

# Development of the ADNOC HRO-Based Safety Measures-Safety Culture-Operational Efficiency Mediation Framework

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## Abstract

High-risk process industries cannot sustain operational reliability through compliance and technology alone. In ADNOC-type oil and gas environments, safety controls must be enacted consistently under production pressure to prevent incidents, avoid disruption, and protect continuity of operations. Drawing on High Reliability Organization (HRO) theory, this paper develops an ADNOC-relevant mediation framework explaining how Safety Measures (SM) translate into Operational Efficiency (OE) both directly and through Safety Culture (SC). Safety Measures are specified as a higher-order construct represented by Advanced Safety Technology (AST), Compliance with Safety (CWS), Emergency Response (ER), and Personal Protective Equipment (PPE). Safety Culture is modelled as a higher-order construct reflected by Safety Awareness (SA) and Management Commitment to Safety (MCS), capturing the behavioural and leadership conditions that determine reliable enactment. Operational Efficiency is conceptualized as a higher-order construct reflected by Perceived Downtime Reduction (PD) and Perceived Productivity Improvement/Stability (PI), emphasizing reliability-based efficiency in asset-intensive operations. By integrating process safety, operational excellence, and HRO perspectives, the framework clarifies where safety investments deliver operational value and provides a structured basis for future survey-based

validation and benchmarking across ADNOC operating contexts.

**Keywords:** High Reliability Organization, Safety Measures, Safety Culture, Operational Efficiency, Mediation, ADNOC, Process Safety

## 1. Introduction

Oil and gas operations are characterised by high hazard potential, complex socio-technical systems, and tightly coupled processes in which small deviations can escalate into major incidents, extended shutdowns, and significant production losses. For national energy companies such as ADNOC, safety performance is therefore inseparable from operational excellence because preventing incidents protects people and assets while also safeguarding operational continuity, reliability, and long-term value creation. In line with this view, recent industry discussions increasingly treat process safety, operational excellence, and sustainability as an integrated performance agenda, emphasising resilience, responsibility, and barrier integrity across upstream and downstream operations (Tayab et al., 2022; Tayab et al., 2024).

Building on this integrated agenda, prior industry studies and practice narratives illustrate the safety–performance link in practical terms. For example, SPE-based operational excellence discussions describe how strengthening process safety barriers and disciplined execution reduces the likelihood of disruptions that typically drive downtime and recovery burdens, particularly across integrated upstream and downstream operations (Tayab et al., 2022; Tayab et al., 2024). Similarly, within ADNOC-specific initiatives, the implementation of integrated work management has been presented as a governance improvement approach in which standardised work planning, control, and verification reduce variability in execution while strengthening both safety and operational performance (Saleem, 2024). Moreover, process safety guidance reinforces this logic by emphasising leading indicators and barrier integrity monitoring as mechanisms for sustaining stable operations, rather than relying solely on lagging incident metrics (American Petroleum Institute, 2021; International Association of Oil & Gas Producers, 2011).

However, despite these well-established principles and tools, uneven returns from safety investments remain common in practice. Many organisations deploy advanced safety technology, formal compliance programmes, emergency preparedness systems, and personal protective equipment, yet disruptions and inefficiencies can persist. This paradox suggests that formal controls do not automatically translate into reliable day-to-day enactment. In particular, under time pressure and competing production demands, controls may be applied inconsistently, deviations can become normalised, and frontline decision-making may drift away from intended standards unless reinforced by strong leadership signals and disciplined work governance.

Importantly, this implementation challenge is also reflected in safety climate and culture research, which argues that shared expectations and management commitment influence whether safety systems are enacted consistently across teams and sites (Zohar, 1980; Griffin & Neal, 2000; Guldenmund, 2000). Consistent with that view, research in the UAE oil and gas context shows that these cultural mechanisms can be captured empirically and are relevant to complex, contractor-intensive environments similar to ADNOC operations (Al Mazrouei et al., 2020). Taken together, these streams of evidence imply that the “missing link” between safety measures and performance outcomes may lie in the cultural and

behavioural conditions that determine how controls are actually used.

