshore oil and gas, subsea construction, and renewable energy sectors. The analysis integrates technical system perspectives with human-centred safety science, drawing on IMCA guidelines, IMO circulars, classification society rules, and peer-reviewed occupational health literature (Endsley, 1995; IMCA, M103).

II. BACKGROUND: EVOLUTION OF DP SYSTEMS

A. Historical Development

DP technology developed in direct response to the operational constraints of conventional anchoring in deepwater environments. The first operational system was installed on the CUSS I in 1961 (IMCA, M103, current edition). During the 1970s and 1980s, major technology companies including Kongsberg, Honeywell, and Converteam developed early digital control systems incorporating gyrocompasses, hydroacoustic reference, and closed-loop feedback control. The 1990s brought the first formal regulatory responses, leading to the formalisation of DP class notations DP1, DP2, and DP3 (IMO, MSC/Circ.645, 1994). Contemporary DP systems are characterised by full digital integration with power management, navigation, and propulsion systems; remote diagnostics; and emerging integration with autonomous vessel technology (IMO, MSC.1/Circ.1580, 2017; ISO 45001:2018).

B. DP Classification and OHS Risk Profile

Table I summarises the three DP vessel classifications defined by the IMO (IMO, MSC/Circ.645, 1994) and their associated redundancy levels, risk tolerances, and OHS risk profiles.

TABLE I DP VESSEL CLASSIFICATION, REDUNDANCY LEVEL, AND OHS RISK PROFILE

DP Class	Redundancy Level	Risk Tolerance	Typical Operations	OHS Risk Profile
DP1	None (no redundancy)	High — single failure = position loss	Cable-laying, supply runs, survey	Highest crew risk on failure; used for lower-criticality operations
DP2	Redundant systems — single fault tolerant	Medium — active redundancy maintained	Diving support, subsea operations, pipe-lay	Improved; permitted for life-critical operations
DP3	Full segregation including fire and flood barriers	Low — designed to survive any single failure	Drilling, manned saturation diving	Highest protection; mandatory for certain manned diving operations

Note. Sources: IMO MSC/Circ.645 (1994); IMCA M103 (current edition); DNV Classification Rules.

III. DP SYSTEM ARCHITECTURE AND OHS IMPLICATIONS

A. Core System Components

The DP system architecture comprises multiple interlinked technical subsystems whose functions are tightly coupled and mutually dependent (IMCA, M220, current edition). Understanding how failures in one subsystem propagate through connected components is essential to appreciating how technical faults escalate into occupational safety events. Table II summarises the principal subsystems, their functions, and their key OHS relevance.

TABLE II DP SYSTEM CORE SUBSYSTEMS AND KEY OHS RELEVANCE

Subsystem	Function	Key OHS Relevance
Power System (IMCA, M182)	Supplies electricity to thrusters and control units	Blackout = immediate position risk; most common single cause of position loss
Thruster System (IMCA, M103)	Azimuth, tunnel, and main propellers for vessel movement	Failure = drift-off risk; injury from thruster wash and propeller forces
DP Control System (IMO, MSC.1/Circ.1580)	Processes sensor inputs; calculates corrective thrust vectors	Software fault = incorrect vessel response; may be difficult to detect rapidly
Position Reference Systems (IMCA, M103)	Real-time positioning data (DGPS, USBL, Taut Wire, Laser)	PRS dropout = loss of position awareness; voting logic failures allow inaccurate data
Environmental Sensors (IMCA, M103)	Wind, wave, and current measurement	Incorrect data = inappropriate thrust response; position kept against wrong forces
Motion Reference Units (IMCA, M103)	Pitch, roll, heave measurement	Inaccurate data = unexpected vessel motion and false thruster activation
Human-Machine Interface (IMCA, M206; Endsley, 1995)	DPO interaction, monitoring, and alarm management	Poor design = cognitive overload, delayed response, alarm desensitisation

Note. Sources: IMCA M103; IMCA M220; IMO MSC.1/Circ.1580 (2017); Endsley (1995).



B. OHS Risks from System Interdependencies

The integrated nature of modern DP systems creates interdependency risks that are particularly hazardous from an OHS perspective. A failure in any single subsystem can cascade through connected systems, potentially triggering rapid escalation from Green Alert (fully operational) to Red Alert (position-holding no longer guaranteed) (IMCA, M103, current edition). The speed of such cascades — sometimes measured in seconds — places extreme cognitive and physical demands on operators (Endsley, 1995).

