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A Human-Centred Approach to Accident Analysis

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Abstract
The form and scope of accident investigation reports reflect underlying assumptions about causality, responsibility, and learning. Although official investigations address technical, human, and systemic factors, the way inquiry is structured shapes how coordination and sensemaking are examined, often leaving these dimensions implicit. This study offers a human-centred reinterpretation that makes these aspects more explicit. When comparable accidents are investigated under similar premises, this may result in recurring patterns in how causes are framed and learning is articulated. This article presents a parallel analysis of two Norwegian maritime accidents: Thor Heyerdahl and Helge Ingstad, based on official investigation reports and examined through the lens of an established accident investigation maturity model. The analysis identifies recurring patterns across the two cases in how causal factors are framed, which questions are posed, and how learning is defined, as well as elements that remain outside the analytical scope of the investigations. The article concludes by discussing how these patterns relate to the maturity level of the investigative approach and how a human-centred perspective on accident analysis may support broader organizational learning in high-risk maritime contexts.

Keywords: Human factors, Socio-organizational learning, Human-centred analysis, Maritime accident, Accident investigation

1. Introduction

Accidents expose organizational arrangements and create opportunities for learning. Beyond reconstructing events, investigations can shape how organizations understand action, coordination, and decision-making under constraints, and may support the development of both declarative and procedural knowledge (Braut & Njå, 2013). Historically, many investigation approaches have relied on linear models of causation, which frame accidents as chains of discrete failures. While such models support standardized analysis, they tend to emphasize technical malfunction or individual error as primary explanatory categories (Dekker, 2015). These representations offer limited insight into contemporary socio-technical systems, where outcomes emerge from interactions among technical systems, organizational structures, and human activity, often under conditions of time pressure, ambiguity, and competing goals (Leveson, 2011).

Later models such as Swiss Cheese, STAMP, and FRAM expanded the analytical scope of accident investigation, but their adoption has not consistently translated into changes in investigative practice. At the same time, empirical studies suggest that investigative practices may vary in how explicitly they engage with organizational and socio-technical conditions, even when such factors are recognized (Mazaheri et al., 2015). This focus often limits attention to observable actions and formal deviations, while giving less consideration to how organizational practices shape trust, authority, communication, and ownership of decisions (Flyvbjerg, 2012; Steen et al., 2024). Although many contemporary investigation reports do include organizational and systemic analysis, these dimensions are not always equally developed or connected to real-time coordination and action. As a result, the visibility of individual experience and collective sensemaking in investigations remains constrained, consistent with what has been described as the streetlight and shadow effect (Klein, 2011). Existing research documents this tendency but gives limited attention to how it is shaped by the questions that guide accident investigations.

With this background, The study examines how questions in accident investigations shape what is noticed, discussed, and acted upon, focusing on how official reports activate different levels of investigative depth and the implications for organizational learning, based on two Norwegian maritime cases: the NSIA investigations of HNoMS Helge Ingstad (2018) and HNoMS Thor Heyerdahl (2022).

Although these incidents differ in operational context and event dynamics, they are analytically comparable as institutional narratives produced within the same national safety regime. The empirical material consists of official investigation reports, analyzed thematically to examine how human agency and organizational constraints are represented. The analysis in this study focuses on how inquiry is structured within the reports and how different analytical layers are made explicit or remain implicit.

2. Theoretical Framing

2.1 *Accident investigation, organizational learning, and inquiry*

Recent studies highlight that learning from failure is complicated by ambiguity and noise in organizational environments. Dahlin et al. (2018) distinguish between action-based errors and performance-based failures (adverse outcomes), noting that these do not map linearly onto one another. Errors may not result in failure, and failures may occur despite correct action, complicating causal inference and increasing the risk that learning efforts focus on outcomes rather than underlying processes. In such contexts, learning depends less on outcomes themselves and more on the quality of questioning used to interpret events. Learning from failure further depends on the interaction of opportunity, motivation, and ability. Opportunity concerns access to information and time for analysis, motivation reflects willingness to engage with failure (Steen et al., 2023); and ability reflects the skills required to analyze and act on insights. These mechanisms are interdependent and may be jointly undermined in noisy environments, where ambiguous signals reduce confidence in causal explanations As a result, organizations may risk entering cycles of non-learning if underlying processes are not fully examined (Blackman & Henderson, 2005).