To explain this missing link more explicitly, this paper develops an HRO-grounded mediation framework that theorises how Safety Measures translate into Operational Efficiency through Safety Culture in ADNOC-type operating environments. High Reliability Organization (HRO) theory is particularly relevant for high-hazard industries because it focuses on the organisational conditions that sustain reliable performance despite complexity and risk, including vigilance to weak signals, disciplined routines, learning, resilience, and leadership reinforcement (Weick & Sutcliffe, 2015; Cantu et al., 2021; Enya et al., 2018). In parallel, practitioner discussions of HRO traits in offshore and energy settings emphasise that reliability depends on how organisations behave under pressure, not only on the existence of procedures or technologies (Dingee, 2019). Furthermore, while digitalisation trends can strengthen hazard visibility and decision support, their operational impact still depends on disciplined use and organisational reinforcement, precisely the type of mechanisms HRO theory highlights (Al-Rbeawi, 2023).

Accordingly, the paper proposes a Safety Measures–Safety Culture–Operational Efficiency (SM–SC–OE) mediation framework tailored to ADNOC-type operations. In this framework, Safety Measures are conceptualised as a higher-order construct represented by Advanced Safety Technology, Compliance with Safety, Emergency Response, and Personal Protective Equipment. Safety Culture is modelled as a higher-order construct represented by Safety Awareness and Management Commitment to Safety, capturing the behavioural and leadership conditions that shape reliable enactment under pressure. Operational Efficiency is represented through perceived downtime reduction and perceived productivity improvement and stability, reflecting reliability-based efficiency outcomes relevant to asset-intensive operations (Reason, 1997; Weick & Sutcliffe, 2015). By integrating process safety and operational excellence perspectives with HRO theory and safety climate evidence, the framework clarifies why safety investments sometimes fail to deliver expected operational gains and provides a structured basis for diagnosis and improvement planning in ADNOC operating environments (Tayab et al., 2022; Tayab et al., 2024; Saleem, 2024).

### *1.1 Research Gap and Contribution*

Although prior studies have extensively linked safety culture/climate to safety outcomes and, to a lesser extent, to operational performance, many models still treat safety culture as a standalone predictor or emphasise lagging safety metrics such as recordable incidents. Consequently, they often do not make clear how tangible safety measures such as investments, operational controls, preparedness systems, and protective equipment that translate into broader operational efficiency in high-hazard, tightly coupled process environments. This paper addresses that gap by developing an ADNOC-relevant mediation framework grounded in High Reliability Organization (HRO) theory, in which Safety Measures (SM) are positioned as an actionable, multi-dimensional antecedent (Advanced Safety Technology, Compliance with Safety, Emergency Response, and Personal Protective Equipment) that shapes Safety Culture (SC). In turn, Safety Culture that captured through Situational Awareness and Management Commitment to Safety which functions as the mechanism

through which safety controls are consistently enacted under pressure, thereby enabling Operational Efficiency (OE) through stable, disruption-resistant operations. Finally, the paper strengthens its practical and empirical value by providing a clear testing blueprint, including HOC–LOC construct modelling, PLS-SEM estimation, and robustness checks aligned with oil and gas operational excellence systems.

### *1.2 Measurement Design and Construct Specification*

To support transparent empirical validation of the proposed SM–SC–OE framework, this section clarifies how each construct should be operationalised and measured using a survey design suitable for PLS-SEM. As a baseline assumption, and unless theory indicates otherwise, the lower-order components (LOCs) are best specified as reflective constructs because the observed items are intended to represent manifestations of each LOC. By contrast, the specification of the higher-order constructs (HOCs) depends on the conceptual relationship between the HOC and its LOCs: an HOC should be modelled as reflective when the LOCs are viewed as manifestations of a common underlying factor, but as formative when the LOCs are treated as distinct building blocks that jointly form the HOC.

Following this logic, the recommended HOC–LOC specification is: (i) Safety Measures (SM) as a formative HOC formed by AST, CWS, ER, and PPE, because each dimension represents a unique and non-substitutable facet of safety control; (ii) Safety Culture (SC) as a reflective HOC manifested by Situational Awareness (SA) and Management Commitment to Safety (MCS), because an underlying safety culture should be expressed through both frontline attentiveness and leadership reinforcement; and (iii) Operational Efficiency (OE) as a reflective HOC manifested by Process Discipline (PD) and Performance Improvement (PI), reflecting the view that efficiency in asset-intensive operations is expressed through disciplined execution and continuous improvement.

