FUEL SAFETY FRAMEWORKS

Ammonia

Ammonia Process Safety Management Maturity Self-Assessment Tool

Element Maturity Tables

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

The Decarb Hub

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Fuel Safety Frameworks: Ammonia is a practitioner series from the Lloyd's Register Maritime Decarbonisation Hub and the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping.

Ammonia as Fuel Competencies and Training (2025)

- Project Summary Report
- Competencies and Training Proposed Overall Framework
- Detailed Competency & Training Operational, Maintenance and Emergency Response Scenario Evaluations

Ammonia Competency and Training Practitioners Handbooks (2026)

- Emergency Response
- Maintenance
- Leak Detection, Management, Isolation and Repair

Ammonia Process Safety Management Maturity Self-Assessment Tool (2026)

- User Guide
- Element Maturity Tables
- Assessment Template

Executive summary

Why use this tool?

The adoption of alternative fuels in shipping, for the purpose of lowering greenhouse gas (GHG) emissions, will entail significant changes in maritime safety management. Ammonia has received particular attention as a high-potential route to maritime decarbonisation that – in its deployment – also requires a careful re-evaluation of maritime safety practices. While the general need for this re-evaluation is clear, our understanding of the particular character of the required changes is less settled. Vessel owners, operators and managers contemplating use of ammonia as a fuel are confronted with important safety management questions for which there are few ready answers: 'where do we begin?', 'what aspects of our operation should we focus on when implementing change?', 'how can we be confident that our operation is ammonia-ready?'.

This tool provides a basis for developing initial answers to these questions. It is grounded in a belief that the maritime industry can learn from other safety-critical industries that have track-records of safely handling hazardous molecules like ammonia. Specifically, it describes how the process safety management (PSM) approach to managing safety – well-established in sectors such as chemical engineering and oil and gas – can be applied in the maritime context to help orient the industry to the safety management requirements of an ammonia-powered future.

Who is this tool for?

The primary audiences for this tool are those vessel owners, operators and managers who are in the process of adopting ammonia as a marine fuel, or considering doing so. This includes both shore-based and sea-going vessel management. For these audiences, this tool provides a mechanism for evaluating present safety management arrangements against a PSM framework, and for identifying the aspects of these arrangements that may require improvement.

In addition to these primary audiences, this tool may also be of interest to stakeholders with a more general interest in assuring safe maritime operations, including seafarers, operators using fuels other than ammonia, regulators and training establishments. While the development of this tool has been motivated by the challenge of assuring the safe deployment of ammonia as a marine fuel, there may nevertheless be value in maritime stakeholders who are not (or not yet) considering adopting ammonia as a fuel evaluating their activities through the lens provided by PSM. We welcome engagement from this extended audience as part of the wider dialogue supporting continuous improvement in maritime safety outcomes.

Structure

For ease of use, the tool is separated into 3 documents that should be used together when performing self-assessments. These are:

- The **User Guide**
- The **Element Maturity Tables**
- The **Assessment Template** (click here to download the editable template)

Feedback

We are keen that this publication – and future work – is as relevant and useful to industry as possible. To this end, we welcome feedback on this tool using the following QR code or click here.

Contents

About these tables

Each section in this set of tables provides a framework for evaluating a shipping organisation's safety management maturity in the context of a single PSM element. Each PSM element corresponds to one row in the **Template**, which can be used to record findings.

The PSM elements described are based on the Center for Chemical Process Safety (CCPS) Risk-Based PSM (RBPSM) Framework (Guidelines for Risk Based Process Safety, CCPS, 2007), while the maturity levels draw on the Capability Maturity Model and, complementary to it, the safety-culture maturity work of Parker, Lawrie and Hudson.

While it is not possible to provide exact analogues of the meanings of maturity descriptors in current practice, Table 1 below provides general accounts of these meanings to assist users with orientation.

Table 1: Maturity band with indication of equivalent performance level in ISM/ PSM performance standards.

Maturity band	Indicative ISM/ PSM reference
Ad-hoc	Below current maritime safety standards (e.g. ISM Code requirements); inconsistent with CCPS RBPSM performance expectations.
Reactive	May meet minimal requirements for maritime safety compliance; shows embryonic RBPSM development.
Standardised	Generally aligned with current maritime safety expectations; systematic implementation of RBPSM.
Proactive	Demonstrates 'good practice' against current maritime safety expectations; an effective implementation of RBPSM.
Generative	Highly mature implementation of RBPSM; active, sustained and deep organisational safety focus.

Please refer to the **User Guide** for more detailed guidance on using both this document and the **Template**.

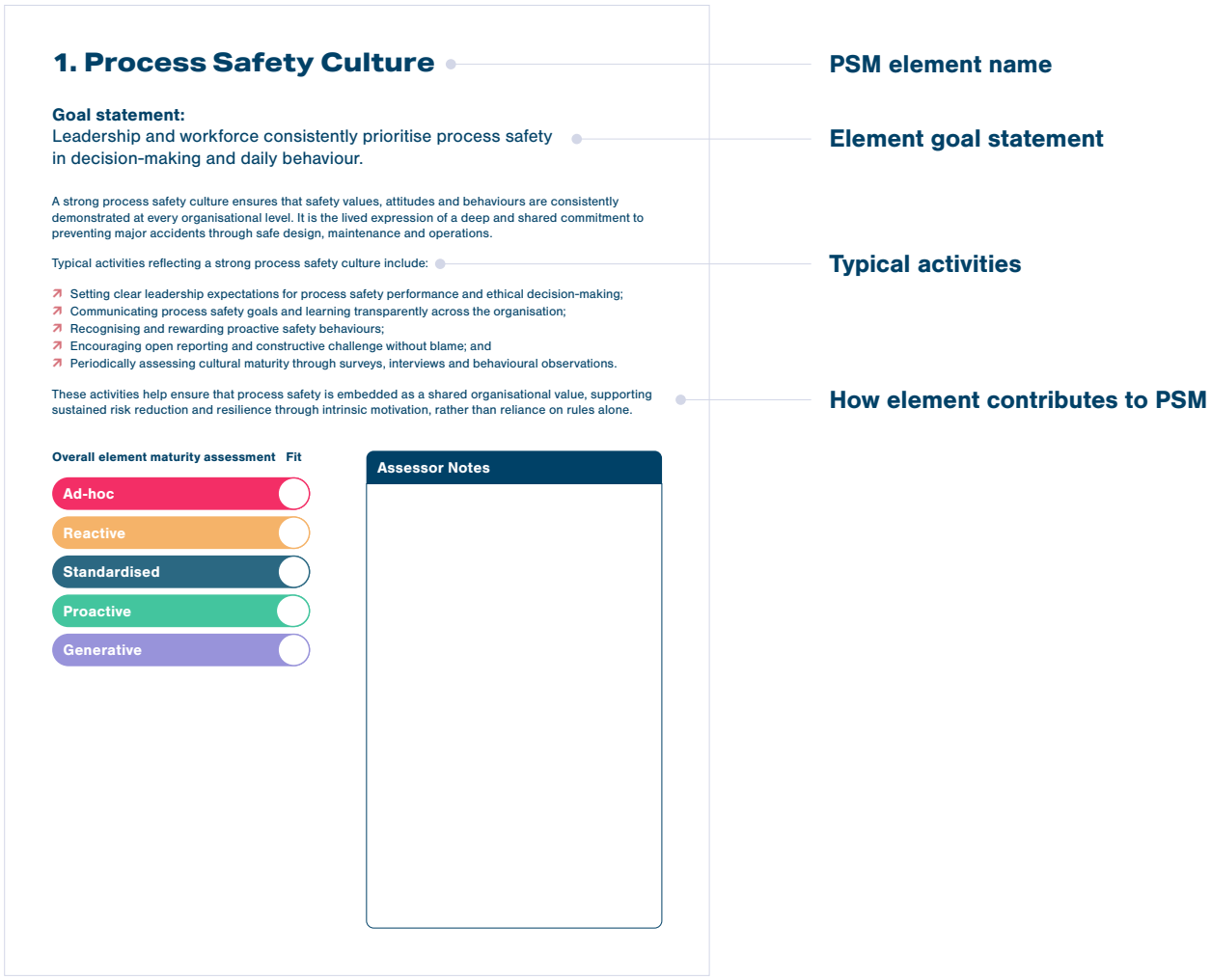
Understanding the structure of the elements

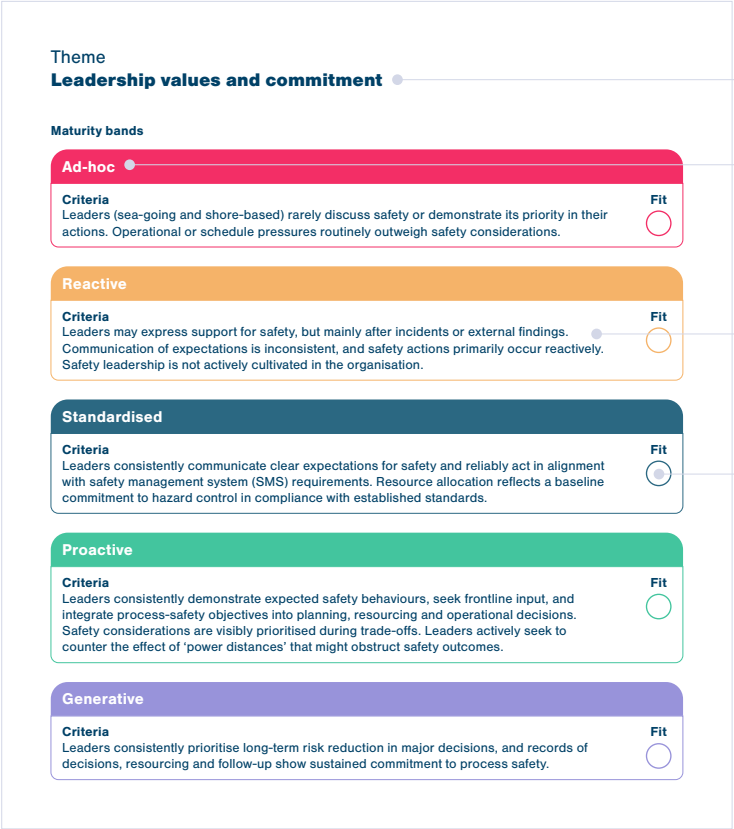
Each element section opens with a goal statement that describes the overall goal for that element.

Next comes a brief description of the element, the typical activities that contribute to achieving the element goal, and how the element contributes to process safety.

Some assessors may wish to work with the **Element Tables** in hard copy. To support such use, the tables contain space for notes and a 'Fit' column provided to allow users to mark the activity descriptions that seem to best fit their organisations.

Finally, the main table within each element description offers a breakdown of maturity criteria that can be used to evaluate the safety management maturity of an organisation within that element. These maturity criteria are organised into four themes per element. Users should record maturity findings in the **Template**.





Note on terminology

So far as has been practicable, this document describes PSM maturity with reference to explicit, observable activities within an organisation. This approach supports the integrity of assessments made using this tool, and allows for performance to be unambiguously supported by evidence.

This approach has, however, posed a challenge when referring to the actors within shipping organisations who are expected to perform a given activity. Activities need to be framed in language that is sufficiently broad to encompass the variety of operational models within the maritime industry, while sufficiently narrow to remain meaningful. For clarity, the actor types referred to in this tool are generally defined as follows:

- **'Crew' –** is used to refer to sea-going personnel within an organisation;
- **'Leaders' –** refers to sea-going and shore-side personnel who hold responsibility for, and decision-making authority over, safety management within the organisation;
- **'Management' –** means those individuals with a supervisory responsibility over organisational activities; and
- **'Workforce' –** is used, in alignment with the CCPS definition (Guidelines for Risk Based Process Safety, CCPS, 2007) to refer to those (non-management) personnel responsible for directly performing operational and technical activities.

1. Process Safety Culture

Goal statement:
Leadership and workforce consistently prioritise process safety in decision-making and daily behaviour.

A strong process safety culture ensures that safety values, attitudes and behaviours are consistently demonstrated at every organisational level. It is the lived expression of a deep and shared commitment to preventing major accidents through safe design, maintenance and operations.

Typical activities reflecting a strong process safety culture include:

- Setting clear leadership expectations for process safety performance and ethical decision-making;
- Communicating process safety goals and learning transparently across the organisation;
- Recognising and rewarding proactive safety behaviours;
- Encouraging open reporting and constructive challenge without blame; and
- Periodically assessing cultural maturity through surveys, interviews and behavioural observations.

These activities help ensure that process safety is embedded as a shared organisational value, supporting sustained risk reduction and resilience through intrinsic motivation, rather than reliance on rules alone.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Leadership values and commitment

Maturity bands

Ad-hoc

Criteria
Leaders (sea-going and shore-based) rarely discuss safety or demonstrate its priority in their actions. Operational or schedule pressures routinely outweigh safety considerations.