Position Reference System (PRS) failures are among the most common triggers of DP incidents (IMCA, M182, current edition). Using at least three independent PRS is recommended for DP2 and DP3 vessels to enable sensor cross-checking and voting logic. When PRS redundancy is compromised, the risk of inaccurate positioning data going undetected increases substantially, especially under conditions of operator fatigue or distraction (Reason, 1997). The power system represents another critical vulnerability — the complexity of switchboard management during generator changeover has been implicated in multiple blackout incidents (IMCA, M182).

IV. REGULATORY AND CLASSIFICATION FRAMEWORKS

A. International Regulatory Landscape

DP operations are governed by a multi-layered regulatory environment comprising international conventions, industry guidelines, and classification society rules (IMO, MSC/Circ.645, 1994). The IMO provides the foundational regulatory structure through MSC/Circ.645, which defines DP system requirements, redundancy principles, and alert state protocols. The ISM Code requires vessels to maintain a Safety Management System (SMS) integrating emergency preparedness, risk assessment, and documentation — all directly applicable to DP operations (IMO, ISM Code, 2018).

B. IMCA Guidance Framework

The International Marine Contractors Association (IMCA) is the primary source of operational and technical guidance for DP (IMCA, M103, current edition). Key documents include: IMCA M103 — Guidelines for the Design and Operation of DP Systems; IMCA M117 — Training and Experience of Key DP Personnel; IMCA M182 — Analysis and Classification of DP Incidents; and IMCA M220 — Guidance on FMEA.

Their voluntary nature means enforcement consistency varies significantly across flag states and operators (ILO, MLC 2006).

C. Classification Societies

Classification societies — including DNV, ABS, Lloyd's Register, and Bureau Veritas — assign DP class notations and verify compliance through FMEA certification, annual trials, and capability assessments (IMCA, M220, current edition). Manned saturation diving is typically only permitted on DP3-classified vessels due to the life-critical nature of maintaining position during such operations (IMO, MSC/Circ.645, 1994).

D. Regulatory Gaps

Despite the comprehensiveness of this framework, significant OHS-relevant gaps remain (Reason, 1997). These include: (1) inconsistent enforcement across flag state jurisdictions (ILO, MLC 2006); (2) operator fatigue and human error incompletely addressed by existing frameworks (IMCA, M117, current edition); (3) outdated FMEA reports never revalidated following system modifications (IMCA, M220); (4) alarm fatigue and cognitive overload under-represented in regulatory guidance (Endsley, 1995); and (5) cybersecurity provisions that remain fragmented relative to the expanding digital attack surface of modern DP systems (IMO, MSC.428(98), 2017). These gaps collectively suggest the need for more human-centred regulation integrating ergonomics, fatigue modelling, and psychological safety indicators alongside technical requirements (ISO 45001:2018).

V. TECHNICAL FAILURE FACTORS

A. Categories of Technical Failure

Technical failures in DP operations encompass mechanical, electrical, and software failure modes. IMCA incident data consistently identifies position loss events as the most frequent and consequential category, with approximately 60% of reported events involving some degree of position excursion (IMCA, M182, current edition). Table III summarises the principal failure categories, examples, and their OHS consequences.

TABLE III CATEGORIES OF TECHNICAL FAILURE IN DP OPERATIONS

Failure Category	Examples	OHS Consequence
Mechanical (IMCA, M182)	Thruster malfunction, azimuth lock, hydraulic leak	Vessel drift, injury from thruster wash, dropped load
Electrical (IMCA, M182)	Generator blackout, switchboard fault, UPS failure	Rapid position loss, fire risk, control system shutdown
Software/Control (IMO, MSC.1/Circ.1580)	System freeze, control loop fault, sensor voting error	Incorrect thrust allocation, unexpected vessel movement
Position Reference (IMCA, M103)	GPS jamming/spoofing, USBL acoustic noise, taut wire break	Inaccurate positioning, undetected drift
Environmental (IMCA, M103)	Sudden squall, current surge, extreme swell	Exceeded DP capability envelope, uncontrolled excursion

Note. Sources: IMCA M182 (current edition); IMCA M103 (current edition); IMO MSC.1/Circ.1580 (2017).

B. The FMEA Imperative

Failure Modes and Effects Analysis (FMEA) is the primary technical tool for mapping component failure chains and their consequences in DP systems (IMCA, M220, current edition). Mandatory for DP2 and DP3 vessels under IMO MSC.1/Circ.1580 (2017), FMEA provides systematic examination of all critical components, their potential failure modes, the effects of those failures, and the mitigations in place (IMO, MSC.1/Circ.1580, 2017). From an OHS perspective, FMEA is only as valuable as its accuracy and currency — analysis of DP incidents has revealed cases where FMEA reports were outdated following system modifications, or where proving trial findings were not translated into updated operating procedures (IMCA, M182, current edition).