2.2. *Maturity model to accident investigation*

Steen & Johnsen (2026) propose a maturity model for accident investigation that reconceptualizes investigative depth as a layered sphere rather than a linear scale. The model (Figure 1) is designed to guide investigators to ask different kinds of questions at increasing analytical depth, supporting richer learning by complementing existing technical, human, and systemic analyses. Its central idea is that a single event can be examined across four concentric layers, from the outer, visible technical failures to the inner, interpretive and relational dynamics, where each layer exposes different explanations and points to different measures. Applied in practice, the model encourages teams to extend analyses beyond immediate fault-finding and human error attributions, to explore socio-technical interdependencies and, where needed, probe the deeper sensemaking, communication, and cultural and relational conditions that determine whether shared understanding can form under pressure. In more detail, the four layers of the maturity model are defined as follows:

- Layer 1: Technical Causality Focus, addresses concrete, observable breakdowns, examining safety barriers, equipment failures, and hardware-based system malfunctions.
- Layer 2: Human Factors and Performance Analysis, highlighting human error, breaches of compliance, and individual cognitive limitations. It investigates how situational awareness, heuristics, and individual skills influence human performance.
- Layer 3: Systemic Sociotechnical Analysis which moves beyond linear cause-and-effect, this layer focuses on the interdependencies and functional variability within a system.

- Layer 4: Relational-Centered Approaches: The deepest analytical layer makes explicit relational and interpretive dynamics that are often implicitly present but less systematically developed in investigation reports. It is theoretically grounded in sensemaking theory and the Human Readiness Level (HRL) framework (Phillips, 2010).

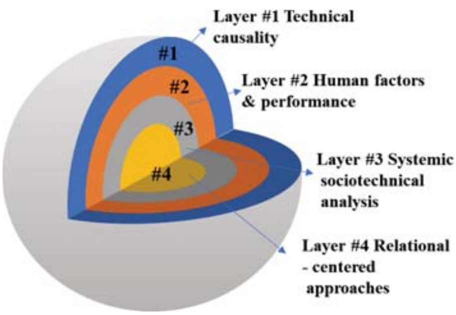

Figure 1 Maturity model to accident investigation

The fourth layer examines how shared understanding forms or breaks down at critical moments, showing how systems can drift toward failure as situational awareness and common meaning erode, even when rules are followed. This layer uses sensemaking theory and the HRL framework to assess the maturity of the human dimension of socio-technical systems, including learning culture, communication, and the capacity to sustain shared understanding of risk during complex operations.

3. Methodology

3.1. *Research design & data material*

This study employs a systematic document analysis approach (Morgan, 2022), focusing on official investigation reports as institutional accounts that reflect both factual reconstruction and analytical priorities. The empirical material comprises reports on two Norwegian naval incidents:

- AIBN/DAIBN Part 1 (AIBN, 2019): reconstruction of events leading to the Helge Ingstad collision, causal analysis, and initial safety recommendations.
- NSIA Part 2 (NSIA, 2021): extended analysis of post-collision with additional recommendations.
- NSIA report on Thor Heyerdahl (NSIA, 2023): analysis of a loss-of-power incident during harbor approach, addressing technical faults, manning constraints, and oversight issues.

The investigations differ in scope and format. The Helge Ingstad inquiry is a comprehensive, multi-part collision investigation, whereas the Thor Heyerdahl report is explicitly limited in scope, uses a simplified format, and draws on internal Armed Forces and materiel investigations for its factual basis. This asymmetry is analytically relevant and is treated as part of the phenomenon under study, reflecting variation in investigative practice rather than methodological inconsistency.