Fit

Reactive

Criteria
Leaders may express support for safety, but mainly after incidents or external findings. Communication of expectations is inconsistent, and safety actions primarily occur reactively. Safety leadership is not actively cultivated in the organisation.

Fit

Standardised

Criteria
Leaders consistently communicate clear expectations for safety and reliably act in alignment with safety management system (SMS) requirements. Resource allocation reflects a baseline commitment to hazard control in compliance with established standards.

Fit

Proactive

Criteria
Leaders consistently demonstrate expected safety behaviours, seek frontline input, and integrate process-safety objectives into planning, resourcing and operational decisions. Safety considerations are visibly prioritised during trade-offs. Leaders actively seek to counter the effect of 'power distances' that might obstruct safety outcomes.

Fit

Generative

Criteria
Leaders consistently prioritise long-term risk reduction in major decisions, and records of decisions, resourcing and follow-up show sustained commitment to process safety.

Fit

Theme
Roles, accountability & decision-making

Maturity bands

Ad-hoc

Criteria
Safety responsibilities are unclear; failures are attributed to individuals without examining system weaknesses. Decisions commonly prioritise short-term operational needs over long-term hazard control.

Fit

Reactive

Criteria
Basic safety roles exist, but performance and accountability are uneven. Deviations from safety management requirements prompt corrective actions, but focus is on compliance rather than understanding and managing underlying hazards.

Fit

Standardised

Criteria
Roles and authorities for managing safety are documented and understood throughout the workforce. Managers actively reinforce required behaviours. Decision-making on safety matters reflects established standards/ procedures.

Fit

Proactive

Criteria
Individuals at all levels have the authority and confidence to make safety-based decisions. Managers actively foster constructive challenge and work to support safe adaptations to changing conditions. Safety is managed holistically, incorporating perspectives from relevant technical disciplines and from both sea-going and shore-side personnel.

Fit

Generative

Criteria
Safety accountability is consistently demonstrated through decision-making and actions at all organisational levels. Individuals at all organisational levels feel empowered to challenge decisions assessed as unsafe. Unauthorised deviations from safety standards are rare and trigger visible corrective actions.

Fit

Theme
Workforce trust & openness

Maturity bands

Ad-hoc

Criteria
Reporting of safety concerns is discouraged or met with blame. Workforce often choose not to speak up about near misses or procedural deviations.

Fit

Reactive

Criteria
Workforce raise issues primarily after significant events. Minor deviations are under-reported. Engagement in structured safety activities depends on individual initiative.

Fit

Standardised

Criteria
Reporting is encouraged and blame-free. There are opportunities for the workforce to participate in hazard assessments as part of routine practice. Feedback mechanisms are in place, but may be somewhat rigid and/ or unwieldy.

Fit

Proactive

Criteria
The workforce openly raises concerns, including minor deviations. Constructive challenge is routine. The workforce contributes substantively to procedure development and risk assessment. Effective systems support easy reporting of incidents and concerns.

Fit

Generative

Criteria
Psychological safety is deeply embedded in the working culture. People readily share mistakes and insights without fear. Workforce helps to co-create elements of the SMS and routinely identifies opportunities for improvement.

Fit

Theme
Learning culture

Maturity bands

Ad-hoc

Criteria
Little evidence of structured learning from incidents or audits. Similar issues recur without meaningful organisational change. Organisational awareness of incidents – including records – is sparse or non-existent.

Fit

Reactive

Criteria
Lessons from incidents and audits are discussed, but changes tend to be local or short-lived. Learning is not routinely integrated into procedures, design information or training.

Fit

Standardised

Criteria
Incident learnings, audit findings and debrief insights are tracked and acted upon in a sustainable manner. Improvements are incorporated into documentation and training on a defined basis.

Fit

Proactive

Criteria
Insights from near misses and external sources are systematically integrated into risk assessments, procedures and equipment planning. The culture treats failures as opportunities to learn and reporting occurs freely and without fear of reprisals

Fit

Generative

Criteria
Learning systems are established, routinely used and support timely sharing of safety learnings across the organisation. External lessons and emerging best-practices are actively incorporated into design, procedures, and training. The organisation influences safety management improvements across the wider maritime sector.

Fit

2. Compliance with Standards

Goal statement:
All operations demonstrably meet or exceed relevant codes, standards and legal requirements.

Effective compliance ensures that technical systems, operational practices and behaviours consistently align with recognised good practice, while remaining responsive to evolving regulatory expectations and industry learning. In the context of the emerging regulatory frameworks around use of ammonia as a marine fuel, compliance can also require evaluation of safety equivalence where alternative designs or arrangements are proposed.

Typical activities reflecting effective compliance with standards include:

- Maintaining knowledge of, and access to, applicable laws, regulations, codes, class rules and industry standards;
- Translating compliance obligations into clear technical, operational and procedural requirements;
- Verifying compliance through structured design reviews, inspections, audits and assurance activities;
- Monitoring emerging standards and regulations to support proactive integration of changes; and
- Assessing and justifying equivalence where alternative measures are adopted, supported by documented risk-based arguments.

These activities ensure that compliance functions as an enabler of safe operations and continuous improvement, rather than a purely reactive obligation.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Identification of standards

Maturity bands

Ad-hoc

Criteria
The organisation has no systematic method for identifying applicable laws, codes, regulations, classification requirements or industry standards. Compliance needs are discovered only after problems arise.

Fit

Reactive

Criteria
Primary regulatory, class and industry requirements are recognised, but assessments of applicability occur only when prompted by inspections, incidents or other external instigators.

Fit

Standardised

Criteria
Applicable laws, codes, class rules and industry standards are identified, held and reviewed periodically for applicability. Where appropriate, these standards are referenced in the SMS. Relevant industry standards relating to ammonia safety are recognised.

Fit

Proactive

Criteria
The organisation actively scans for emerging standards, regulatory initiatives and classification rules updates – including those relating to ammonia safety management – assessing applicability early and across the vessel lifecycle.

Fit

Generative

Criteria
The organisation routinely reviews emerging requirements and can demonstrate early internal action on relevant developments before formal compliance deadlines.

Fit

Theme
Managing & communicating

Maturity bands

Ad-hoc

Criteria
Standards information is stored inconsistently or informally. Individuals rely on personal knowledge or *ad-hoc* communication to understand regulatory obligations.

Fit

Reactive

Criteria
Basic roles for managing compliance exist, but communication of obligations is inconsistent across vessels and departments (aboard vessels and ashore). Deviations are handled informally and without structured risk justification.

Fit

Standardised

Criteria
A formal system exists for maintaining access to standards and communicating updates. The workforce receives structured training on major compliance obligations. There are formal processes in place for handling deviations.

Fit

Proactive

Criteria
Compliance obligations are communicated fleet-wide. The workforce has timely access to updated standards and refresher training is implemented when requirements change. Deviations are reviewed to identify patterns and learnings.

Fit

Generative

Criteria
Compliance insights, challenges and deviations are transparently shared across the fleet and, where appropriate, with external stakeholders. Deviations are treated as offering learning opportunities for improving performance.

Fit

Theme
Verification & assurance

Maturity bands

Ad-hoc

Criteria
Compliance is largely assumed rather than verified. There is no structured assurance process to confirm that regulatory, class or internal requirements are being met in practice. Deviations are not systematically detected, recorded or analysed.

Fit

Reactive

Criteria
Verification of compliance typically occurs in response to incidents or through external audits/ inspections. Assurance focuses on reactive demonstration of compliance after issues arise. Deviations are corrected but root causes and systemic weaknesses are rarely examined.

Fit

Standardised

Criteria
A defined verification and assurance process is in place, including planned audits, inspections and document reviews against regulatory, class and internal requirements. Deviations are formally recorded, risk-assessed and tracked to closure with evidence.

Fit

Proactive

Criteria
Compliance assurance activity is prioritised with reference to trends in non-conformities, near misses, maintenance deferrals, MoC performance and audit findings. Assurance planning explicitly seeks to identify emerging compliance risks before formal non-compliance occurs.

Fit

Generative

Criteria
The organisation uses forward-looking performance indicators, cross-fleet benchmarking and external peer comparison to detect early signs of declining compliance performance.

Fit

Theme
Review & update

Maturity bands

Ad-hoc

Criteria
Updates to standards or regulations are not monitored. Operational, technical and design documents become outdated/ superseded without detection.

Fit

Reactive

Criteria
Significant regulatory changes are integrated only when mandated. There is limited forward planning to understand applicability of emerging standards or developing interpretations of requirements.

Fit

Standardised

Criteria
Changes to standards and regulations are systematically incorporated into design information, operating procedures and maintenance requirements (as required) through an established MoC process for compliance with standards.

Fit

Proactive

Criteria
Emerging requirements – including non-mandatory good practice recommendations – are integrated proactively into technical, operational and training documentation. Impacts are assessed across vessel types, ship-shore interfaces and contractors.

Fit

Generative

Criteria
Updates to standards are anticipated and assessed in advance of formal regulation, with documented changes made to relevant technical, operational and training materials where warranted.

Fit

3. Process Safety Competency

Goal statement:
Organisational processes and resources support the maintenance and application of effective process safety knowledge and practices (technical and non-technical).

This element relates to the deliberate effort to develop quality process safety knowledge within an organisation and assure consistent behaviour in accordance with this knowledge. Competency includes both technical knowledge (e.g. of hazards, systems) and non-technical capabilities (e.g. communication, fatigue management). Comprehensive guidance on recommended competencies for ammonia operations is available in the report *Ammonia as a Fuel: Competencies and Training*.

This element is primarily concerned with organisational competence. Personal competences are addressed in the Training and Performance Assurance element. Typical activities include:

- Defining clear competency requirements for all roles influencing safety outcomes, distinguishing between requirements for sea-going and shore-based staff;
- Running organisational knowledge development programmes (e.g. mentoring schemes);
- Verifying competence through observation and performance review mechanisms;
- Capturing and transferring knowledge from incidents, experience and departing personnel; and
- Embedding learning and skill development within leadership expectations, resource planning and continuous improvement processes.

These activities help ensure that process safety competence is defined, assured and sustained across the organisation.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Expectations & ownership

Maturity bands

Ad-hoc

Criteria
Process safety knowledge expectations are not explicitly defined. There is no shared articulation of what the workforce should understand about ammonia hazards, safety barriers or operating limits. Ownership of competence expectations is unclear or absent. Decision-making accountability is not grounded in appropriate competency.

Fit

Reactive

Criteria
Some process safety knowledge expectations exist for selected roles, but these are incomplete or implicit. Expectations are often derived from external requirements rather than systematic risk analysis of the organisation's own operations.

Fit

Standardised

Criteria
Process safety knowledge expectations for ammonia-related roles – informed by hazard control requirements – are identified and documented within a competency matrix or similar. Responsibility for defining and maintaining these expectations (e.g. through training) is assigned in the SMS.

Fit

Proactive

Criteria
Competence expectations are reviewed as operational experience/ risk understanding of ammonia fuel systems evolves. Team knowledge redundancies are analysed to prevent latent knowledge gaps.

Fit

Generative

Criteria
The organisation anticipates future competence needs related to ammonia operations and prepares in advance. Leadership allocates resources to pre-emptive development of competency.

Fit

Theme
Knowledge development

Maturity bands

Ad-hoc

Criteria
There is no structured approach to developing or maintaining organisational process safety knowledge. Understanding depends on individual experience. There is no evidence of systematic knowledge capture.

Fit

Reactive

Criteria
Organisational learning occurs mainly after incidents or through audits/ external findings. Lessons may be discussed or circulated, but processes for building shared understanding are informal, localised and inconsistently applied.

Fit

Standardised

Criteria
Defined processes exist to develop shared process safety knowledge, such as incident reviews, abnormal operation debriefs and facilitated hazard discussions. Where relevant, findings are used to update risk assessments, procedures or other knowledge artifacts. Knowledge development activities are planned and repeatable.

Fit

Proactive

Criteria
The organisation deliberately cultivates process safety knowledge through structured scenario workshops, tabletop exercises and cross-disciplinary reviews of abnormal or degraded operation situations. These activities test assumptions about hazard control and decision-making, with findings systematically captured where appropriate.

Fit

Generative

Criteria
Knowledge development is continuous and embedded in operations, with mechanisms for capturing lessons learned from operations provided. Learnings from drills, abnormal events and incidents are shared across the fleet for review.

Fit

Theme
Application & reinforcement

Maturity bands

Ad-hoc

Criteria
Operational decisions rely heavily on individual judgement. Management attention focuses on task completion rather than quality of understanding/ risk considerations. Weak decision-making is addressed only after incidents.

Fit

Reactive

Criteria
Management checks focus primarily on procedural compliance. Indicators of misunderstanding or skill-fade are recognised mainly after errors occur. Contractor competence is checked inconsistently.