VI. HUMAN FACTORS AND ERGONOMICS

A. The Centrality of Human Performance

Human error has been identified as a contributing factor in approximately 30% of DP-related incidents by IMCA (IMCA, M182, current edition), with some analyses placing the contribution substantially higher when latent organisational factors are included (Reason, 1997).

The DPO occupies a critical safety role, responsible for continuous monitoring of complex multi-source data, alarm management, emergency decision-making, and coordination with bridge, engineering, diving, and deck teams. Despite extensive automation, the human operator remains the last line of defence in DP safety — a position consistent with Reason's (1990) formulation of the active failure-latent condition relationship in complex system accidents.

B. Key Human Factor Vulnerabilities

1) *Cognitive Overload*: DPOs monitor multiple screens displaying high-density data simultaneously. During alarm events or adverse weather, the volume and urgency of information can exceed the cognitive capacity of a single operator, leading to degraded situational awareness and delayed responses. Endsley (1995, p. 36) defines situational awareness as “the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” — all three levels of which are systematically undermined by cognitive overload (Endsley, 1995).

2) *Complacency and Automation Over-Reliance*: Extended periods of uneventful DP watchkeeping promote complacency — a reduction in vigilance associated with passive monitoring tasks (Reason, 1997). Operators may come to rely on the automated system to self-correct minor deviations, delaying manual intervention. This is especially dangerous because DP system degradation is often gradual and subtle until a threshold is breached that triggers rapid position loss (IMCA, M182, current edition).

3) *Shift Handover Deficiencies*: Watch handovers are a recognised high-risk period in DP operations (IMCA, M117, current edition). Incomplete transfer of situational awareness — including current DP status, active alerts, ongoing operations, and system anomalies — can leave the incoming operator without critical context, contributing directly to SA Level 1 failure as described by Endsley (1995).

4) *Communication Breakdown*: Effective coordination between DPO, bridge officers, engineers, dive supervisors, crane operators, and client representatives is essential to safe simultaneous operations (IMCA, M103, current edition). Language barriers, undefined communication protocols, and absent pre-task briefings all increase the risk of miscommunication during time-critical events (Wiegmann & Shappell, 2003).

C. Ergonomic Design of DP Control Stations

Table IV presents the key ergonomic dimensions of DP control stations, the optimal standard for each dimension per ISO 11064 (2000) and IMCA M206, and the OHS risk associated with non-compliance (ISO 11064:2000; IMCA, M206, current edition).

TABLE IV ERGONOMIC DESIGN STANDARDS FOR DP CONTROL STATIONS AND OHS RISKS OF NON-COMPLIANCE

Ergonomic Aspect (ISO 11064; IMCA M206)	Optimal Standard	OHS Risk of Non-Compliance
Console layout	Critical controls within natural reach zone; unobstructed sightlines	Excessive reach causes musculoskeletal strain and delayed response
Seating	Adjustable ergonomic chairs with lumbar support	Prolonged poor posture causes MSDs; discomfort reduces concentration
Display readability	Anti-glare screens; appropriate font size and contrast per ISO 9241	Eye strain and visual fatigue impair alarm detection accuracy
Lighting	Adjustable ambient lighting; avoidance of screen glare	Poor lighting accelerates fatigue; impairs instrument reading
Noise and vibration	Acoustic dampening per ISO 2631; climate control	Noise increases cognitive load; vibration causes physical fatigue
Alarm system design (IMCA M206)	Prioritised, tiered alarms; minimal nuisance alerts	Alarm flooding causes desensitisation and missed critical warnings (Endsley, 1995)

Note. Sources: ISO 11064:2000; IMCA M206 (current edition); ISO 2631-1:1997; Endsley (1995).

VII. FATIGUE, SHIFT WORK, AND PSYCHOSOCIAL HEALTH

A. Fatigue as a Primary Risk Factor

Fatigue is among the most thoroughly documented and consequential risk factors in marine operations (ILO, MLC 2006; Reason, 1997). Offshore rotations commonly involve 12-hour shift patterns over 28-day rotations, combined with the low-stimulation demands of watchkeeping and the physical effects of vessel motion. IMCA surveys have reported that over 40% of DPOs experience moderate to high fatigue on night shifts (IMCA, M182, current edition), and fatigue has been identified as a contributing factor in multiple serious DP incidents.

This aligns with the occupational health literature linking shift work and extended watchkeeping to impaired cognitive function, slower reaction times, and increased error rates (ILO, MLC 2006; ISO 45001:2018).