Given this combination of formative and reflective specifications, the HOC–LOC structure can be modelled in PLS-SEM using either (a) a two-stage approach; estimating LOC scores first and then using those scores as indicators for the HOC which is commonly preferred when the HOC is formative, or (b) a repeated-indicators approach, which can be appropriate for reflective HOCs when indicator reuse is theoretically justified. Regardless of the option selected, the modelling choice should be explicitly justified in relation to construct type, model complexity, and sample size.

For the survey instrument itself, a 5 or 7-point Likert format (1 = Strongly disagree to 5/7 = Strongly agree) is suitable for capturing perceptions consistently across roles and sites. To strengthen content validity, items should be adapted from peer-reviewed safety culture, HRO, and operational excellence literature and then contextualised to ADNOC operations through expert review and pilot testing. In practical terms, the measurement section should also provide indicative items (or item themes) for each LOC to demonstrate how the constructs are operationalised and how content coverage is ensured during piloting and refinement.

Finally, because Operational Efficiency is partially captured through perceptions (such as perceived downtime reduction and productivity stability), the framework should be

strengthened through triangulation wherever feasible. Specifically, objective indicators such as unplanned downtime hours, equipment reliability (time between failures) and maintainability (time to restore equipment after failure), schedule adherence, maintenance backlog, permit-to-work cycle time, and corrective action closure timeliness can be linked to survey responses at the unit/asset/team level. This combination reduces common-method bias and increases practical relevance by connecting cultural mechanisms to observable performance outcomes.

## 2. Literature Review

This literature review develops the conceptual foundations for an ADNOC-relevant framework linking Safety Measures to Operational Efficiency through Safety Culture under High Reliability Organization (HRO) theory. In high-hazard oil and gas operations, safety is not only an ethical and regulatory requirement but also a practical condition for sustaining operational continuity. The reviewed studies and industry-oriented practice narratives consistently highlight scenario patterns in which disruptions, near misses, and process safety events translate into downtime, recovery burdens, and productivity instability. At the same time, they show that strong technical and procedural controls do not automatically produce reliable outcomes unless they are enacted consistently under pressure, supported by workforce vigilance and leadership commitment. Accordingly, this review synthesizes four complementary streams: (i) safety and operational excellence integration in oil and gas, (ii) the components of Safety Measures as a bundled control system, (iii) safety culture and climate as mechanisms that shape consistent implementation, and (iv) HRO theory as an explanatory lens for reliability in complex, risky environments. Together, these streams establish the rationale for modelling Safety Culture as the pathway through which formal safety controls are translated into reliability-based operational efficiency outcomes in ADNOC-type settings (Weick & Sutcliffe, 2015; Tayab et al., 2022; Tayab et al., 2024; Al Mazrouei et al., 2020).

### 2.1 Importance of Safety to ADNOC-Type Oil and Gas Operations

Safety is a strategic priority in oil and gas because adverse events impose multi-dimensional costs, including human harm, regulatory consequences, reputational damage, asset integrity impacts, and production disruption. In upstream and downstream environments, a single process safety incident can trigger unplanned shutdowns and long recovery cycles, eroding operational reliability and productive stability (Reason, 1997; Weick & Sutcliffe, 2015). Previous industry-oriented discussions provide scenario-based illustrations of this linkage: strengthening process safety barriers and disciplined execution is repeatedly framed as a practical route to reduce disruption risk across integrated assets, where failures in one segment can cascade into schedule instability and recovery burdens elsewhere (Tayab et al., 2022). More recent discussions extend these scenarios by positioning sustainability and organisational resilience as part of the same incident-prevention agenda, emphasising responsibility-driven systems that anticipate failure, strengthen barriers, and embed reliability into everyday operations (Tayab et al., 2024).

Within ADNOC-specific change initiatives, the implementation of integrated work

management has been presented as a scenario of governance improvement in which standardised work processes, stronger verification, and execution discipline support both safer work and steadier operational outcomes (Saleem, 2024). This aligns with the broader view that safety effectiveness is not only a technical question, but also a management system and organisational behaviour question, specifically how consistently work is planned, controlled, verified, and improved in real operating conditions (ISO, 2018; Weick & Sutcliffe, 2015).