Fit

Standardised

Criteria
Management routinely verifies that the workforce demonstrates appropriate understanding during operations. Identified gaps trigger defined responses such as mentoring, supervision or targeted development. Processes for assurance of contractor safety competence are in place.

Fit

Proactive

Criteria
Management monitors behavioural indicators of strong and weak process safety performance. Early signs of overload, misunderstanding or skill fade are addressed before incidents occur.

Fit

Generative

Criteria
Management assurance, peer challenge and self-checking are routinely evident in work practices. The workforce actively intervenes to protect safety performance without reliance on authority.

Fit

Theme
Learning infrastructure

Maturity bands

Ad-hoc

Criteria
There are no defined systems to capture, retain or disseminate process safety learning. Learning is sporadic and informal. Process safety knowledge is primarily retained by individuals and is frequently lost through staff turnover.

Fit

Reactive

Criteria
Basic mechanisms exist to record incidents, audit findings or lessons learned, but these operate largely as repositories. There is limited evidence that learning outputs are systematically reviewed, prioritised or translated into changes to expectations for competency or operational practice.

Fit

Standardised

Criteria
Defined systems exist for the capture, review and implementation of knowledge resources. Handover and debrief processes ensure that operational learning is captured and retained. Responsibilities for maintaining knowledge resources/ systems are assigned.

Fit

Proactive

Criteria
Structured mentoring programmes are facilitated. Electronic knowledge repositories are actively managed and quality-checked. Learning infrastructure generates outputs (e.g. performance dashboards) that are used to inform safety management priorities.

Fit

Generative

Criteria
Organisational learning infrastructure supports rapid and systematic sharing of knowledge across the fleet and, where appropriate, externally.

Fit

4. Workforce Involvement

Goal statement:
Personnel from across the organisation actively participate in developing, improving and assuring integrated PSM.

Workforce involvement ensures that employees and contractors actively contribute their knowledge and experience to improve process safety performance and outcomes. It promotes shared ownership of hazard control and establishes participation as a crucial component of safety decision-making processes.

Typical activities include:

- Involving operational personnel in hazard identification, risk assessments and incident investigations;
- Consulting workers on changes affecting safety and validating practicality of procedures;
- Establishing representative safety committees or working groups;
- Providing accessible mechanisms for raising concerns and suggesting improvements; and
- Tracking workforce feedback and demonstrating how input informs design, operational practice and system development, reinforcing trust and engagement.

These activities help embed workforce participation as a normal and expected part of managing process safety, rather than an occasional or reactive occurrence.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Structure, roles & inclusion

Maturity bands

Ad-hoc

Criteria
There is no clear plan or structure for workforce involvement in safety management activities. Roles and responsibilities for participation are undefined, and contractors are generally excluded from safety discussions.

Fit

Reactive

Criteria
Basic structures for workforce involvement exist, for example a shipboard safety committee, but membership and roles are unclear and substantive meetings occur mainly after incidents or external findings. Contractors are only irregularly involved in safety discussions.

Fit

Standardised

Criteria
Documented plans define roles, responsibilities and expectations for workforce involvement in safety management activities, including crew, shoreside technical staff and contractors. Personnel are designated to 'own' workforce involvement outcomes (e.g. effective communication up organisational hierarchies), with resources allocated to assure effectiveness.

Fit

Proactive

Criteria
Workforce involvement structures are well established across departments, ranks and contractors. Roles are understood and participation in process safety decision-making is explicitly built into job descriptions/ expectations. Managers responsible for safety regularly engage with all ranks/ specialisms within the workforce.

Fit

Generative

Criteria
Workforce involvement is fully embedded in governance and culture. Workers at all levels see themselves as joint owners of the SMS. Contractors are effectively integrated into safety structures with routes to provide safety feedback to the organisation provided.

Fit

Theme
Participation in PSM activities

Maturity bands

Ad-hoc

Criteria
Workforce are rarely invited to take part in hazard reviews, procedure development or incident investigations. Participation in process safety activities is informal and depends on individual managers.

Fit

Reactive

Criteria
Crew are invited to participate in some safety activities, such as incident investigations or specific risk assessments, usually after problems have occurred. Such participation is driven by the initiative of individuals involved rather than procedural expectations.

Fit

Standardised

Criteria
Individuals representing all levels of the organisation routinely participate in activities such as hazard identification, risk assessments, standard operating procedure (SOP) development/ review, inspections and incident investigations. Representation from workforce is planned and recorded in resulting artifacts.

Fit

Proactive

Criteria
The workforce plays key roles in process safety activities, including hazard identification studies, design and modification reviews, drills and readiness assessments. Frontline experience is deliberately sought when designing or revising controls for high-risk operations. Individual safety performance objectives are specified.

Fit

Generative

Criteria
The workforce plays an active role in shaping the safety management system (SMS). Employees and contractors propose and drive improvements in design, operations and emergency arrangements, and their participation is visible in decisions about hazard control.

Fit

Theme
Feedback mechanisms

Maturity bands

Ad-hoc

Criteria
There are no reliable channels for raising concerns or making suggestions about process safety. The workforce often feels that speaking up will have little impact or may attract blame. Records of reporting are sparse and there is little/ no evidence of close-out of feedback provided.

Fit

Reactive

Criteria
There are informal ways to raise concerns, such as email or verbal reporting, but suggestions are not tracked and management responses are inconsistent. Workforce access to safety information (e.g. 'safety flashes', industry circulars) depends on local practice.

Fit

Standardised

Criteria
Formal mechanisms exist for workers to raise concerns and suggest improvements, for example anonymous reporting boxes, toolbox talks and structured debriefs. Access to relevant safety information is provided as part of routine communication.

Fit

Proactive

Criteria
Multiple accessible channels exist for raising concerns and suggestions, including anonymous digital and 'paper' options. Suggestions and reports are logged, tracked and responded to in a timely and transparent way, with explanations of decisions.

Fit

Generative

Criteria
A strong open-reporting culture exists. The character of feedback received demonstrates that people feel safe to challenge, raise 'weak signals' of declining safety and report near misses. Feedback loops are robust, and workers can clearly see how their input influences system design, procedures and operational practice.

Fit

Theme
Review & assurance

Maturity bands

Ad-hoc

Criteria
Leaders do not review how, or whether, worker input is used, and there is no evidence that participation influences system design or operational practice.

Fit

Reactive

Criteria
Leaders occasionally review workforce involvement following incidents or audit findings, but there are no defined metrics or routine reviews directed towards assuring engagement or addressing barriers to participation.

Fit

Standardised

Criteria
Workforce involvement is monitored using basic indicators, such as number of suggestions and participation in reviews. Leaders can demonstrate examples where worker input has led to specific changes in procedures, equipment or training.

Fit

Proactive

Criteria
The organisation uses defined metrics and feedback, such as survey results, suggestion close-out, performance and participation levels, to understand the effectiveness of workforce involvement and to remove barriers to participation.

Fit

Generative

Criteria
Workforce involvement is regularly reviewed using both qualitative and quantitative measures and benchmarked against industry experience, giving high confidence that the character of workforce participation is understood. Lessons learned and good practices are shared across the fleet and with external partners.

Fit

5. Process Knowledge Management

Goal statement:
Accurate, accessible and current process safety information is maintained and used to enable effective risk-based decision-making.

Process Knowledge Management (PKM) ensures that critical information – e.g. design intent, safety philosophy, hazard assumptions, operating limits and integrity requirements – is captured, verified, maintained and made available to support safe design, maintenance and operations.

Activities include:

- Developing, maintaining and archiving design basis documents, Piping and Instrumentation Diagrams (P&IDs), process flow diagrams (PFDs) and system descriptions;
- Recording key design decisions, engineering calculations, material compatibility assessments and similar;
- Documenting hazard identification and risk analyses and their outcomes;
- Managing updates to process knowledge arising from change, incidents, operational learning and industry developments; and
- Establishing effective cataloguing, version control and protection of all PKM artefacts.

This ensures that the organisation's process safety intent and technical knowledge are preserved and remain usable, supporting safe operations and informed decision-making over time, including during maintenance, refits, modifications and changes to vessel classification or regulatory requirements.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Knowledge integrity

Maturity bands

Ad-hoc

Criteria
There is no defined system for collecting or maintaining process knowledge. Information is scattered across personal drives, emails, or outdated binders.

Fit

Reactive

Criteria
Some knowledge repositories exist but these vary by vessel or department. Updates occur mainly after incidents or audit findings.

Fit

Standardised

Criteria
A documented system defines responsibilities, minimum information requirements and storage arrangements. Standards for knowledge usability are specified, including use of clear language. Data integrity is periodically monitored through routine 'spot checks' or similar.

Fit

Proactive

Criteria
Requirements for knowledge are reviewed proactively to reflect changes in vessel technologies, operational practices and regulatory expectations. Data validation routines confirm alignment between practical conditions and design assumptions for systems/ operations.

Fit

Generative

Criteria
Process knowledge is treated as a critical corporate asset with strong governance and cross-department/ cross-fleet coordination. The ownership structure for PKM extends throughout the organisation.

Fit

Theme
Organising & retrieving

Maturity bands

Ad-hoc

Criteria
Process knowledge is difficult to locate. No central information repositories exist. Personnel rely on informal knowledge management arrangements or memory.

Fit

Reactive

Criteria
Basic knowledge indexing exists (e.g. planned maintenance system (PMS) equipment registers) but these may be partial or lacking required detail. Knowledge management structures are embryonic and effective retrieval depends heavily on personal experience/ knowledge.

Fit

Standardised

Criteria
Knowledge is catalogued in structured systems with reliable search capability and standard naming conventions. Evolving fleet and industry data on ammonia safety management (e.g. P&I Club/ insurance bulletins, incident reports, class communications) is captured and made available.

Fit

Proactive

Criteria
Information is organised for effective retrieval by frontline users, acknowledging diversity in knowledge work proficiency. The workforce receives appropriate training in how to access and manage information. Relevant knowledge from the vessel design and build processes is readily available to operators and maintainers in usable form.

Fit

Generative

Criteria
Fleet-wide, standardised and integrated knowledge repositories support comprehensive access to knowledge resources across organisational siloes. Relevant developments in ammonia safety management are proactively reviewed and circulated to the workforce.

Fit

Theme
Protecting & updating

Maturity bands

Ad-hoc

Criteria
Documents are rarely updated and obsolete versions remain in circulation. Unauthorised updates occur without oversight. Cyber security governance is effectively absent.

Fit

Reactive

Criteria
Documents are generally created by competent staff, but governance of update procedures is weak. Misfiled or outdated documents are common. Cyber security is treated as a 'nice-to-have' with little or no consistent application of security measures.

Fit

Standardised

Criteria
Formal document version control is in place. Updates follow an approved change process and obsolete documents are withdrawn. Backups exist. Cyber security standards and procedures are in place for both ship and shore-side systems.

Fit

Proactive

Criteria
Assigned information custodians ensure updates to key information resources are prompt and accurate. Misfiled or outdated information is treated as a near miss. A mature cyber-security organisation is in place, with defined ownership and regular audits of effectiveness.

Fit

Generative

Criteria
Accuracy and currency of knowledge resources is maintained through organisation-wide processes that align ship and shore knowledge management. Secure update pathways, storage and backup/ recovery arrangements assure knowledge integrity.

Fit

Theme
Use of knowledge resources

Maturity bands

Ad-hoc

Criteria
Process knowledge resources are seldom referenced or accessed, with decisions often made on the basis of personal expertise only. The workforce is often unaware of available information.

Fit

Reactive

Criteria
Information is used reactively to understand incidents or resolve problems, but knowledge resources are not treated as offering a comprehensive/ reliable basis for safety management across design, maintenance and operations.

Fit

Standardised

Criteria
Process knowledge resources are routinely consulted during 'set-piece' safety management work (e.g. risk studies, management of change (MoC) and procedure updates). Key PKM artifacts (e.g. major risk and MoC databases, P&IDs) are in place, current and accessible at relevant control stations. Learnings from operations feed into design work.

Fit

Proactive

Criteria
Process knowledge resources are explicitly structured for ease of use and are routinely consulted during day-to-day work (e.g. operations/ maintenance planning, troubleshooting, training). Learnings from wider industry are used in review/ update of resources.

Fit

Generative

Criteria
Knowledge management requirements are fully integrated into 'Plan, Do, Check, Act' (PDCA) cycles for improving processes. Mechanisms are in place for capture of innovations and improvements identified and, where appropriate, sharing of these across the maritime industry.

Fit

6. Hazard Identification and Risk Analysis

Goal statement:
Hazards and associated risks are systematically identified and assessed to enable control of risks within tolerable limits.

Hazard Identification and Risk Analysis (HIRA) addresses the organisation's structures for understanding hazards and risks, including how hazardous scenarios may arise, how controls prevent or mitigate them and how risk-informed decisions are made across design, maintenance and operations.