B. Psychosocial Stressors

Beyond fatigue, DP crew face a constellation of psychosocial stressors that bear directly on OHS outcomes — high-responsibility workloads, the psychological burden of operating in life-critical environments, social isolation from remote offshore locations, and anxiety associated with potential emergency scenarios (IMCA, M182, current edition; ISO 45001:2018). IMCA research has documented that approximately 15% of DPOs report symptoms of anxiety or emotional exhaustion (IMCA, M182, current edition). Physical health risks are also significant: 25% of DPOs report chronic back pain associated with prolonged seated console work, consistent with ergonomic risk factors identified in ISO 11064 (2000) for sustained control room monitoring tasks (ISO 11064:2000; NIOSH, 2021).

C. Fatigue Risk Management

The following evidence-based fatigue risk management interventions are recommended for DP vessel operations (ILO, MLC 2006; IMCA, M117, current edition; ISO 45001:2018):

1. Implementation of validated Fatigue Risk Management Systems (FRMS) aligned with STCW and MLC 2006 rest hour requirements (ILO, MLC 2006).
2. Circadian-friendly shift scheduling minimising night-shift concentration and avoiding disruptive rotation patterns (IMCA, M117).
3. Adequate rest facilities with acoustic insulation, temperature control, and protection from engine vibration (ISO 11064:2000).
4. Pre-task fatigue self-assessments and supervisory monitoring of crew alertness (IMCA, M103).
5. Mental health first aiders and confidential Employee Assistance Programme (EAP) access for all offshore personnel (ISO 45001:2018; NIOSH, 2021).

VIII. ALARM MANAGEMENT AND SITUATIONAL AWARENESS

A. Alarm Fatigue: A Critical OHS Hazard

Alarm fatigue occurs when high rates of false or nuisance alarms cause operators to become desensitised to alarm signals, increasing the risk that critical warnings are missed or responded to with inappropriate delays (IMCA, M206, current edition).

Common failures include: poorly calibrated alarm setpoints generating excessive nuisance alerts; absence of alarm prioritisation distinguishing safety-critical warnings from informational notifications; and simultaneous alarm cascades during system degradation that overwhelm operator processing capacity (IMCA, M206, current edition; Endsley, 1995). Endsley (1995) identifies Level 1 situational awareness failure — the failure to perceive a critical environmental signal — as the primary pathway through which alarm fatigue produces adverse safety outcomes.

B. Situational Awareness

Situational awareness (SA) is the cognitive foundation of safe DP operation (Endsley, 1995). Endsley (1995, p. 36) identifies three hierarchical levels of SA: perception of environmental elements (Level 1), comprehension of their meaning and significance (Level 2), and projection of their status into the near future (Level 3). In the DP context: Level 1 — failing to notice a PRS dropout indicator; Level 2 — misattributing position deviation to sensor noise rather than a thruster fault; Level 3 — underestimating the rate of position excursion and failing to anticipate threshold breach (Endsley, 1995, p. 36). Recommended best practices include root-cause-based alarm grouping, mandatory alarm rationalisation reviews, and regular alarm performance auditing (IMCA, M206, current edition; IMCA, M182, current edition).

IX. TRAINING, COMPETENCY, AND CERTIFICATION

A. The Nautical Institute DPO Certification Scheme

Table V summarises the five phases of the Nautical Institute DPO Certification Scheme, the requirement for each phase, and its OHS relevance (Nautical Institute, current edition; IMCA, M117, current edition).

TABLE V NAUTICAL INSTITUTE DPO CERTIFICATION SCHEME: PHASES, REQUIREMENTS, AND OHS RELEVANCE

Phase	Requirement	OHS Relevance
Induction Course (NI)	Theory: DP principles, system architecture, watchkeeping procedures	Baseline competency; introduction to DP hazards and alert protocols
Phase 1 Sea Time	Minimum 60 days supervised DP operations; NI logbook completion	Real-world exposure under qualified supervision
Advanced Simulator (NI)	High-fidelity emergency scenarios; fault-finding exercises	Builds emergency response capability and decision-making resilience under pressure
Phase 2 Sea Time	Additional 60+ days; increasing operational independence	Consolidation of competency under real operating conditions
Certification (NI)	Logbook review; issuance of Unlimited or Limited DPO certificate	Formal verification of readiness for safety-critical watchkeeping role

Note. Sources: Nautical Institute DPO Certification Scheme (current edition); IMCA M117 (current edition).