3.2. *Data analysis and procedures*

Following Braun and Clarke's (2021) reflexive thematic analysis, initial codes were generated inductively from the report material and iteratively reviewed across the dataset. Codes were then examined for conceptual similarity and analytic focus, and clustered into broader patterns that captured recurring issues across the investigation reports. In a subsequent interpretive step, coded segments were mapped to the maturity-model layers based on how the investigation reports analytically developed the issue (e.g., as technical failure, human performance, systemic interaction, or relational sensemaking). Through this process, 37 initial codes were consolidated into four overarching themes:

- Th#1: Navigation & bridge management
- Th#2: Leadership & emergency management
- Th#3: Technical & structural constraints
- Th#4: Organizational & crew preparedness

Mapping to the maturity-model layers followed how the reports themselves framed their explanations. This included explicit technical failure analysis (e.g., "loss of power on main switchboard 2 resulted in total blackout"; NSIA, 2023), human performance explanation (e.g., "the bridge team misinterpreted the lights ahead as part of the terminal"; AIBN, 2019), and systemic organizational conditions (e.g., "marginal manning and multifunctional roles reduced leadership capacity"; NSIA, 2023). Where relational or sensemaking dynamics were described but not analytically examined (e.g., observations that prevailing assumptions were not challenged across the bridge team; AIBN, 2019), these were treated as implicit, meaning that they were noted as present in the narrative but not analyzed as explanatory factors in the reports.

3.3. Case description

The following brief descriptions provide contextual background for the document analysis; note that they are not intended as equivalent event reconstructions.

HNoMS Helge Ingstad (2018)

On 8 Nov 2018, the Norwegian frigate KNM Helge Ingstad, with 137 personnel aboard, collided with the tanker Sola TS near Fedje shortly after a bridge watch change. Seven crew were slightly injured. The collision caused extensive reputational and financial damage (≈USD 80M) and prompted two official investigation reports (AIBN, 2019; NSIA, 2021): one focusing on navigational decisions leading to the collision, and one addressing post-impact loss of buoyancy and evacuation.

HNoMS Thor Heyerdahl (2022)

On 6 Aug 2022, the Norwegian frigate KNM Thor Heyerdahl, with approximately 114 personnel aboard, experienced a docking incident in which a heaving line entered a bow thruster, causing a mechanical overload that cascaded into protective trips, generator failure, and a full blackout. The ship drifted and struck a floating barrier. Damage and injuries were minimal, but the event exposed vulnerabilities in power protection and system redundancy under routine operational conditions (NSIA, 2023).

4. Findings

4.1 *Navigation & bridge management*

The Nansen-class frigates were designed for reduced crewing under the Lean Manning Concept (LMC), adopted by the Norwegian Navy in 2004 prior to ship design. The concept shaped vessel configuration, system operation, and bridge organization, and preceded the current safety-management directive. Consequently, budget constraints and personnel limits informed key operational assumptions in command and control and navigation. No Human Factors or workload assessments were identified to support the LMC doctrine. The NSIA further reported that working hours and rest periods were not systematically logged, limiting the investigation of fatigue among bridge personnel. On this basis, the NSIA recommends further evaluation of the LMC concept. The LMC assumes that ship systems can provide robust, error-tolerant support and enable crews to maintain a “situation at a glance.” Both investigation reports describe challenges related to bridge-system design and usability, which may increase cognitive workload under operational conditions. Previous studies of bridge design on Nansen-class frigates indicate high cognitive workload and usability limitations (Bjørneseth, 2021), suggesting that the implementation of the LMC places high demands on system design and operational support.

Regarding the Thor Heyerdahl incident (NSIA, 2023), the investigation describes gaps in situational awareness and communication between the bridge, engine room, and operational decks. The Officer of the Watch (OOW) was not informed that mooring lines had entered the water or that the bow thruster had stopped due to mechanical obstruction, resulting in limited shared awareness across functions. The report links these communication failures to shortcomings in mooring procedures. Although the incident did not result in total loss, the ship drifted without propulsion or steering and collided with a floating barrier.