Activities include:

- Conducting structured hazard analyses (e.g. HAZID, HAZOP) during concept design, detailed design and – as applicable – for operational activities;
- Performing additional studies where warranted by hazard complexity or consequences (e.g. dispersion analyses, quantitative risk assessments);
- Using 'structured what-if', bow-tie and similar techniques to define hazard scenarios, causal pathways and safety barriers;
- Defining and applying risk acceptance criteria aligned with industry requirements and societal expectations; and
- Documenting assumptions, uncertainties and justifications for barrier selection, control strategies and residual risk acceptance.

These processes influence system design, embed hazard understanding into technical and operational decision-making, and provide a transparent basis for managing risk throughout the life of the vessel.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
HIRA governance

Maturity bands

Ad-hoc

Criteria
There is no formal system for hazard identification and risk analysis. Risk reviews are rare and occur only after major incidents or external pressure.

Fit

Reactive

Criteria
Basic HIRA activities only are carried out for some projects and operations, typically in response to regulatory requirements. Some simple acknowledgement of risk ownership (e.g. Master's over-riding authority) is evident in the SMS but responsibilities for assessing, accepting and managing risk are incomplete or inconsistently applied in practice.

Fit

Standardised

Criteria
A documented HIRA procedure exists and defines when and how hazard/ risk analysis studies must be performed (e.g. for design changes, major system modifications and key operations). Ownership of responsibility for managing risks is specified in detail in the SMS. Safety requirements support the definition and generation of hazard controls.

Fit

Proactive

Criteria
HIRA is integral to vessel and ammonia fuel-system lifecycle management, from concept design through to decommissioning. New or updated HIRA studies are performed at specified intervals or as governed by trigger events. HIRA adequacy is independently assured. Leaders actively assure control effectiveness.

Fit

Generative

Criteria
HIRA is a central tool for organisational decision-making. Fleet-wide risk insights are used to prioritise investment, influence design standards and guide deployment of technologies/ procedures related to ammonia fuel use in a continuous improvement cycle (e.g. PDCA).

Fit

Theme
Hazard identification

Maturity bands

Ad-hoc

Criteria
Hazards are recognised informally and usually only for obvious scenarios. Non-standard conditions, human error and ship-shore interfaces are not systematically considered.

Fit

Reactive

Criteria
Simpler risk-assessment methods such as ‘structured what-if’ or checklists are used, but assessment coverage is typically limited to specific items of machinery or operations, with negligible or no consideration of system effects. Competence of risk assessment teams is partial and may omit some relevant disciplines entirely.

Fit

Standardised

Criteria
All relevant systems are considered under a scoped form of hazard assessment. Recognised hazard assessment methods (e.g. HAZID/ HAZOP/ FMEA) are selected and applied in a manner proportionate to hazard complexity and the decision required. Ammonia dispersion is assessed for relevant areas. HIRA covers normal operations, emergency response and relevant interfaces. Multidisciplinary competence of assessment teams is mandated/ demonstrated.

Fit

Proactive

Criteria
Comprehensive hazard identification covers all vessel lifecycle stages and systematically incorporates consideration of human factors, layout/ occupied spaces, Simultaneous operations (SIMOPS), dispersion effects, interfaces between systems and credible external events. Hazard scenarios and causal logics are clearly described using ‘bow-tie’ analyses or similar. Credible degraded, maintenance and temporary operating conditions are considered alongside normal and emergency states. Revalidation confirms that assessments remain aligned with vessel configuration, operating practices and external interfaces.

Fit

Generative

Criteria
The organisation continually improves its hazard identification practices, incorporating learning from incidents, near misses and industry developments. Scenario libraries/ bow-ties are made available to all interested stakeholders. Uncertainty levels are credibly described.

Fit

Theme
Risk evaluation & decision-making

Maturity bands

Ad-hoc

Criteria
Risk is judged subjectively, without reference to clear criteria. Decisions about controls are driven by experience or cost rather than a structured risk justification.

Fit

Reactive

Criteria
Simple risk ranking is used for assessment (e.g. low/ medium/ high), but inclusion criteria may not be defined or consistently applied. Decisions sometimes contradict the stated risk rankings or over-rely on personal protective equipment (PPE)/ administrative controls rather than more reliable means of controlling hazards.

Fit

Standardised

Criteria
Risk is evaluated using defined criteria and methods appropriate to hazard complexity, with clear authorities for risk acceptance and escalation. The choice of HIRA method is guided by hazard complexity and potential consequences. Risk acceptance authorities and thresholds are clearly specified. HIRA outputs inform the bases for hazardous and toxic zones, detection arrangements and key alarm or shutdown thresholds where applicable. The capabilities and limitations of hazard controls are specified and understood. Key assumptions are recorded.

Fit

Proactive

Criteria
More advanced risk evaluation methods such as LOPA or structured semi-quantitative techniques are applied where warranted by hazard significance. Risk tolerability criteria are explicit, and decisions clearly reference them. The hierarchy of controls is consistently applied.

Fit

Generative

Criteria
Detailed HIRA methods including, where proportionate/ applicable, quantitative risk analysis, are used to support major decisions. Risk-weighted decision-making is evident in the organisation's business and asset integrity strategies, as well as in the conduct of day-to-day operations.

Fit

Theme
Records & communication

Maturity bands

Ad-hoc

Criteria
When risk reviews are performed, results are not recorded consistently. Actions are not consistently tracked, nor findings consistently communicated to affected personnel.

Fit

Reactive

Criteria
Some follow-up actions from risk reviews are implemented, but action tracking is incomplete. HIRA results are shared with a limited audience (e.g. participants in the design phase only) and rarely revisited. Descriptions of hazard controls may be vague and difficult to clearly trace to implementations.

Fit

Standardised

Criteria
Risk registers/ databases are maintained. Risk review outputs are documented with clear controls, recommendations, action owners and implementation timelines. Action tracking is in place, and updates are made to procedures, operating limits and training following closure of key actions. Toxic areas are effectively recorded/ communicated.

Fit

Proactive

Criteria
HIRA results are communicated to all relevant stakeholders, the workforce and contractors. Studies are revalidated on a planned cycle and whenever significant changes occur. Risk artifacts are maintained in a database or similar system that enables continuous improvement based on findings.

Fit

Generative

Criteria
Follow-through on HIRA findings is exemplary – for example, actions are closed out effectively, risk reductions are verified and communicated, and insights are shared externally where appropriate to improve safety across the maritime sector.

Fit

7. Operating Procedures

Goal statement:
Procedures are clear, current, appropriately formulated and dependably followed by trained personnel.

The Operating Procedures element translates safety management intent into practical, executable, written instructions that govern how work is planned, performed and controlled during routine, abnormal and emergency operations. Effective procedures reflect actual system configurations, operating limits and human performance considerations, as well as providing crews with clear guidance on critical steps, required checks and consequences of deviation.

Key activities include:

- Defining and maintaining procedures for routine, abnormal and emergency operating modes;
- Ensuring procedures clearly describe safety-critical steps, operating limits and the consequences of deviations;
- Integrating permit-to-work (PTW) requirements, checklists and verification steps for high-risk activities;
- Designing procedures that account for fatigue, workload and other human performance factors that influence procedural reliability; and
- Maintaining effective version control, approval processes and cross-referencing with technical manuals, drawings and training materials.

These activities ensure that operations are supported by clear, usable and well-governed procedures that are trusted and reliably applied by the workforce.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Management & control

Maturity bands

Ad-hoc

Criteria
There is no formal system for controlling procedures. Procedures are filed in several locations with no over-arching governance structure. Documents are inconsistent in format, with multiple uncontrolled versions in circulation.

Fit

Reactive

Criteria
A policy directing control of procedures exists, but roles and responsibilities for implementing this policy are unclear. Procedures are stored in a defined file structure, but assurance of this structure is limited. Procedure document control is inconsistent across vessels.

Fit

Standardised

Criteria
A documented approach to procedure management defines roles, responsibilities, approval authorities and standard formats, as well as specifying a clear regime for storing procedures. Procedures follow consistent templates. Procedure document control is effective.

Fit

Proactive

Criteria
Periodic cross-department reviews are used to update and improve procedure governance. Demonstrations of effective use of procedures are integral to training and competency programmes. Lessons from audits, operations and industry practice drive continuous improvement in procedures.

Fit

Generative

Criteria
The approach to procedure management is periodically reviewed by leadership to assure integrity and quality. An integrated procedure management approach is implemented fleet-wide.

Fit

Theme
Procedure development

Maturity bands

Ad-hoc

Criteria
Procedures are created informally as a result of individual initiative and without reference to criticality. Authorities for procedure development and approval are unspecified. A substantial fraction of key tasks have no written procedures.

Fit

Reactive

Criteria
Procedures exist for key operating and maintenance tasks, but these vary in quality. A process for approval of procedures is in place, but is patchy in its application.

Fit

Standardised

Criteria
Procedures are in place for all key tasks. These address normal operating modes, as well as credible abnormal and emergency operating modes. Procedures for managing vessel interfaces are in place. Procedures for major ammonia operations define required checks, communications and precautions for emergency situations.

Fit

Proactive

Criteria
Procedure development is traceable to HIRA work. The workforce plays an active role in procedure development. Human factors considerations are explicitly considered in the development of procedures (both activities and documentation). Procedures for vessel interfaces are well-developed, and co-developed with external stakeholders where practicable/ useful.

Fit

Generative

Criteria
Cross-fleet procedure reviews enable shared learning and rapid deployment of useful changes. Procedure deviations are captured and analysed for risks/ significance with findings fed-back into the procedure development process.

Fit

Theme
Procedures in use

Maturity bands

Ad-hoc

Criteria
Procedures are often unclear. Operating limits and safety-critical consequences of deviation are routinely omitted. Procedures do not account for human factors considerations, and can be impractical under real operating conditions. Specific guidance on ammonia hazards is absent.

Fit

Reactive

Criteria
The structure of procedures varies substantially, reducing intelligibility. Procedure deviations and 'work-arounds' are common. Rudimentary use is made of checklists, flowcharts and diagrams and cautions for ammonia hazards.

Fit

Standardised

Criteria
Clear, structured procedure formats are used, including PTW requirements, checks and warnings. Checklists, flowcharts, photos and diagrams are effectively used. Procedures are designed with fatigue and workload assumptions in mind. System limits/ safe operating envelopes are specified and understood, including for ammonia fuel systems. Safety-critical steps are clearly identified.

Fit

Proactive

Criteria
Procedure validation assures that procedures map to 'work as done', rather than 'work as imagined'. Ammonia hazards are explicitly and clearly handled in procedural guidance, including clear directions for ensuring that mechanisms for hazard control are effective. Procedures are clearly tailored to vessels and operating circumstances.

Fit

Generative

Criteria
Procedures are demonstrably resilient under stress, with deviations rare and easily understood/ justified. Emergency procedure effectiveness under stress and degraded conditions is periodically demonstrated through drills and observation.

Fit

Theme
Review & update

Maturity bands

Ad-hoc

Criteria
Procedures are rarely reviewed or updated. Changes to processes or equipment occur without accompanying changes in procedures. An absence of quality, documented guidance forces crews to rely on informal knowledge.

Fit

Reactive

Criteria
Procedures are reviewed irregularly and often only after issues occur. Reviews are calendar-driven only, rather than being driven by risk. MoC processes occasionally trigger procedure revisions, but not reliably.

Fit

Standardised

Criteria
Procedures are reviewed at defined intervals and as required by defined risk triggers. Obsolete versions are promptly and comprehensively removed from circulation with changes communicated. Lessons from incidents and operational issues are incorporated in revisions.

Fit

Proactive

Criteria
Procedures are validated and maintained through periodic walk-throughs, operator drills and pre-task briefings. The workforce participates in improving procedure formats and usability. Updates and revisions are communicated fleet-wide where useful.

Fit

Generative

Criteria
Procedure updates are prompt, thorough and tightly integrated with MoC, PKM, HIRA and training. Improvements are shared externally to support learning in the wider industry. The organisation actively seeks out emerging procedural best-practices.

Fit

8. Safe Work Practices

Goal statement:
Safety practices for hazardous work are developed and consistently implemented to assure the safety of those affected by the work, as well as the integrity of the assets involved.

The Safe Work Practices element addresses the operational controls that ensure that hazardous and non-routine work are executed within defined parameters that assure the safety of these classes of work.

Typical Safe Work Practices activities include:

- Defining and operating a structured, auditable permit-to-work (PTW) system covering all hazardous and non-routine work;
- Maintaining accurate isolation registers and lockout/ tagout (LOTO) controls aligned with current P&IDs and system configurations;
- Verifying the availability, calibration and effectiveness of safety-critical monitoring systems (e.g. gas detection, ventilation, alarms);
- Ensuring clear coordination, control and handover of operations, including contractor and ship-shore interfaces; and
- Reviewing, auditing and trending control-of-work records (e.g. PTWs, isolations, overrides) to confirm effectiveness and identify systemic weaknesses.