B. Continuous Professional Development

Manual control skills deteriorate significantly within 12–24 months without practice (IMCA, M117, current edition). A documented case study analysed using the HFACS framework (Wiegmann & Shappell, 2003) of a DP2-class DSV position loss during diving operations found that the DPO had not practised manual control for two years, had expired simulator training, and did not use the prescribed checklist for PRS mode switching — illustrating Reason's (1997) argument that latent organisational failures (inadequate training governance) create the conditions in which active operator failures become probable (Reason, 1997). These findings underscore the need for mandatory annual simulator currency requirements and vessel-specific familiarisation protocols (IMCA, M117, current edition).

X. RISK ASSESSMENT METHODOLOGIES

Table VI summarises the four principal risk assessment methodologies applied to DP operations, their descriptions, and their specific applications in the DP OHS context (IMCA, M220, current edition; IMO, ISM Code, 2018).

TABLE VI PRINCIPAL RISK ASSESSMENT METHODOLOGIES APPLIED TO DP VESSEL OPERATIONS

Method	Description	Application in DP (Source)
HAZID	Structured brainstorming of potential hazards by cross-functional team (IMCA, M103)	Pre-mobilisation; planning new DP operations in novel environments
FMEA	Component-level mapping of failure modes, effects, and criticality (IMCA, M220; IMO MSC.1/Circ.1580)	Mandatory for DP2/DP3 certification; updated on system modification
Bowtie Analysis	Visual mapping of threats, top events, consequences, and barriers (Energy Institute, 2013)	Training and communication of DP drift-off risk scenarios
Task-Based Risk Assessment (TBRA)	Step-level hazard analysis for specific operational activities (ISO 45001:2018)	Pre-task briefing for diving, crane lifts, and positioning near assets

Note. Sources: IMCA M103; IMCA M220; IMO MSC.1/Circ.1580 (2017); Energy Institute (2013); ISO 45001:2018.

Risk in DP operations is managed under the ALARP (As Low As Reasonably Practicable) principle, as required by the UK Health and Safety at Work etc. Act 1974 and the Offshore Installations (Offshore Safety Directive) Regulations 2015. DP capability plots — which define the vessel's station-keeping ability as a function of environmental loading (IMCA, M103, current edition) — provide a critical tool for operationalising risk tolerance. Operations approaching or exceeding the capability envelope represent an elevated ALARP threshold and should trigger enhanced monitoring, reduced operational tempo, or cessation of the activity (IMO, MSC/Circ.645, 1994; IMCA, M103, current edition).

XI. SAFETY MANAGEMENT SYSTEMS INTEGRATION

Table VII presents the principal SMS elements, their DP-specific application, and the relevant standards or guidance instruments governing each element (ISO 45001:2018; IMO, ISM Code, 2018).

TABLE VII OHS MANAGEMENT SYSTEM ELEMENTS AND THEIR DP-SPECIFIC APPLICATIONS

SMS Element (ISO 45001)	DP-Specific Application	Reference
Safe Operating Procedures (Cl.8)	DP Alert Status protocols; pre-DP checklists; handover standards	IMCA M103; IMO ISM Code
Emergency Preparedness (Cl.8.2)	Drift-off procedures; blackout recovery; diver recall protocols	IMCA M103; IMO MSC/Circ.645
Role Clarity (Cl.5.3)	Defined responsibilities for DPO, Bridge Officer, Engineer during DP events	IMCA M117; ISO 45001:2018
Training and Competency (Cl.7.2)	Simulator currency; vessel familiarisation; cross-functional DP awareness	IMCA M117; Nautical Institute
Documentation (Cl.7.5)	DP logbooks; FMEA reports; incident logs; capability assessments	IMCA M220; IMO ISM Code
Reporting Culture (Cl.10.2)	Near-miss reporting; non-punitive investigation; lessons-learned dissemination	Reason, 1997; ISO 45001:2018
Internal Audit (Cl.9.2)	DP-specific KPIs; alarm performance review; training compliance	ISO 45001:2018; IMCA M182

Note. Sources: ISO 45001:2018; IMO ISM Code (2018); IMCA M103; IMCA M117; IMCA M182; IMCA M220; Reason (1997).

A critical OHS integration point is the linkage between DP Alert Status and Permit to Work (PTW) systems, as recommended in IMCA M103 (current edition). Yellow Alert conditions — indicating loss of redundancy — should trigger automatic review of ongoing PTW approvals and, in many cases, suspension of permitted activities involving personnel at heightened risk (divers, crane operatives, ROV teams) (IMCA, M103, current edition). The practical implementation requires clear procedural definition within the vessel's SMS (IMO, ISM Code, 2018), crew training, and management support to resist commercial pressure to continue operations during periods of elevated DP risk (Reason, 1997).