### *2.2 Safety Components and the Logic of “Safety Measures”*

Safety Measures can be understood as a bundle of engineered, procedural, and administrative mechanisms designed to prevent incidents and reduce risk exposure. In high-hazard settings, these measures often include technology-enabled detection and monitoring, procedural compliance and verification, emergency preparedness and response capability, and effective personal protection systems (ISO, 2018). Process safety guidance provides practical scenario logic for why this bundle matters: organisations that monitor leading indicators and verify barrier integrity are better positioned to identify weakening controls before escalation, which supports prevention and operational stability (American Petroleum Institute, 2021; International Association of Oil & Gas Producers, 2011).

Digitalisation and advanced technologies are increasingly associated with improvements in operational performance and risk control in oil and gas, particularly where they strengthen visibility, decision-making, and system responsiveness (Al-Rbeawi, 2023). However, the presence of measures does not guarantee their reliable enactment. Safety culture research provides many scenarios where systems exist “on paper” but performance varies because work is executed differently under pressure. Evidence from safety climate and culture literature indicates that the effectiveness of safety programmes depends on how consistently they are implemented, reinforced, and learned from, especially in environments where production pressures create incentives for shortcuts (Zohar, 1980; Griffin & Neal, 2000; Guldenmund, 2000). Occupational safety culture management perspectives similarly emphasise that safety policy becomes effective only when organisations institutionalise learning and leadership accountability that reinforce consistent practice (Glebova et al., 2023). Together, these scenarios support treating Safety Measures as necessary enabling conditions, but not sufficient on their own, because the way people interpret and apply measures under operational pressure matters (Weick & Sutcliffe, 2015).

### *2.3 Safety Culture and Safety Climate as Mechanisms of Implementation*

Safety Culture reflects shared values, norms, and expectations that shape safety behaviours, especially under competing performance demands (Guldenmund, 2000). A closely related concept, safety climate, captures employee perceptions of safety at a given point in time and is widely operationalised through survey measurement (Zohar, 1980; Griffin & Neal, 2000). Previous research offers a consistent scenario explanation: two sites can have similar formal rules and safety systems, yet one experiences more deviations and disruptions because shared expectations and leadership signals differ, shaping how workers behave when time, cost, or production demands conflict with safety (Griffin & Neal, 2000; Guldenmund, 2000).

In the UAE oil and gas context, Al Mazrouei et al. (2020) developed and validated a safety climate scale, providing empirical grounding that these cultural and perceptual factors can be measured reliably in the sector (Al Mazrouei et al., 2020). This is relevant for ADNOC-type environments where multicultural workforces, contractor interfaces, and operational complexity can influence whether safety is prioritised consistently across teams and shifts (Weick & Sutcliffe, 2015). A recurring scenario in the literature is that management commitment functions as a “signal” to the workforce. When leaders reinforce safety through priorities, resourcing, and consistent decision-making, safety becomes a genuine organisational value; when signals are mixed, safety can be reduced to compliance behaviour that weakens under pressure (Griffin & Neal, 2000; Guldenmund, 2000).

#### *2.4 High Reliability Organization Theory for Safety in High-Hazard Operations*

HRO theory explains how organisations achieve consistently safe performance despite operating in hazardous, complex environments. It emphasises constant attention to weak signals, reluctance to oversimplify risk, sensitivity to frontline operations, commitment to resilience, and deference to expertise (Weick & Sutcliffe, 2015). Prior work has positioned these principles as practical traits for organisations seeking reliability in offshore and energy settings, including scenarios where safe outcomes depend on frontline sensitivity to abnormal conditions and the capacity to respond quickly before escalation (Dingee, 2019).

To translate HRO into actionable assessment, tools and techniques have been proposed for evaluating an organisation’s high-reliability state and diagnosing where reliability may be fragile, thereby supporting targeted improvement interventions (Cantu et al., 2021). Systematic review evidence further suggests that HRO theory can function as an overarching safety management strategy by focusing on organisational processes and behaviours that sustain reliable performance (Enya et al., 2018). Collectively, these studies reinforce a key scenario-based conclusion: safety outcomes are not merely the product of controls, but of mindful organising, meaning the cultural and leadership conditions that allow controls to remain effective in real time and under pressure (Weick & Sutcliffe, 2015; Cantu et al., 2021).