In the Helge Ingstad case, the official investigation describes how the collision resulted from breakdowns in situational awareness and communication on the bridge. The bridge team interpreted the bright lights ahead as part of the Sture Terminal rather than a tanker on a collision course. The report notes that the bridge team shared a common situation assessment when the OOW assumed command shortly before the accident. The frigate sailed with the Automatic Identification System (AIS) in passive mode, and radar information was under-used, contributing to reliance on assumptions rather than verification. The collision caused extensive damage when Sola TS’s anchor struck the frigate, eventually leading to the total loss of the vessel after grounding.

In both investigation reports, situational awareness is described as being affected by experience, system support, and communication across functions. In both incidents, crews acted on inaccurate assumptions. Although the consequences differed markedly, the reports indicate that the lack of shared situational awareness contributed to the escalation of otherwise manageable operational challenges.

4.2 *Leadership & emergency management*

AIBN (2019) briefly notes that the 2016 decision by the Norwegian Parliament to increase the number of frigate crews from 3.5 to 5 further stretched naval capacity beyond the constraints already introduced by the LCM.

In the Thor Heyerdahl case, the NSIA (2023) report describes how leadership was affected by organizational arrangements that left the command structure thin. The electrical department lacked three crew members, requiring the Technical Officer and other leaders to perform manual operational tasks, while leadership roles for aft mooring and the boat deck were unfilled during the voyage. According to the investigation, task overload during the emergency meant that no individual maintained a full overview of the vessel's status. Crew members therefore relied on improvisation, including manual bypass of stalled systems. The report characterizes these actions as necessary adaptations under the conditions present and notes organizational-level similarities with the Helge Ingstad case.

In the Helge Ingstad investigation, leadership challenges are described in relation to the overlap between training and operational duties. The Officer of the Watch (OOW) was also responsible for instructing a trainee, dividing attention during a complex navigation task. The trainee was an English-speaking exchange officer from another NATO country. Subordinates observed unusual lights from Sola TS but did not challenge the prevailing interpretation held by the bridge team, allowing an incorrect situation assessment to persist. The investigation identifies limitations in Bridge Resource Management (BRM), particularly with respect to communication, assertion, and decision-making under time pressure.

In both cases, the investigation reports describe how the formal leader was drawn into operational tasks, which can be interpreted as reducing the capacity for overarching command and coordination. On Thor Heyerdahl, leadership capacity was reduced by staffing gaps and technical task demands. On Helge Ingstad, the OOW's attention was divided by training responsibilities. In both investigations, these conditions are linked to reduced situational awareness and weakened oversight, suggesting that the competence and experience assumptions underlying the LMC were not fully met in practice.

The outcomes differed. On Thor Heyerdahl, the crew's improvised actions helped prevent more serious consequences. On Helge Ingstad, the failure to challenge assumptions and re-establish shared understanding in time contributed to the loss of the vessel.

4.3 *Technical & structural constraints*

The technical issues on HNoMS Thor Heyerdahl showed a high sensitivity to single-point failures in the ship's electrical and automation systems. The incident began when a mooring line jammed the bow thruster, but the vessel's design amplified this local problem into a total power failure. With propulsion and steering lost, the ship became effectively a "dead ship," drifting without control. This occurred because the technical systems had no built-in autonomy to prevent a grounding once the main power failed. In this case, a single mechanical issue triggered cascading failures, highlighting how sensitive the vessel was to minor events.

On the Helge Ingstad case, the technical constraints were primarily structural. The situational awareness of the bridge crew was affected by poor design, high noise levels, and insufficient use of available technical aids such as radar and AIS. The initial collision with the tanker's anchor caused a localized hull breach, but the frigate's design allowed progressive flooding through areas intended to remain watertight. These failures undermined stability calculations, as assumed watertight integrity no longer held. Damage-control resources on the bridge were limited, and the crew had no real-time data on which compartments were flooding, delaying their understanding of the vessel's condition. The combination of structural weaknesses and insufficient monitoring contributed to a point of no return, ultimately leading to the total loss of the vessel.