XII. EMERGENCY PREPAREDNESS AND RESPONSE

A. Emergency Drill Programme

Table VIII presents the recommended emergency drill types for DP vessels, their recommended frequency, and primary OHS objective (IMCA, M103, current edition; IMO, MSC/Circ.645, 1994).

TABLE VIII RECOMMENDED DP EMERGENCY DRILL PROGRAMME: TYPES, FREQUENCY, AND OHS OBJECTIVES

Drill Type	Recommended Frequency	Primary OHS Objective (Source)
DP control failure / position loss	Monthly	Practise rapid manual takeover and position recovery (IMCA M103)
PRS failure and fallback mode	Monthly	Validate alternate sensor configuration procedures (IMCA M103)
Emergency Disconnect (EDP)	Per operation or campaign	Ensure diver/ROV recovery and umbilical safety (IMCA M103)
Blackout recovery	Bi-monthly	Practise power restoration and DP system restart (IMCA M182)
Manual mode joystick control	Quarterly	Maintain manual handling currency in all DPOs (IMCA M117)
Cybersecurity incident	Annually	Practise breach detection, isolation, and manual fallback (IMO MSC.428(98))

Note. Sources: IMCA M103 (current edition); IMCA M117 (current edition); IMO MSC.428(98) (2017).

B. Psychological Preparedness

DP emergencies — particularly those involving diver endangerment or imminent collision risk — are acutely stressful events that can trigger cognitive freeze, panic, and sequential decision-making failures even in well-trained operators (Wiegmann & Shappell, 2003; Reason, 1997). Emergency training should incorporate stress inoculation elements, developing operator resilience to performance degradation under pressure (NIOSH, 2021). Following serious incidents, Critical Incident Stress Debriefing (CISD) should be offered to all affected personnel as a standard OHS provision (ISO 45001:2018).

XIII. ENVIRONMENTAL AND CYBERSECURITY CONSIDERATIONS

Environmental protection and occupational safety are closely linked in DP operations — loss-of-position events frequently result in collisions with subsea infrastructure, which may cause hydrocarbon releases or physical damage to marine protection zones (IMO, MSC/Circ.645, 1994).

As DP systems become increasingly networked, their exposure to cybersecurity threats has grown substantially (IMO, MSC.428(98), 2017). Cyber attacks on GPS/DGPS position reference signals, thruster control logic, or power management systems could directly cause position loss. IMO Resolution MSC.428(98) (2017) requires maritime cybersecurity to be addressed within the SMS. Key OHS-relevant controls include cyber risk assessment of DP control systems, physical and logical network segregation, regular vulnerability scanning, and cyber-specific emergency response procedures (IMO, MSC.428(98), 2017; ISO 45001:2018).

XIV. TECHNOLOGICAL INNOVATION AND FUTURE OHS CHALLENGES

Machine learning algorithms capable of predicting equipment failures, digital twin platforms enabling real-time simulation, and adaptive control systems that autonomously adjust to changing sea states all offer significant potential for reducing technical failure rates (IMO, MSC.1/Circ.1580, 2017; NIOSH, 2021). Wearable fatigue sensors, biometric monitoring, and AI-powered well-being analytics represent emerging tools for directly monitoring operator health state in real time (NIOSH, 2021). However, increased automation introduces skill degradation risk in manual control, reduced vigilance through complacency, and automation-induced brittleness (Reason, 1997; Endsley, 1995). The future DPO role is likely to shift from direct operational control toward supervisory oversight of AI decision systems — requiring a parallel evolution in training focused on trust calibration, anomaly detection, and resilience to automation failure (IMCA, M117, current edition).

XV. STAKEHOLDER ROLES AND COLLABORATIVE SAFETY GOVERNANCE

Table IX presents the primary OHS responsibilities of each major stakeholder group in the DP vessel safety ecosystem (ISO 45001:2018; IMO, ISM Code, 2018). Effective DP safety governance requires coordinated action across all of these groups — technical excellence from designers, regulatory rigour from authorities, operational commitment from operators, and individual accountability from DPOs and crew (Reason, 1997; Wiegmann & Shappell, 2003).