#### *2.5 Operational Efficiency Outcomes and the Safety–Performance Link*

Operational Efficiency is often conceptualised as producing stable outcomes with minimal waste, rework, disruptions, and downtime. In high-hazard sectors, efficiency cannot be separated from reliability because operational disruptions frequently originate from safety incidents, near misses, equipment failures, or process deviations that require shutdowns and recovery (Reason, 1997; Weick & Sutcliffe, 2015). A recurring scenario in asset-intensive operations is that even minor deviations can create cascading impacts, including equipment unavailability, schedule slippage, and productivity instability, meaning reliability-based safety performance becomes a practical driver of operational efficiency (Weick & Sutcliffe, 2015; Reason, 1997).

Studies in adjacent operational domains indicate that operational efficiency can function as an organisational pathway linking investments to performance outcomes, supporting the

relevance of OE as an outcome construct (Mardanov et al., 2026). In oil and gas operational excellence discussions, efficiency is frequently linked to continuity and stable output, reinforcing that incident prevention and barrier integrity contribute to both safety and performance sustainability (Tayab et al., 2022; Tayab et al., 2024). Accordingly, this study conceptualises OE in terms consistent with operational reliability, focusing on reduced unplanned downtime and improved or stabilised productivity.

### 3. Formulation of the Framework

Building on the reviewed literature on operational excellence, process safety, safety culture/climate, and High Reliability Organization (HRO) theory, this study formulates an integrated conceptual framework to explain how safety-related interventions translate into operational performance outcomes in ADNOC-type oil and gas environments. In high-hazard operations, safety performance is not solely determined by the presence of technical controls or procedural requirements; it also depends on how reliably these controls are enacted under operational pressure, how risks are communicated, and how leadership priorities shape frontline decision-making (Cantu et al., 2021; Dingee, 2019; Enya et al., 2018). This aligns with the operational excellence view that preventing incidents requires strengthening both safety barriers and execution discipline across upstream and downstream segments (Tayab et al., 2022; Tayab et al., 2024), including system-level integration through standardized work management and governance (Saleem, 2024).

Figure 1 summarises the proposed mediation logic. The direct path  $SM \rightarrow OE$  reflects the proposition that improved safety measures can reduce variability, interruptions, and rework, thereby improving operational efficiency. The  $SM \rightarrow SC$  path reflects HRO-aligned mechanisms where consistent safety practices, training, preparedness, and protective systems cultivate shared norms and attentive operations. The  $SC \rightarrow OE$  path captures how situational awareness and visible management commitment enable early detection of weak signals, rapid recovery from deviations, and disciplined execution, which collectively improve efficiency. Accordingly, SC is expected to partially mediate the relationship between SM and OE.

#### 3.1 Research Hypotheses

H1 ( $SM \rightarrow SC$ ): Safety Measures positively influence Safety Culture.

H2 ( $SC \rightarrow OE$ ): Safety Culture positively influences Operational Efficiency.

H3 ( $SM \rightarrow OE$ ): Safety Measures positively influence Operational Efficiency.

H4 (Mediation): Safety Culture mediates the relationship between Safety Measures and Operational Efficiency; the indirect effect  $SM \rightarrow SC \rightarrow OE$  is expected to be positive.

Accordingly, the present study conceptualizes safety interventions as a structured bundle of Safety Measures that include both enabling technologies and disciplined work practices. In modern oil and gas systems, advanced technologies and digitalization are increasingly recognized as contributors to safer and more efficient operations by strengthening detection, decision support, and operational responsiveness (Mudaa et al., 2026; Mondal et al., 2026). However, evidence from occupational safety culture management emphasizes that such

measures generate consistent results only when organizations institutionalize learning, accountability, and leadership reinforcement-core features of strong safety culture (Glebova et al., 2023). In the UAE oil and gas context, validated safety climate measurement also supports the feasibility and importance of capturing cultural mechanisms empirically (Al Mazrouei et al., 2020).

Operational performance in this study is represented through Operational Efficiency, recognizing that in high-risk systems efficiency is inseparable from reliability. Disruptions, near misses, and incidents can degrade continuity and productivity, while disciplined and resilient operations reduce variability and support stable output (Tayab et al., 2024; Tayab et al., 2022). This logic is consistent with studies that treat operational efficiency as a meaningful pathway linking organizational investments to performance outcomes (Mardanov et al., 2026). Therefore, the framework is designed to capture both the direct technical contribution of safety measures to efficiency and the indirect cultural pathway through which safety measures are translated into reliable practice.