These practices ensure that work remains consistent with the safety bases of the system, particularly during maintenance, modifications and other activities that temporarily alter normal operating conditions.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Management & control

Maturity bands

Ad-hoc

Criteria
There is no structured system for safe work practices. Human performance risks such as fatigue, workload, time pressure and communication demands are not recognised or managed at the organisation level.

Fit

Reactive

Criteria
Basic governance for safe work exists, but control of permits, supervision and work planning is inconsistent. Procedures are stored in a defined file structure, but assurance of this structure is limited. Work planning does not systematically account for crew condition (e.g. requirements to consider exposure, attention limitations etc).

Fit

Standardised

Criteria
A documented safe work system defines roles, PTW governance and supervision requirements as well as specifying a clear regime for storing procedures. Procedures follow consistent templates. Document control is effective. PTW controls are effectively and consistently applied.

Fit

Proactive

Criteria
Safe work governance explicitly integrates human performance limits into work planning and permit approvals. Lessons from audits, operations and industry practice drive continuous improvement.

Fit

Generative

Criteria
Human performance is treated as a safety-critical system property. Fatigue, workload, time pressure and communication quality are actively managed as part of task risk control.

Fit

Theme
Safe work practice development

Maturity bands

Ad-hoc

Criteria
Non-routine work or hazardous tasks (e.g. hot work, enclosed space entry, work at height) are performed without formal risk review, written guidance (e.g. company safety manuals/ SOPs) or defined controls.

Fit

Reactive

Criteria
Safe work practice procedures for some high-risk tasks are in place, but these may be incomplete in the context of use of ammonia as a marine fuel. A process for approval of safety-critical work procedures is nominally in place, but is patchy in its application.

Fit

Standardised

Criteria
Procedures are in place for all safety-critical tasks covering risk assessment, preparation, execution, controls and recovery. Procedures for managing vessel interfaces and third-party entities during safety-critical work are in place. High-risk ammonia system work is supported by a documented safety assurance process, including considerations such as verification of line conditions/ purging status and implementation of required isolations.

Fit

Proactive

Criteria
Human factors considerations are explicitly considered in the development of procedures (both activities and procedure documentation). Procedures for SIMOPS/ vessel interfaces are co-developed with all involved entities to ensure aligned risk management.

Fit

Generative

Criteria
The organisation anticipates new hazards and develops practices ahead of external requirements. Procedure deviations are proactively analysed for risks/ significance with findings fed-back into the development process.

Fit

Theme
Safe work practices in use

Maturity bands

Ad-hoc

Criteria
Work execution relies heavily on experience rather than documented guidance. Oversight is minimal and critical checks are not identified in work instructions. Coordination of safety-critical work between crew and shore-side personnel and/ or third-party entities is absent or poor.

Fit

Reactive

Criteria
'Work as done' commonly deviates from documented steps. Routines for assuring safe work (e.g. PTWs, LOTO, sensor calibration routines) are in place, but inconsistently applied. There is some evidence of limited coordination with shore-side entities.

Fit

Standardised

Criteria
Critical steps (e.g. LOTO, atmosphere tests, sensor calibrations) are performed and recorded. Deviations are infrequent and appropriately authorised/ managed. Authority to stop unsafe work is defined and used where conditions deviate from those assumed in the permit or task plan. Routines for effective coordination of shoreside and third-party work are in place and consistently implemented.

Fit

Proactive

Criteria
Management of safety-critical work – including third-party work – is robust, with active verification and reinforcement of safe behaviours evident in work routines. The workforce is equipped with a proper understanding of the rationale for hazard controls and compliance is instinctive. Interface hazard controls are jointly verified with counterpart organisations.

Fit

Generative

Criteria
Personnel at all levels of the organisation demonstrate commitment to the rigorous implementation of safe work practices as a key control on hazards, including ammonia hazards. The workforce freely voice concerns about impairments to human performance, including from fatigue.

Fit

Theme
Review & update

Maturity bands

Ad-hoc

Criteria
Effectiveness of work practices is not audited. Deviations and unsafe practices are common but not recorded or analysed.

Fit

Reactive

Criteria
Reviews of work practices occur mainly after incidents or audit findings. Recurring issues show that learning from experience does not become embedded in the organisation. Near-misses may be discussed on board, but are not adequately recorded or fed-back to the wider organisation.

Fit

Standardised

Criteria
Procedures for hazardous work are validated by management before implementation and are reviewed periodically. Records of measures associated with safety-critical work (e.g. isolation/ LOTO registers, PTW records) are maintained and routinely audited for adequacy.

Fit

Proactive

Criteria
Observation programmes, PTW reviews and trend analyses drive continuous improvement in procedures. Near misses trigger procedural improvement. Updates and revisions are communicated fleet-wide where useful.

Fit

Generative

Criteria
Improvements in safety-critical work management are shared externally to support learning in the wider industry. The organisation actively seeks out emerging best-practice in procedures, including from other safety-critical industries (e.g. oil and gas, chemical).

Fit

9. Asset Integrity and Reliability

Goal statement:
Technical system assets are designed, installed and maintained to operate safely throughout their lifecycle.

Asset integrity and reliability are established through robust design and technical practices that ensure systems can prevent loss of containment, tolerate degradation mechanisms and maintain required performance over their intended life. Ammonia fuel systems require particular attention in this connection.

Key activities include:

- Translating safety/ integrity/ reliability requirements into verifiable performance standards (including safety margins and layered hazard controls);
- Ensuring that controls identified in HIRA/ design phases are implemented and maintained through dependable and risk-aware testing and maintenance;
- Selecting materials, coatings and construction practices suitable for ammonia exposure and anticipated operating environments; and
- Designing systems to facilitate isolations, atmosphere control, inspection, testing, maintenance and modification without compromising safety.

Where the HIRA element is directed towards assurance that credible hazard scenarios are identified and required safeguards are specified, activity in this element ensures that systems and safeguards remain well-maintained and effective through-life, giving confidence that systems are safe to operate.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Performance standards

Maturity bands

Ad-hoc

Criteria
Asset integrity/ reliability is generally undefined. Safety-critical equipment is not explicitly identified. There are no defined performance standards for equipment relied on to prevent or mitigate major accidents. System documentation is disorganised and lacks internal coherence.

Fit

Reactive

Criteria
Some asset integrity/ reliability standards are defined, but these are partial. Some critical equipment is recognised, but identification may be partial and documentation of performance expectations is vague or incomplete. Asset inventories are held in spreadsheets or similar, but there is no single system for through-life shipboard asset management.

Fit

Standardised

Criteria
Safety-critical equipment is comprehensively identified and consistently documented. Clear, accessible performance standards for systems specify acceptance criteria for integrity/ reliability derived in a principled manner. These include how performance is checked/ tested. System asset hierarchies and dependencies are defined in the PMS.

Fit

Proactive

Criteria
Technical performance standards are refined using operational insights and may exceed minimums for compliance. System integration effects are considered. Hazard control barrier dependencies are understood and managed. Control arrangement efficacy is validated. Human-centred design principles inform asset design and configuration.

Fit

Generative

Criteria
Performance standards are optimised through modelling, benchmarking and monitoring/ review of system/ safety function performance through-life. There is evidence of organisational pursuit of best-in-class performance/ asset integrity management. Where indicated, definition of system design parameters is underpinned by functional safety analysis.

Fit

Theme
Lifecycle design integrity

Maturity bands

Ad-hoc

Criteria
Design decisions/ associated documentation show little or no evidence of considering definition or maintenance of asset integrity/ reliability through-life. Asset condition requirements are undefined/ poorly understood, and maintenance/ modifications occur in a largely uncontrolled manner.

Fit

Reactive

Criteria
Verification/ validation of asset performance standards occurs occasionally, but is not systematically conducted. There is some evidence of design consideration of asset integrity management, however this is sparse/ inconsistent. Review of the adequacy of designs in supporting asset integrity generally occurs only after incidents or failures.

Fit

Standardised

Criteria
Integrity requirements for safety-critical equipment/ functions are traceable to the design basis, including safety requirements and HIRA outputs. System maintainability is explicitly required in design. Requirements are reflected in performance standards and PMS tasks/ condition-based monitoring that assure through-life implementation.

Fit

Proactive

Criteria
Design for ammonia fuel systems asset integrity integrates risk, reliability and lifecycle considerations in a coherent, through-life safety philosophy. Through-life integrity requirements have a clear risk basis, that is traceable to supporting risk analyses (e.g. HAZOP, LOPA). Monitoring of spares/ lube oil consumption informs maintenance planning, including procurement/ holding requirements.

Fit

Generative

Criteria
Asset degradation mechanisms are systematically identified, monitored and managed, with findings used to update design standards, maintenance strategies and change controls.

Fit

Theme
Inspection, testing & maintenance

Maturity bands

Ad-hoc

Criteria
Scope of initial and subsequent asset assessments is limited to the asset built not the asset required. Maintenance is reactive. Inspections are missed or skipped. Provision of spares is *ad-hoc* and ineffectively controlled.

Fit

Reactive

Criteria
A PMS exists but its use is inconsistent. The maintenance backlog is poorly controlled and quality of system testing varies. Some spares are held, but inventory requirements are under-specified.

Fit

Standardised

Criteria
A PMS, with defined inspection and testing intervals, is consistently followed. The PMS includes functional checks on safeguard efficacy, particularly in connection with ammonia systems. Known ammonia system weak links (e.g. valves, seals, gaskets, purging) are identified and controlled (e.g. through material specification, inspection and maintenance, proactive leak detection, and defined and verified procedures). The task backlog is controlled and maintenance quality is generally consistent. Credible requirements for spares inventories are specified. Temporary impairment of safety-critical equipment is formally recorded, risk assessed and managed with defined compensatory measures.

Fit

Proactive

Criteria
The maintenance strategy is risk-informed, condition-based and preventive, with safety-critical systems receiving particular attention. Asset maintenance histories are high quality.

Fit

Generative

Criteria
Safety-critical impairments are visible and tracked to closure. High levels of system reliability substantiate the effectiveness of inspection, testing and maintenance arrangements. Real-time monitoring/ predictive maintenance tools are used where appropriate.

Fit

Theme
Defect management

Maturity bands

Ad-hoc

Criteria
Defects are not tracked and failures recur without investigation or improvement. Breakdowns are common.

Fit

Reactive

Criteria
Defect management systems exist but are rudimentary. Defect follow-up is typically reliant on individual diligence. Similar defects occur repeatedly. Organisation-level assurance of defect management is minimal.

Fit

Standardised

Criteria
Defects and deviations from expected performance are logged, classified and tracked to closure within defined time-frames. Impairments to safeguards are treated as high-priority defects. Repeat failures and failures to safety-critical systems trigger investigations. Company-level verification provides assurance that maintenance is effective. Defects affecting safety-critical barriers are made visible to operators, maintenance teams and management until resolved.

Fit

Proactive

Criteria
Defect management is proactive, with defect occurrences analysed for patterns/ common causes (including control configuration and human-system interface issues), not just component faults. Improvement plans target recurring issues with design, technical or operational interventions as appropriate. Reporting requirements assure progress.

Fit

Generative

Criteria
Defect management effectiveness is periodically verified across the organisation against defined criteria, with documented results and clear ownership. Learnings are used to inform update of design standards, test strategies and acceptance criteria. Defect management learning is shared internally and externally as appropriate.

Fit

10. Training and Performance Assurance

Goal statement:
Adequate training is provided to all persons serving on ammonia-fuelled vessels and shore-side staff managing such vessels. Safe human performance is verified.

Training and Performance Assurance ensures that personnel who operate, maintain or supervise safety-critical systems understand hazards, operating limits and control measures, and can reliably perform required tasks under all foreseeable conditions. Further guidance on training is available in the report *Ammonia as a Fuel: Competencies and Training*.

Training and Performance Assurance differs from Process Safety Competency in that it primarily addresses individual competencies, rather than provisions for organisational learning. Typical activities include:

- Defining both generally applicable and role-specific training and competency requirements (to include normal ops, emergency response, and medical);
- Assuring completion of STCW-mandated training and additional task, system or fuel-specific training where required (e.g. ammonia hazard familiarisation);
- Verifying competence through tests, demonstrations, drills and on-the-job assessments before assigning safety-critical duties;
- Integrating lessons from incidents, near misses, audits and operational experience into training content; and
- Monitoring training effectiveness and competence gaps through audits, performance reviews and supervision/ operational feedback.

These arrangements test and validate the human performance assumptions embedded in hazard analyses, procedures and emergency plans (e.g. detection-to-response times, efficient donning of PPE, decision-making under stress, and effective supervision).