TABLE IX PRIMARY OHS RESPONSIBILITIES OF KEY STAKEHOLDER GROUPS IN DP VESSEL SAFETY GOVERNANCE

Stakeholder	Primary OHS Responsibility (Reference)
Shipowners/Operators	Compliant SMS; training funding; wellness programmes; OHS-DP liaison officers (ISO 45001:2018; IMCA M103)
DP Operators (DPOs)	Safe watchkeeping; near-miss reporting; training currency; health self-monitoring (IMCA M117; NI Scheme)
Engineering Crew	System integrity; maintenance compliance; emergency response participation (IMCA M103; IMO ISM Code)
Shore-Based Management	Audit oversight; training governance; fatigue policy enforcement; incident review (ISO 45001:2018)
Regulatory Authorities	Standard-setting; enforcement; human factor regulatory updates (IMO; ILO MLC 2006)
Classification Societies	DP class certification; FMEA verification; annual trial oversight (IMCA M220; DNV)
Vessel Designers/Builders	Human-centred bridge design; ergonomic workstations; redundancy engineering (ISO 11064:2000)
Training Institutions	Accredited courses; scenario realism; human factors integration (Nautical Institute; IMCA M117)
Technology Vendors	User-centred HMI design; safe automation; lifecycle support (IMCA M206; Endsley, 1995)

Note. Sources: ISO 45001:2018; IMO ISM Code (2018); IMCA M103; IMCA M117; IMCA M220; ILO MLC 2006; Endsley (1995); Reason (1997).

XVI. RECOMMENDATIONS

A. For Shipowners and Operators

The following recommendations are directed at shipowners and vessel operators, informed by findings from IMCA incident databases, ISO 45001:2018, and the OHS literature reviewed in this paper (IMCA, M182; ISO 45001:2018; Reason, 1997):

1. Embed OHS audits within DP audits, using integrated inspection protocols that assess both technical compliance and human factor performance (ISO 45001:2018; IMCA M103).
2. Appoint dedicated OHS-DP liaison officers on vessels undertaking high-risk DP operations — diving support, drilling, heavy lift (IMCA M103; ISO 45001:2018).

3. Implement validated Fatigue Risk Management Systems aligned with STCW and MLC 2006, with independent monitoring and transparent reporting (ILO, MLC 2006; IMCA M117).
4. Invest in HMI modernisation programmes that apply ergonomic design standards and reduce alarm burden on DPOs (IMCA M206; ISO 11064:2000; Endsley, 1995).
5. Establish comprehensive mental health programmes including confidential counselling access, onboard wellness champions, and psychosocial risk assessment (ISO 45001:2018; NIOSH, 2021).

B. For Training Institutions

The following recommendations are directed at institutions delivering DPO and crew training (IMCA, M117, current edition; Nautical Institute, current edition; Wiegmann & Shappell, 2003):

1. Integrate mental resilience, stress management, and cross-cultural communication modules into all DPO training programmes (Wiegmann & Shappell, 2003; IMCA M117).
2. Design simulator scenarios replicating human factor conditions including fatigue-state simulation, alarm flooding, and multi-operator coordination (Endsley, 1995; IMCA M117).
3. Mandate annual simulator currency requirements to maintain manual control proficiency and emergency response readiness (IMCA M117; Nautical Institute).

C. For Regulators and Flag States

The following recommendations are directed at regulatory authorities, including flag states, Port State Control authorities, and international standards bodies (IMO, MSC/Circ.645, 1994; ILO, MLC 2006; ISO 45001:2018):

1. Mandate OHS-specific components in DP Safety Cases and Emergency Response Plans, including psychosocial hazard assessments and fatigue management plans (ILO, MLC 2006; ISO 45001:2018).
2. Update STCW and MLC provisions to include crew wellness and fatigue protections specifically tailored to DP shift patterns and rotation structures (ILO, MLC 2006).
3. Develop regulatory guidance on cybersecurity risk management specific to DP systems, bridging the gap between IMO MSC.428(98) and operational implementation (IMO, MSC.428(98), 2017).

D. For Technology Developers

The following recommendations are directed at DP system technology developers and HMI designers (IMCA, M206, current edition; ISO 11064:2000; Endsley, 1995):

1. Prioritise user-centred design in HMI development, applying neuroergonomic principles and involving operational DPOs in design validation (ISO 11064:2000; Endsley, 1995).
2. Design adaptive automation systems that maintain meaningful human engagement and preserve manual control proficiency (Reason, 1997; IMCA M117).
3. Develop alarm management systems that support intelligent alarm prioritisation, root-cause grouping, and alarm rationalisation auditing (IMCA M206; Endsley, 1995).

XVII. CONCLUSION

Dynamic Positioning technology represents a remarkable achievement in offshore engineering — enabling precise station-keeping in some of the world's most challenging marine environments (IMO, MSC/Circ.645, 1994). Yet this technological sophistication does not insulate DP operations from risk. The complexity of DP systems, the demands they place on human operators, and the high-consequence nature of the activities they enable create an OHS risk profile of exceptional breadth and depth (Reason, 1997; IMCA, M182, current edition).