In comparison, the reports show how a single error can escalate into a major problem, but the nature of the failures was different. On Thor Heyerdahl, a small mechanical issue propagated through the electrical system, cutting power to the entire ship. The problem was functional: the ship became unpropelled and lost steering because the electrical systems were highly sensitive to overload and the emergency power supply was too limited to maintain control. On Helge Ingstad, the situational awareness of the crew under navigation caused the collision. This accident caused a localized hull breach, but structural weaknesses allowed water to spread through supposedly watertight compartments. This failure was physical. In both cases, a single point of failure, electrical for Thor Heyerdahl, structural for Helge Ingstad, overwhelmed the ship's systems.

4.4 *Organizational & crew preparedness*

The investigation into Thor Heyerdahl describes how organizational constraints under the LMC directly affected the crew's ability to respond. The vessel sailed with key technical positions unstaffed, and the electrical department lacked three of its ten personnel. As documented in the report, leaders were drawn into operational tasks, leaving no individual with a full overview of the ship's status. The investigation describes a culture of risk acceptance in which operational schedules took precedence over safety considerations. At the same time, the crew's initiative and ability to manually restart systems helped prevent more severe consequences. However, the report notes limited institutional learning, as prior warnings about LMC-related risks had not resulted in changes to staffing or procedures.

For Helge Ingstad, organizational issues centered on the balance between training and operational safety. A bridge team with a high proportion of trainees led to shifting roles and responsibilities, drawing the OOW into instruction and reducing shared situational awareness. These conditions were compounded by expectations about competence and controllability embedded in the crewing concept, along with limited follow-up of earlier safety findings. In both investigations, organizational conditions shaped how events unfolded: on Thor Heyerdahl, staffing gaps reduced leadership oversight, while on Helge Ingstad a trainee-heavy bridge contributed to experience gaps. Backlogs, unresolved issues, and limited redundancy are described as contributing to a gradual weakening of safety management, with known vulnerabilities remaining unaddressed.

5. Discussion

From an organizational learning perspective, accident investigations differ in the kinds of learning they support according to how uncertainty, performance variability, and organizational constraints are analyzed. Learning does not follow automatically from identifying causal factors; it depends on whether inquiry enables reflection on the assumptions and structures shaping action in complex socio-technical systems. Accident investigations therefore function as institutionalized forms of inquiry that shape not only explanations of events but the development of organizational reliability over time.

The Helge Ingstad investigation reflects an inquiry orientation that gives priority to explaining deviations from expected performance within an otherwise broad organizational and systemic analysis. The investigation documents contextual and organizational conditions, these are mainly used to frame explanations of operational decisions and procedural breakdowns. The analysis gives more limited attention to how coordination and sensemaking unfolded during the event itself. In this respect, parts of the analysis resemble single-loop learning, where corrective actions restore compliance without questioning the organizational conditions that make deviations likely (Dekker, 2015). While such inquiry supports accountability, it offers limited insight into how organizations develop the capacity to anticipate, absorb, and respond to unexpected situations central to high-reliability operations.

By contrast, the Thor Heyerdahl investigation reflects a broader learning orientation through its explicit attention to organizational arrangements, including lean manning, multifunctional roles, fragmented oversight of technical deviations, and limited integration of risk information. Rather than attributing the loss of propulsion and power to isolated faults, the investigation shows how multiple known deficiencies interacted to produce an escalating and initially unrecognized risk state. This analytical move aligns with system-oriented and resilience-informed research emphasizing how adverse events emerge from interacting latent conditions rather than discrete failure (Reason, 1997; Leveson, 2011). From an HRL perspective, such inquiry supports reliability by making explicit how staffing choices, system dependencies, and oversight arrangements affect the ship's ability to maintain control when conditions deteriorate.