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Governance & role requirements

Maturity bands

Ad-hoc

Criteria
Ammonia familiarisation expectations are undefined in the SMS. Personnel learn mainly through on-the-job exposure. Critical roles lack documented competence requirements in the SMS and recruitment is governed solely by statutory compliance.

Fit

Reactive

Criteria
Basic training and familiarisation specifications exist – including addressing ammonia – but implementation is inconsistent across roles and vessels. There are basic policies on recruitment, selection and training requirements, but these are not linked to management of risk.

Fit

Standardised

Criteria
A structured framework defines training and competence requirements for all roles. This framework is risk-informed, and may exceed STCW minimum requirements where appropriate. It includes attention to the requirements of ammonia-fuelled operations. There are processes in place to manage organisational competence, including succession and resilience planning.

Fit

Proactive

Criteria
There is a comprehensive competence management system in place, based on thorough risk assessments of operational requirements and hazardous tasks. This includes policies on recruitment, selection and training in line with identified safety objectives.

Fit

Generative

Criteria
The organisation periodically reviews future competence needs for ammonia operations and can demonstrate a strategy for implementing updates to training and competence plans.

Fit

Theme
Training delivery, content & methods

Maturity bands

Ad-hoc

Criteria
Training is limited to mandatory STCW certificates. Specific hazard awareness and system familiarisation topics are minimal or absent.

Fit

Reactive

Criteria
Training is provided as and when training needs are locally identified. Training delivery is inconsistent, with limited assurance of trainer competence or training material adequacy. Training content does not systematically address ammonia-specific human performance challenges (e.g. respiratory protection, time pressure, sensory impairment).

Fit

Standardised

Criteria
STCW training requirements are consistently and proactively achieved. Supplementary training covers system or ship-specific hazards, operating limits, emergency actions, protective systems and safe work practices. Ammonia hazard management is addressed, including toxicity, release behaviour and realistic expectations for human response times and use of respiratory protection.

Fit

Proactive

Criteria
Training uses realistic scenarios, simulations and case studies – including specific attention to ammonia-specific circumstances. Crew are equipped with a sound understanding the rationale behind risk controls. Training includes 'soft skills' (e.g. leadership, open communication, fatigue management).

Fit

Generative

Criteria
A culture of continuous learning is encouraged through support for onboard coaching/ mentoring and other mechanisms for continuous professional development. Leaders contribute to developing and improving training programmes.

Fit

Theme
Competence assurance

Maturity bands

Ad-hoc

Criteria
There is no formal process for assessing competence on ships or ashore. Performance is assumed based on experience.

Fit

Reactive

Criteria
Testing of competence is informal. Refresher training – beyond mandatory minimums – is inconsistently undertaken. Records are incomplete and inconsistent across ships and shore-side systems. Competence checks occur primarily through external audits/ regulatory compliance.

Fit

Standardised

Criteria
Crew competence is verified through shipboard demonstrations, observations and drills administered by more senior crew/ managers. Competent performance is assured before safety-critical tasks are assigned. Routine refresher training is undertaken.

Fit

Proactive

Criteria
Drills, exercises and – as applicable – tests/ simulator training are used to verify technical performance. Deviations from the requirements of the competence management systems are recorded and managed through appropriate adjustments to operations.

Fit

Generative

Criteria
Performance is assured and benchmarked to best-practice standards. High-fidelity drills validate technical, human and organisational performance, including multi-vessel, port interface and external responder coordination for ammonia release scenarios.

Fit

Theme
Monitoring & improvement

Maturity bands

Ad-hoc

Criteria
There is no consistent approach to maintaining records of training. No evaluation of training effectiveness occurs.

Fit

Reactive

Criteria
Training gaps are addressed, but reactively. Incident learnings may prompt updates to training but without a structured process supporting these updates or for promulgating them through the organisation. There is an organisation-wide policy addressing maintenance of training records, but these records are incomplete or missing in practice.

Fit

Standardised

Criteria
Training effectiveness is monitored, with feedback records maintained and content periodically reviewed. Significant changes in vessel risk profiles are associated with changes to the competencies required to support operations. Competence requirements are reviewed periodically to reflect changes in equipment/ procedures.

Fit

Proactive

Criteria
Training effectiveness is evaluated against observed human performance during drills and abnormal condition simulations. Observed human performance during drills is analysed to identify systemic human performance vulnerabilities (e.g. delayed response, communication breakdown, PPE usability issues) to feed-in to future training.

Fit

Generative

Criteria
Learning programme feedback, drill performance and competence data indicate that training programmes are effective. The organisation proactively engages with the wider industry to develop training best-practices. Learning is informed by analysis of human performance data, drill outcomes and near-miss patterns.

Fit

11. Management of Change

Goal statement:
Effective change management ensures that neither the quantity, frequency nor the nature of changes (to assets, processes or organisation) adversely affects system safety.

Management of Change (MoC) provides a structured means of identifying, assessing and controlling changes across the full lifecycle of ammonia-fuelled vessels. This includes design modifications, technical alterations, procedural changes and organisational adjustments. Effective MoC ensures that new hazards are not introduced without appropriate controls, existing safeguards are not undermined and that the safety intent of original designs is preserved as systems evolve.

Key activities include:

- Systematically identifying changes to design, equipment, software, procedures, operating conditions and organisational arrangements that may affect safety;
- Performing proportionate hazard identification and risk analysis where changes affect safety-critical systems or interfaces;
- Updating drawings, P&IDs, procedures, performance standards and training materials to reflect approved changes;
- Assessing impacts of changes on system performance attributes such as ammonia containment, emergency response and human performance; and
- Verifying correct implementation of changes and capturing lessons learned from both successful and problematic changes.

These activities ensure that change is deliberately managed rather than inadvertently accumulated, supporting continued effective control of hazards.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Change identification

Maturity bands

Ad-hoc

Criteria
Changes occur informally without recognising them as properly subject to MoC. Screening criteria do not exist and significant changes may proceed unnoticed.

Fit

Reactive

Criteria
Some attention is given to change management, but often after incidents or issues rather than proactively. Classification of 'what counts' as subject to MoC (e.g. what counts as 'replacement in kind') is inconsistent and varies by vessel management.

Fit

Standardised

Criteria
A documented MoC process – including assessment criteria – defines which changes require formal management and which roles are authorised to determine whether MoC procedures are to be followed. Concept of change includes supplier/ contractor/ service provider substitutions and updates to vessel software systems.

Fit

Proactive

Criteria
Personnel at all levels of the organisation are empowered to proactively identify changes in design, technical arrangements and operations. Change requirements identified on particular vessels are promulgated across the fleet. Organisational changes (e.g. staffing, competence, reporting lines) are systematically assessed for their impact on safety.

Fit

Generative

Criteria
Mechanisms are established to support the workforce with identifying change-related concerns. Decisions relating to application of MoC processes are transparent and clearly documented.

Fit

Theme
Risk assessment & approval

Maturity bands

Ad-hoc

Criteria
Changes are made without structured review or hazard evaluation. Approvals, if any, are informal or verbal.

Fit

Reactive

Criteria
Basic risk assessments occur for most conspicuous changes but these may lack requisite depth. Reviews are compliance-driven rather than risk-driven. Risk assessors are often determined as a function of availability rather than competence.

Fit

Standardised

Criteria
Risk assessment is consistently implemented in MoC. Risk assessment expertise, change approval authorities and occasions for multidisciplinary review are defined. Changes affecting safety-critical systems must apply MoC and be authorised by a competent approval authority, as defined by the organisation. Temporary changes and time-limited approvals are explicitly controlled, tracked and reviewed.

Fit

Proactive

Criteria
MoC risk assessments consider system integration, including human factors, ship-shore interfaces and failure of engineered hazard controls. Risk assessments also attend to the through-life implications of changes implemented. MoC assessments include justifications of changes and additional resources required (e.g. time/ spares/ original equipment manufacturer support).

Fit

Generative

Criteria
Risk assessments make use of modelling and more advanced analysis techniques where proportionate to the significance of the change. Assessments are shared to support fleet learning and benchmarking as appropriate.

Fit

Theme
Implementation & communication

Maturity bands

Ad-hoc

Criteria
Changes are neither adequately documented nor properly communicated to affected personnel. Procedures, drawings and training materials are frequently outdated.

Fit

Reactive

Criteria
Some documentation/ communication of changes occurs (e.g. through the PMS), but this is inconsistent and varies by manager. Documentation updates often lag substantially behind technical/ or operational changes.

Fit

Standardised

Criteria
Changes (including temporary changes) are communicated to those affected. Temporary/ permanent changes are clearly differentiated. The PMS, procedures, drawings and training materials are promptly updated to reflect changes. Changes that are not implemented within the approved timeframe, are reviewed/ revalidated before execution.

Fit

Proactive

Criteria
Communications are timely and – where appropriate – utilise multiple-channels. Crew rejoining a vessel are familiarised with changes that have occurred since they left. Training/ familiarisation is delivered to affected crew before they are expected to work with systems that have undergone high-impact changes.

Fit

Generative

Criteria
Implementation is disciplined across relevant interfaces, with documentation, training and affected parties updated before changed systems or practices enter use. Third party entities (e.g. terminal operators) are included in communications where relevant.

Fit

Theme
Close-out & learning

Maturity bands

Ad-hoc

Criteria
There is no follow-up to verify correct implementation of changes. Mistakes reoccur because learning is not captured.

Fit

Reactive

Criteria
MoC follow-up is limited/ unstructured and occurs mainly after problems. There is no formal change close-out process and 'temporary changes' may remain in-place indefinitely. Learning associated with change is unstructured.

Fit

Standardised

Criteria
MoC actions are tracked to closure. Pre-start up safety reviews are conducted before systems are returned to service. Verification confirms changes work as intended and associated documentation/ training has been updated. Lessons-learned from change processes are captured.

Fit

Proactive

Criteria
A review period for completed changes is defined and documented. These reviews validate that changes perform as intended in use. Findings feed into periodic management review. Validation of change efficacy includes field observations and testing. Validation includes demonstration of equivalent safety where changes involve systems approved through alternative design processes.

Fit

Generative

Criteria
The organisation actively monitors external developments for strategies that might improve safety, and communicates effective changes fleet-wide. At its fullest expression, insights from MoC processes – both positive and negative – are also shared externally to support industry learning.

Fit

12. Conduct of Operations

Goal statement:
Operations are conducted in a disciplined, controlled and consistent manner that delivers required outputs while maintaining the integrity of systems.

The Conduct of Operations element focuses on how work is performed day-to-day, ensuring that operating practices, communications, staffing, supervision and human-performance controls reliably support safe operations during routine and non-routine activities.

Key activities include:

- Operating within approved operating procedures and defined operating limits;
- Maintaining formal, effective shift/ watch handovers and operational communications;
- Managing fatigue, fitness for duty and impairment risks, including drug & alcohol (D&A) controls;
- Ensuring adequate staffing, supervision and operational discipline; and
- Monitoring performance, correcting deviations promptly and reinforcing standards of conduct.

Together, these activities reduce the likelihood of human errors and assure high standards of performance.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Operational discipline & control

Maturity bands

Ad-hoc

Criteria
Conduct of operations is based largely on experience and is under-supported by procedures/ process. SOPs are incomplete, outdated or not readily available; consequently, deviations are common. Arrangements for control of non-routine operations are informal or non-existent.

Fit

Reactive

Criteria
SOPs exist for key operations but are not consistently followed. Deviations are common during non-routine or time-pressured activities. Management oversight is inconsistent – e.g. it may be adequate after incidents, but is not sustained.

Fit

Standardised

Criteria
Approved SOPs reflect actual operating practices and are routinely followed. Start-up, shutdown and abnormal operations are planned and executed in accordance with procedures, with defined requirements for authorisation and supervision (e.g. these operations are supported by effective PTW arrangements).

Fit

Proactive

Criteria
Operational control is risk-based, with higher-risk activities receiving enhanced planning, supervision and verification. Management observations confirm deliberate, disciplined execution, particularly during transient and non-routine operations.

Fit

Generative

Criteria
Operational discipline is consistently evident in routine and non-routine work. Management observations consistently show procedures being followed, with operators actively protecting operating limits (for machinery, systems and crew) and challenging unsafe conditions without prompting.

Fit

Theme
Communication & coordination

Maturity bands

Ad-hoc

Criteria
Shift handovers are informal and inconsistent in content and quality. Critical operational information is exchanged verbally without structure or (where operations require) adequate records. Interfaces between shipboard teams – and between these teams and contractors – are poorly defined.

Fit

Reactive

Criteria
Shift handovers and work coordination occur but these vary in quality and completeness. Written logs are used inconsistently, and confirmation of critical communications is not routine. Order books (e.g. Captain's night orders) are inconsistently or inadequately used.

Fit

Standardised

Criteria
Formal processes exist for shift handovers, work coordination and interdepartmental communication. Logbooks and written work controls are consistently used, and critical communications are documented.