This paper has demonstrated that the factors affecting OHS in DP vessel operations are multidimensional, encompassing technical failure modes, human performance vulnerabilities, ergonomic deficiencies, regulatory gaps, and psychosocial stressors that are often inadequately addressed by existing frameworks (Wiegmann & Shappell, 2003; Endsley, 1995). Incidents rarely arise from a single cause — they emerge from the interaction of technical degradation with human factors: operator fatigue, cognitive overload, training deficiencies, communication failures, and the organisational pressures that shape safety culture and decision-making (Reason, 1997; Reason, 1990).

The evidence reviewed throughout this paper converges on a consistent and actionable conclusion: the path to improved OHS in DP operations lies in a more integrated, human-centred approach to safety management (ISO 45001:2018; ILO, MLC 2006). Technical redundancy and regulatory compliance are necessary but insufficient foundations.

They must be complemented by ergonomically designed work environments (ISO 11064:2000), evidence-based fatigue management (ILO, MLC 2006), realistic and comprehensive training (IMCA, M117), psychologically safe reporting cultures (Reason, 1997), and the proactive identification of human and organisational risk factors alongside technical hazards (Wiegmann & Shappell, 2003). Ultimately, a vessel's true position is not only measured by satellites and sensors — it is shaped by the health, competence, and psychological state of the crew who monitor and manage those systems.

REFERENCES

- [1] Endsley MR. Toward a theory of situation awareness in dynamic systems. *Human Factors*. 1995;37(1):32–64. <https://doi.org/10.1518/001872095779049543>
- [2] Energy Institute. *Bowtie Risk Assessment in the Oil and Gas Industry: Guidance for Good Practice*. London: Energy Institute; 2013.
- [3] International Labour Organization (ILO). *Maritime Labour Convention 2006 (MLC 2006)*. Geneva: ILO; 2006.
- [4] International Maritime Organization (IMO). *MSC/Circ.645 — Guidelines for Vessels with Dynamic Positioning Systems*. London: IMO; 1994.
- [5] International Maritime Organization (IMO). *MSC.428(98) — Maritime Cyber Risk Management in Safety Management Systems*. London: IMO; 2017.
- [6] International Maritime Organization (IMO). *MSC.1/Circ.1580 — Revised Guidelines for Failure Mode and Effects Analysis (FMEA) on DP Systems*. London: IMO; 2017.
- [7] International Maritime Organization (IMO). *International Safety Management Code (ISM Code), 2018 Consolidated Edition*. London: IMO; 2018.
- [8] International Maritime Organization (IMO). *Standards of Training, Certification and Watchkeeping for Seafarers (STCW Convention)*. London: IMO. Current edition.
- [9] International Marine Contractors Association (IMCA). *M103 — Guidelines for the Design and Operation of Dynamically Positioned Vessels*. London: IMCA. Current edition.
- [10] International Marine Contractors Association (IMCA). *M117 — Training and Experience of Key DP Personnel*. London: IMCA. Current edition.
- [11] International Marine Contractors Association (IMCA). *M182 — Analysis and Classification of Dynamic Positioning Incidents*. London: IMCA. Current edition.
- [12] International Marine Contractors Association (IMCA). *M206 — Guidance on the Design of Human-Machine Interface in DP Systems*. London: IMCA. Current edition.
- [13] International Marine Contractors Association (IMCA). *M220 — Guidance on Failure Modes and Effects Analysis (FMEA)*. London: IMCA. Current edition.
- [14] International Organization for Standardization (ISO). *ISO 11064:2000 — Ergonomic Design of Control Centres*. Geneva: ISO; 2000.



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- [15] International Organization for Standardization (ISO). ISO 2631-1:1997 — Mechanical Vibration and Shock: Evaluation of Human Exposure to Whole-Body Vibration. Geneva: ISO; 1997.
- [16] International Organization for Standardization (ISO). ISO 45001:2018 — Occupational Health and Safety Management Systems. Geneva: ISO; 2018.
- [17] Nautical Institute. Dynamic Positioning Operator Certification Scheme. London: Nautical Institute. Current edition.
- [18] National Institute for Occupational Safety and Health (NIOSH). Total Worker Health Programme Framework. Cincinnati: NIOSH; 2021.
- [19] Reason J. Human Error. Cambridge: Cambridge University Press; 1990.
- [20] Reason J. Managing the Risks of Organisational Accidents. Aldershot: Ashgate; 1997.
- [21] Wiegmann DA, Shappell SA. A Human Error Approach to Aviation Accident Analysis: The Human Factors Analysis and Classification System. Aldershot: Ashgate; 2003.