At the same time, the analysis suggests that learning is developed unevenly, with organizational conditions examined primarily as contributing factors rather than as part of the unfolding decision-making process. Although the report notes under-manning and role overload, it does not fully examine how these conditions affected authority, information flow, or shared situational awareness in real time. Sensemaking research identifies these processes as central to action under uncertainty (Weick, 1995), while HRL research emphasizes their role in sustaining reliable performance under surprise. When such dynamics remain implicit, insight into how reliability is enacted in practice remains constrained.

Within the maturity-model framework, this points to a shift in analytical depth, from treating organizational conditions as contributing factors to examining how they shape action as situations unfold. At this level of analysis, investigations can support prospective learning by addressing not only specific events but also the conditions shaping future performance and reliability. In both cases examined here, the scope of learning is closely related to how the inquiry is structured and which questions are made analytically central.

For investigation practice, this underscores the importance of inquiry design. Questions about how information is integrated across organizational boundaries, how responsibility and authority are enacted under conditions of overload, and how weak or ambiguous signals are interpreted proved salient across both investigations, as these features shape the system's ability to maintain control as conditions deteriorate. Addressing such questions makes visible organizational capacities relevant to high-reliability operation, rather than treating breakdowns solely as the result of isolated decisions or failures.

From this perspective, investigative maturity does not represent a fixed endpoint, but functions as an analytical lens for reflecting on the kinds of learning an investigation enables. Rather than focusing on whether an investigation "closes" an event, this framing directs attention to how inquiry shapes what becomes intelligible for future operations, and how organizations come to understand the limits and possibilities of reliable performance in complex, high-risk settings. Differences in report scope are therefore understood as shaping what becomes analytically visible, rather than as differences in underlying events.

6. Conclusion and final remarks

Official accident and incident investigations do more than reconstruct events; they actively construct meaning by framing causality, responsibility, and learning. Where analytical attention is directed away from how meaning, coordination, and authority are enacted under uncertainty, learning remains limited to corrective measures rather than improved future performance. Across the cases, absorptive capacity for safety knowledge appears constrained, with lessons unevenly integrated over time and across organizational levels. Based on these findings, we identify the following areas for attention in future naval safety inquiries:

- **Recalibrate the Lean Manning Concept:** Analyze and Ensure adequate staffing, redundancy, and minimum experience thresholds; strengthen onboarding and mentoring, securing a safe level of organizational learning.
- **Establish naval oversight and prioritize organizational learning of Work As Done**: Establish independent oversight arrangements adapted to naval contexts, with explicit attention to how work is carried out under real operational conditions.
- **Integrate safety governance:** Improve integration of deviation and incident reporting systems to support organizational learning; clarify and separate regulatory and materiel responsibilities; draw on practices from other high-risk domains.
- **Enforce sensor and communication discipline:** Active AIS (or encrypted W-AIS with compensatory measures), reduced alarm noise, standardized maritime English for external comms, install VDRs.
- **Improve ship design and maintainability:** Improve Design of Ship control systems based on best practices, especially bridge systems and control of propulsion. Accessible safety-critical valves, validated stability tools, tested watertight solutions, and instrumentation to assess inflow vs pumping capacity.
- **Upgrade competence management and team practices:** Routine, realistic CRM/BRM training; structured, unhurried handovers; deconflict training from high-risk transits.
- **Institutionalize learning systems:** Systematically track and audit

implementation of safety recommendations across incidents and organizational units to prevent repeated exposure to known vulnerabilities.

- **Align training and simulation:** Regularly review training scenarios through structured needs analyses to ensure simulator use reflects coordination demands, decision-making under uncertainty, and performance variability observed in practice.

Finally, the study's contribution should be read in light of the analytical boundaries in Sections 3.1–3.3: based on official reports with differing scope, the comparison is interpretive rather than evaluative. The maturity model is used as an analytical lens, and the findings are illustrative rather than generalizable.

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