Fit

Proactive

Criteria
Shift handovers, permits and coordination forums are of consistently high quality and demonstrate effective anticipation and management of interface risks. Critical communications are routinely confirmed, recorded and cross-checked.

Fit

Generative

Criteria
Communication and coordination practices are routinely reviewed using operational feedback. Records show that interface controls remain effective under non-routine and degraded conditions.

Fit

Theme
Human performance

Maturity bands

Ad-hoc

Criteria
Workforce levels, competence and fatigue are not systematically considered in operational planning. There are no formal fitness-for-duty or D&A controls. Errors and unsafe behaviours are typically attributed to individuals alone, with no consideration of the conditions of work.

Fit

Reactive

Criteria
Requirements for assuring competence and hours or rest may exist in the SMS, but these are treated as compliance obligations rather than essential risk mitigations and enforcement is limited. D&A policies exist but are weakly enforced.

Fit

Standardised

Criteria
Roles are staffed with qualified personnel in line with requirements defined in the SMS. Fitness-for-duty expectations, including D&A controls, are documented and enforced. Fatigue risks are recognised but managed mainly through compliance with basic limits.

Fit

Proactive

Criteria
A comprehensive welfare management system – including fatigue management – is in place and applied to all staff at all levels of the organisation. Human factors (e.g. fatigue, workload) are explicitly addressed alongside technical competence in the course of task/ operation planning. D&A policies are proactively enforced.

Fit

Generative

Criteria
Management actions evidence a commitment to supporting high levels of human performance as a core operational risk control. Fatigue risk management is systematic and aims to support high-performance, not only to mitigate the negative effects of fatigue. D&A controls are robust and socially reinforced within the safety culture.

Fit

Theme
Monitoring & learning

Maturity bands

Ad-hoc

Criteria
Managerial verification of operational discipline is rare. Unauthorised deviations from procedures or safe work practices are common but not documented or analysed. Recurring operational issues reflect the normalisation of such deviations.

Fit

Reactive

Criteria
Reviews of operational conduct may occur following incidents, audits or external pressure, but are not routine. Unauthorised deviations are generally corrected locally on the occasions where they occur, but associated lessons are not consistently captured or reviewed for significance to fleet-wide operations or supervision practices.

Fit

Standardised

Criteria
Routine inspections by management (shore-based and ship-board, as appropriate) verify adherence to defined procedures and standards of conduct. Where deviations from standard practices occur, these are authorised, documented and, where appropriate, tracked to closure.

Fit

Proactive

Criteria
Peer checks as well as management observation are used to assure disciplined conduct of operations, including identifying weak signals of deteriorating performance. Unauthorised deviations and near misses reliably trigger improvements to work practices

Fit

Generative

Criteria
Continuous mutual observation and feedback by all involved in operations sustains operational discipline. Unauthorised deviations are rare, quickly addressed and used to strengthen system resilience. Learnings may be shared across vessels and with external peers.

Fit

13. Emergency Management

Goal statement:
Emergency situations – including those involving ammonia hazards – are anticipated and adequately prepared for, with resources and practiced plans available to support effective response to emergencies.

Emergency Management ensures that credible emergency scenarios are identified and effectively mitigated. Crews are equipped to respond to incidents, including incidents involving ammonia fuel systems. This element includes integration of engineered safeguards, clear command and control arrangements, practiced response procedures and defined recovery processes that collectively support incident management and the restoration of a safe system state.

Key activities include:

- Identifying credible emergency scenarios associated with ammonia fuel systems, vessel operations and ship-shore interfaces;
- Integrating emergency response controls into vessel design, including gas detection, ventilation, isolation and effective alarms;
- Defining roles, responsibilities and command structures for onboard, shore-side and external response coordination;
- Planning and practicing response and recovery actions; and
- Capturing lessons from drills, incidents and external events to continuously improve emergency preparedness.

These activities ensure that emergency response is a designed, tested and continuously improved element of the vessel's safety management arrangements.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Planning & hazard identification

Maturity bands

Ad-hoc

Criteria
Credible emergency scenarios are absent from emergency response plans. Emergency responsibilities are unclear, and plans do not adequately reflect vessel operations or ammonia hazards. Preparedness is informal and inconsistent.

Fit

Reactive

Criteria
Basic emergency plans exist but these are generic and weakly integrated with particularities of the vessel/ operations. Roles are loosely assigned. Major hazard scenarios are identified but scenario detail/ capture of dynamics is absent or under-specified.

Fit

Standardised

Criteria
Emergency response plans are derived from defined scenarios and clearly set out response roles, command structures and key actions, including relevant ship-ship and ship-shore interfaces. Plans address vessel-specific hazards, operational scenarios and foreseeable failures and include consideration of escape routes and of toxic areas.

Fit

Proactive

Criteria
Comprehensive emergency plans are in place. These include consideration of human factors, degraded-mode operations, multi-ship/ ship-port interactions and environmental challenges. MoC reviews consider effects of changes on emergency response.

Fit

Generative

Criteria
Emergency plans are routinely updated to reflect emerging understanding of risks, technology developments, fleet-wide learnings and industry good practice. The organisation influences sector-wide emergency response standards.

Fit

Theme
Discovery & containment

Maturity bands

Ad-hoc

Criteria
Detection of abnormal conditions depends on chance or informal recognition. No defined containment actions exist, and critical detection, alarm or isolation systems may be inoperative, untested or inaccessible.

Fit

Reactive

Criteria
Ammonia-related hazards are recognised, but containment strategies are incomplete and lack detail (e.g. about escalation, variability and system interactions). Detection and alarm systems are inconsistently maintained/ tested.

Fit

Standardised

Criteria
Clear expectations for initial detection, alarm response, isolation and containment are in place. Systems supporting early detection and containment are maintained and tested as per the PMS, with defensible maintenance priorities assigned.

Fit

Proactive

Criteria
Thorough containment strategies consider system dependencies, barrier performance and escalation pathways. Strategies also include consideration of human factors. Detection, isolation and containment capabilities are benchmarked against defined performance expectations and relevant external good practice.

Fit

Generative

Criteria
Detection, alarm, isolation and containment capabilities are assured through a combination of operational data, exercises and performance monitoring. System responses under degraded and abnormal conditions are well understood, and insights are used to refine strategies, improve system design and strengthen barrier performance.

Fit

Theme
Sustained response & recovery

Maturity bands

Ad-hoc

Criteria
Drills are rare or superficial. The workforce lacks clarity regarding response roles. Emergency actions are improvised, and equipment may be unusable or unavailable when needed. There are no plans for working with external emergency authorities.

Fit

Reactive

Criteria
Drills occur periodically but these are primarily undertaken for compliance and show little evidence of being directed at developing a response capability that would be effective against a real incident. Response adequacy differs between vessels, and coordination with shoreside personnel and external authorities is inconsistent.

Fit

Standardised

Criteria
Regular drills cover critical scenarios and develop/ demonstrate an effective emergency response capability. Crew understand their roles and emergency actions follow defined procedures. Emergency response equipment is inspected, tested and available. Coordination with shoreside personnel follows a structured process that is periodically validated. Plans define criteria for muster, shelter and evacuation under toxic release conditions.

Fit

Proactive

Criteria
Drills incorporate defined scenarios involving degraded conditions and elevated workload. Competence in emergency roles is assessed through structured observation against defined criteria. Exercises include coordination with shoreside personnel and, where practicable, external agencies. Outcomes from drills are recorded, reviewed and used to update response procedures, training and equipment arrangements.

Fit

Generative

Criteria
Emergency response performance is evaluated using evidence from drills, operations and, where available, incidents. Reviews identify improvement actions that are tracked to closure. Coordination with ports, terminals and external emergency response authorities is routinely exercised, with defined roles and communication methods demonstrated.

Fit

Theme
Learning & improvement

Maturity bands

Ad-hoc

Criteria
No structured debriefing or learning processes exist. Recurring issues remain unaddressed, and emergency readiness is not assured.

Fit

Reactive

Criteria
Minimal post-drill reviews occur but resultant organisational learning is patchy. Improvements are informal, inconsistently applied and rarely verified for effectiveness.

Fit

Standardised

Criteria
Drill outcomes and incident learnings are documented and tracked. Emergency plans and training materials are updated periodically based on findings.

Fit

Proactive

Criteria
Response readiness is assured using metrics, trends and leading indicators addressing, for example, crew competence and drill execution/ participation. Lessons-learned inform systematic improvements to procedures, equipment design and training requirements.

Fit

Generative

Criteria
The organisation proactively seeks to identify best-practices in emergency response from external sources. At its fullest expression, emergency response insights are also shared across the fleet and externally.

Fit

14. Measurement and Metrics

Goal statement:
Performance indicators track leading and lagging safety indicators, and are used to guide risk management decisions and continuous improvement.

Measurement and metrics provide managers with confidence that risk control measures are in place and functioning as intended. This includes both engineered controls and operational practices controlling hazards.

Monitoring should be proportionate to the risks and include:

- Critical system functioning/ performance of engineered controls;
- Specifically identified system vulnerabilities;
- Assurance of normal process functioning; and
- Suitable analysis of the results of monitoring to assist in identifying common underlying issues and systemic problems.

Choosing the correct metrics to monitor is central to effective monitoring – ‘seek to measure what is important; don’t make important what you can measure’.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Metrics framework & governance

Maturity bands

Ad-hoc

Criteria
There is no defined process safety metrics framework. Safety management performance is judged subjectively based on incidents or general impressions.

Fit

Reactive

Criteria
Requirements for basic lagging metric compilation exist, driven mainly by external reporting obligations.

Fit

Standardised

Criteria
The SMS includes a metrics framework that defines clear roles and responsibilities for data capture, validation, storage and reporting. An information system for managing metrics is in place. Metrics include ammonia hazard control indicators such as detector impairments, overdue maintenance and temporary changes remaining in place.

Fit

Proactive

Criteria
Leading indicators directed towards early detection of deteriorating conditions (e.g. sensor fault rates, hours of rest performance, spares lead times) are specified and measured.

Fit

Generative

Criteria
The organisation reviews and adopts new monitoring techniques (e.g. remote condition monitoring, predictive analytics) where these offer demonstrable value. The organisation periodically reviews whether its monitoring arrangements provide timely warning of deteriorating control, and updates arrangements where they are found to be under-performing.

Fit

Theme
Data collection, quality & reporting

Maturity bands

Ad-hoc

Criteria
Safety management-relevant data (e.g. asset condition information, procedure deviations, near miss and incident reporting) are not systematically collected and the picture of operations safety available to management is inconsistent or unreliable.

Fit

Reactive

Criteria
Some safety management performance data is collected but quality varies. Near-miss reporting is inconsistent. Data systems are fragmented.

Fit

Standardised

Criteria
Safety management performance data is collected systematically using defined tools, procedures and quality standards. Both leading and lagging indicators are assessed. Data quality checks exist and are consistently applied. Reporting of defined metrics occurs as a matter of routine.

Fit

Proactive

Criteria
Data integrity is proactively monitored at the organisation level and gaps are interrogated and addressed. Frontline personnel understand the importance of reliable data and how to provide/obtain it. Metric selection is routinely reviewed for relevance and usefulness.

Fit

Generative

Criteria
Where practicable, timely high-quality performance data is obtained for key controls (e.g. through sensor augmentation) and used in system performance assurance and review.

Fit

Theme
Analysis & use of metrics

Maturity bands

Ad-hoc

Criteria
Metrics are not analysed. No structured communication of performance occurs. Decisions rely on intuition alone.

Fit

Reactive

Criteria
Analysis occurs primarily after incidents. Findings are shared irregularly and usually only with leaders.

Fit

Standardised

Criteria
Process safety performance metrics and trends are routinely analysed and reported. Findings influence decision-making.

Fit

Proactive

Criteria
Analysis is forward-looking, identifying weak signals and emerging risks. Insights are widely communicated, including ‘closing the loop’ with the workforce, to show how reporting impacts operations management.

Fit

Generative

Criteria
Analysis uses multiple indicators to identify weak signals of deteriorating control, and findings are used to inform design, maintenance and operational decisions.

Fit

Theme
Performance review & learning

Maturity bands

Ad-hoc

Criteria
No routine reviews of process safety performance occur. ‘Weak signals’ of system safety status are missed and issues frequently reoccur.

Fit

Reactive

Criteria
Process safety performance reviews occur after problems or incidents. Improvements depend on individual initiative and may not be tracked.

Fit

Standardised

Criteria
Regular process safety performance review meetings examine trends and backlogs. Improvements are assigned and tracked to closure.

Fit

Proactive

Criteria
Metric trends are used to support targeted improvement programmes, while awareness that metrics and ’the measured’ performance can be different things is maintained. Lessons learned are integrated into procedures, training and risk assessments. Metric sets evolve in response to feedback.

Fit

Generative

Criteria
Performance review is continuous, transparent and integrated with organisational learning. Metrics drive system improvements. Organisation engages in shared benchmarking, promoting collective safety learning.

Fit

15. Auditing

Goal statement:
Regular audits confirm that PSM systems are functioning as intended and identify areas for improvement.

Auditing provides structured verification that design, technical and operational hazard controls are in place and remain effective over time. Regular, systematic audits identify gaps in compliance, performance and culture, enabling proactive correction before deficiencies contribute to incidents. Audits also test the integrity of the safety management system by comparing practice against policy and verifying that lessons-learned are embedded across system design, maintenance, and operations.

Typical activities include:

- Planning and executing periodic PSM/ SMS audits;
- Verifying implementation of procedures, inspections and training;
- Tracking and closing corrective actions;
- Analysing audit findings for systemic trends; and
- Sharing lessons across silos to strengthen safety improvement.

These activities ensure that management system weaknesses are identified/ addressed, and that learning occurs consistently across the organisation.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Governance & planning

Maturity bands

Ad-hoc

Criteria
There is no formal, routine safety audit programme. Audits occur only after incidents or in response to regulator pressure.

Fit

Reactive

Criteria
A safety audit plan exists but is inconsistently applied. Audit scope and frequency varies significantly between vessels and audit quality is variable. Specifications for auditor competence may be stated, but are not verified.

Fit

Standardised

Criteria
A safety audit function is defined at the corporate level and adequately resourced to perform audit tasks. A documented audit programme defines scope, frequency and responsibilities. All PSM elements are covered over a set cycle. Auditor competence is specified and assured.

Fit

Proactive

Criteria
Audit planning is risk-based and reflects the particular characteristics of the audited - vessel type, fuel system configuration, performance history and operational changes are all considered. Highly competent and experienced auditors are employed.

Fit

Generative

Criteria
There is an organisation-wide understanding of audits as a valuable tool for assuring and improving operating safety. All parts of the organisation support auditors in their work and transparency to the audit process is actively cultivated.

Fit

Theme
Audit execution

Maturity bands

Ad-hoc

Criteria
Audits, when performed, consist mainly of superficial document reviews with little or no operational verification.

Fit

Reactive

Criteria
Audits rely primarily on documentation review. Some assurance of 'work as done' may occur, but this is limited.

Fit

Standardised

Criteria
Audits employ structured checklists, interviews, photographs, sampling and field verification to develop a comprehensive understanding of the organisation's safety performance.

Fit

Proactive

Criteria
Cross-functional teams of auditors with different technical expertises are utilised where appropriate. Audits include demonstrations of human performance, including in emergency functions. Audits attend to the adequacy of the management of vessel interfaces.

Fit

Generative

Criteria
Safety audits incorporate non-standard expertise (e.g. human factors reviews, barrier analyses) to enhance audit quality. Auditors continually seek to improve their expertise through review of emerging best practices in maritime and in other safety-critical industries.

Fit

Theme
Findings & corrective actions

Maturity bands

Ad-hoc

Criteria
Documentation of audit findings is typically superficial and findings are infrequently acted upon. There is no system to track implementation/ closure of corrective actions.

Fit

Reactive

Criteria
Audit findings are consistently documented, but vary in quality. Action tracking is inconsistent and closure relies on individual diligence.

Fit

Standardised

Criteria
Findings are risk-ranked. Corrective actions are assigned owners and tracked to closure with evidence.

Fit

Proactive

Criteria
Systemic causes are addressed, not just local failures. An integrated system tracks audit findings fleet-wide. Implementation of corrective actions is integrated with the MoC process, where appropriate. Leadership routinely reviews progress against audit actions.

Fit

Generative

Criteria
Corrective actions are promptly and effectively implemented. Comprehensive records track completion of these actions and records show that learning is effective.

Fit

Theme
Learning & improvement

Maturity bands

Ad-hoc

Criteria
No analysis of audit results occurs. Issues reoccur across vessels and departments.

Fit

Reactive

Criteria
Some organisation-level review of audit results occurs but this is generally driven by incidents or external pressure and the use of findings to support improvements is inconsistent.

Fit

Standardised

Criteria
Audit results are analysed for trends and communicated to relevant personnel in the sea-going and shore-side organisation. Audit findings are used to inform improvements to safety management practices.

Fit

Proactive

Criteria
Key audit findings are communicated to all levels of the organisation. Fleet-wide trends shape improvement programmes. Insights from audits influence updates to procedures, training and standards. Audit processes and reports are periodically subjected to peer-review.

Fit

Generative

Criteria
Benchmarking within the organisation and – where practicable – externally, drives continuous improvement. Audit outcomes influence organisational strategy. Learning is shared externally to improve industry-wide safety performance.

Fit

16. Management Review and Continuous Improvement

Goal statement:
Leadership/ management reviews ensure that organisation-level policies, strategies and plans remain appropriate and effective over time.

Management Review of safety performance takes a 'big picture' overview of the patterns of evidence arising from all forms of monitoring, investigation and audit to decide whether the overall approach, policies, resources, priorities, improvement targets and the SMS remain relevant and appropriate.

Typical activities include:

- Reviewing leading and lagging indicators, audit outcomes and incident trends;
- Assuring adequacy of resources, competencies and organisational capacity for process safety delivery;
- Re-evaluating risk controls, policies and objectives in light of 'external' changes (e.g. emerging technologies, regulatory changes);
- Communicating review results and improvement priorities throughout the organisation; and
- Updating goals, procedures and resource plans to embed learning and effect continuous improvement.

These activities ensure that process safety performance is actively governed at senior levels, that improvement efforts are coherent and risk-informed, and that the organisation continues to strengthen its safety culture over time.

Overall element maturity assessment **Fit**

- Ad-hoc
- Reactive
- Standardised
- Proactive
- Generative

Assessor Notes

Theme
Leadership & governance

Maturity bands

Ad-hoc

Criteria
There is no structured management review of process safety performance. Oversight depends on individual interest rather than defined responsibilities.

Fit

Reactive

Criteria
Leaders review performance irregularly. Such reviews are typically triggered by incidents or external requirements rather than internal initiative.

Fit

Standardised

Criteria
A formal leadership review process defines frequency, scope, inputs and responsibilities. Reviews examine process safety performance, including trends, incidents and key indicators. Outcomes are recorded, with actions assigned and tracked to closure. The adequacy of SMS objectives and policies is periodically reviewed.

Fit

Proactive

Criteria
Leadership actively challenges process safety performance, including underlying causes and system weaknesses. Reviews are forward-looking and inform priorities, resource allocation and risk management decisions. Leadership engagement is visible through participation in reviews, challenge of performance and follow-up of actions.

Fit

Generative

Criteria
Process safety performance is reviewed routinely at the highest levels of the organisation. The organisation's leadership champions long-term safety improvement and external engagement with the development of emerging best practices in managing ammonia as a marine fuel.

Fit

Theme
Evaluation of PSM performance

Maturity bands

Ad-hoc

Criteria
Performance is judged informally. No systematic review of incidents, audits, metrics or risk assessments occurs.

Fit

Reactive

Criteria
Some elements of PSM performance may be reviewed systematically, but coverage is partial and does not engage with PSM as an integrated approach to assuring safety. Leaders' reviews of PSM performance vary widely in quality.

Fit

Standardised

Criteria
Reviews are performed to a consistent standard and include comprehensive coverage of the full PSM scope. Reviews consider audits, incident reports, metrics, compliance results and emerging risks. Reviews identify system performance gaps/ shortfalls where these exist in underlying sources.

Fit

Proactive

Criteria
Cross-functional participation in reviews ensures that insight is obtained from all relevant disciplines. The scope of PSM performance reviews is comprehensive and detailed, including leading indicators, human performance insights, barrier reliability and operational deviations.

Fit

Generative

Criteria
The organisation proactively works to anticipate and manage future risks, and commissions independent reviews of performance periodically. At its fullest expression, it participates in forums evaluating safety management of ammonia as a marine fuel, incorporating cross-industry insights into its reviews.

Fit

Theme
Resourcing & implementation

Maturity bands

Ad-hoc

Criteria
Resourcing/ implementation decisions for changes are made impulsively and without reference to long-term effects/ trade-offs. Resource allocation is inconsistent and not linked to risk.

Fit

Reactive

Criteria
There is some effort to allocate resources on the basis of effect in managing risks, but decisions lack transparency as to their rationale. Action items are defined but inconsistently resourced/ tracked to closure.

Fit

Standardised

Criteria
Leaders prioritise improvements using risk-based criteria. Actions are allocated to defined owners and tracked to closure. Decisions – including decisions pertaining to resourcing – are documented and transparent.

Fit

Proactive

Criteria
Leadership allocates resources proactively to reduce risk and support initiatives aimed at improving safety. Improvement programmes are coordinated and monitored. There is a process to review lessons learned from external sources (e.g. other organisations, confidential reporting mechanisms).

Fit

Generative

Criteria
Leadership reviews operate as continuous-learning cycles, with technical tools (e.g. live performance dashboards) developed to support this work where practicable. Improvements are validated for effectiveness.

Fit

Theme
Organisational learning

Maturity bands

Ad-hoc

Criteria
Learning from management reviews is minimal. Mistakes evident in reviewed sources reoccur because insights are not captured or shared.

Fit

Reactive

Criteria
Organisational learning occurs after major issues but the scope of learning tends to be localised, slow to spread fleet-wide and may quickly regress. Management reviews give little attention to weak signals or more nuanced performance metrics.

Fit

Standardised

Criteria
Management review ensures that lessons from incidents, audits and near misses are integrated into system improvement processes (e.g. MoC) and shared internally.

Fit

Proactive

Criteria
Failures are treated as learning opportunities. Insights are deployed across the fleet and communicated transparently. Learning addresses systemic implications of findings, not just immediate corrective actions. Repeated findings trigger evaluation of deeper 'root cause' weakness (e.g. in standards, resources or supervision).

Fit

Generative

Criteria
Learning is a continuous, transparent process, with the organisation actively seeking out lessons across its operation. At its fullest expression, it shares good practice externally and contributes to sector-wide improvement.

Fit

Terms and abbreviations

Abbreviation	Expansion
CCPS	Center for Chemical Process Safety
CMM	Capability Maturity Model
D&A	Drug and alcohol
FMEA	Failure mode and effects analysis
HAZID	Hazard identification
HAZOP	Hazard and operability study
HIRA	Hazard identification and risk analysis
IMO	The International Maritime Organization
ISM Code	The International Safety Management Code
LOPA	Layer of protection analysis
LOTO	Lock out, tag out
MoC	Management of change
P&I	Protection and indemnity
P&ID	Piping and instrumentation diagram
PDCA	Plan–Do–Check–Act
PFD	Process flow diagram
PKM	Process knowledge management
PMS	Planned maintenance system
PPE	Personal protective equipment
PSM	Process safety management
PTW	Permit to work
QRA	Quantitative risk assessment
RBPSM	Risk-based process safety management
SIMOPS	Simultaneous operations (e.g. bunkering while loading cargo)
SMS	Safety management system
SOP	Standard operating procedure
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

Fonden Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping is real climate action. We are a not-for-profit, independent research and development center established to accelerate the transition towards a net-zero future for the maritime industry. Together with our partners, we enable and inform the development and implementation of new technologies, build confidence in new concepts, and mature viable pathways to support the systemic and regulatory changes required to decarbonize global shipping.

As an independent and neutral platform for cross-sector collaboration, the Center brings together industry leaders, researchers, policymakers and public institutions to address some of the most complex challenges facing maritime decarbonization. Our work is grounded in scientific integrity, transparency and responsible governance, and is designed to facilitate trusted collaboration while respecting the independent decision-making of all participants.

The Center does not direct, coordinate or endorse commercial behaviour, market strategies or competitive outcomes. Instead, we provide fact-based research, analysis and insights that stakeholders may independently assess and apply within their own organisations and decision-making processes. We are committed to presenting our findings neutrally and transparently, including through clear methodologies and defined scopes of work, in order to support informed dialogue, innovation and evidence-based policymaking across the maritime ecosystem.

Through applied research, partnerships and industry-wide engagement, we aim to accelerate scalable solutions that support a safe, sustainable and commercially viable transition for the global maritime industry.

www.zerocarbonshipping.com

The Decarb Hub

The Lloyd's Register Maritime Decarbonisation Hub (commonly known as the Decarb Hub) is an independent, non-profit initiative established through a partnership between Lloyd's Register Foundation — a global charity with a mission to engineer a safer world — and Lloyd's Register Group, a global provider of maritime professional services with over 260 years of heritage.

This partnership brings together the Foundation's public benefit mandate and focus on societal resilience, with the Group's deep technical expertise and trusted relationships across the maritime industry. Positioned at the intersection of these two organisations, the Hub is uniquely equipped to accelerate the safe, sustainable, and human-centric decarbonisation of global shipping — combining neutrality with influence, and research with real-world application.

www.thedecarbhub.org

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