In this framework, Safety Measures (SM) are positioned as the independent variable because they represent the organisation’s formal portfolio of safety interventions and control capabilities that can be strengthened through investment and governance. Safety Culture (SC) is specified as the mediating mechanism because it captures the workforce and leadership conditions that determine whether those measures are enacted consistently and effectively under operational pressure, consistent with HRO reasoning. Operational Efficiency (OE) is treated as the dependent outcome because reliability-based efficiency in ADNOC-type operations is expected to improve when safety measures reduce disruptions and when safety culture enables disciplined, stable execution across routine and abnormal conditions (Weick & Sutcliffe, 2015; Griffin & Neal, 2000; Tayab et al., 2022; Tayab et al., 2024).

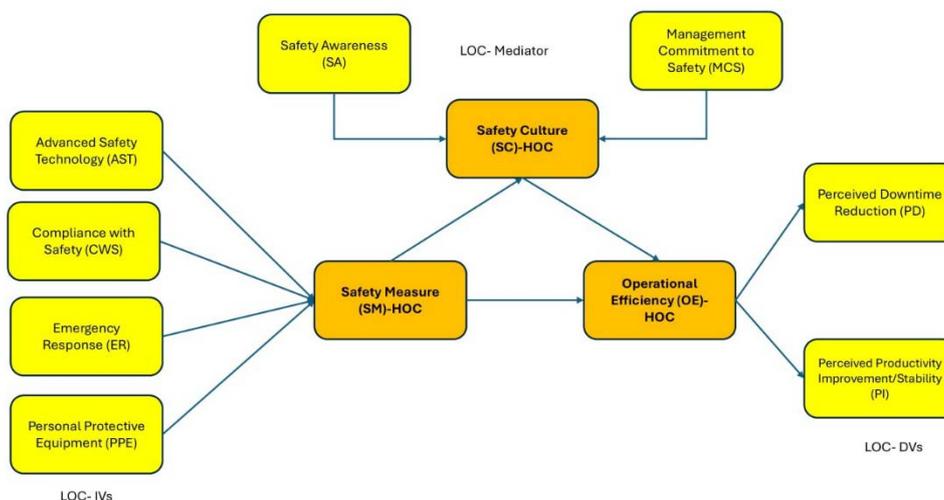


Figure 1. The proposed framework

Synthesizing the above streams, the present study proposes that safety interventions influence operational performance through both direct technical effects and indirect cultural mechanisms. Accordingly, Figure 1 presents the ADNOC HRO-based mediation framework in which Safety Measures (SM) influence Operational Efficiency (OE) directly and indirectly through Safety Culture (SC), with SM, SC, and OE represented as higher-order constructs (HOCs) defined by their lower-order components (LOCs).

As shown in Figure 1, the proposed model specifies three higher-order constructs and their lower-order dimensions to explain how safety interventions translate into operational performance in ADNOC-type environments. Safety Measures (SM-HOC) is positioned as the independent variable and is modeled as a higher-order construct formed by four lower-order components: Advanced Safety Technology (AST), Compliance with Safety (CWS), Emergency Response (ER), and Personal Protective Equipment (PPE). Collectively, these dimensions represent the organization's portfolio of technical, procedural, preparedness, and protective controls, consistent with integrated process safety and operational excellence approaches reported in ADNOC-related practice and governance initiatives (Tayab et al., 2022; Saleem, 2024). Safety Culture (SC-HOC) is modeled as the mediating construct and is represented by two lower-order components: Safety Awareness (SA) and Management Commitment to Safety (MCS). These dimensions capture, respectively, the workforce's attentiveness to risk signals and safe practices, and the leadership signals and resourcing that institutionalize safe decision-making, aligning with occupational safety culture management perspectives and HRO principles emphasizing leadership commitment and mindful organizing (Glebova et al., 2023; Cantu et al., 2021). Operational Efficiency (OE-HOC) is modeled as the dependent variable and is represented by Perceived Downtime Reduction (PD) and Perceived Productivity Improvement/Stability (PI), reflecting an efficiency concept grounded in operational reliability-minimizing disruption and stabilizing performance outcomes (Tayab et al., 2024; Mardanov et al., 2026).

The framework specifies three structural relationships. First, Safety Measures are expected to strengthen Safety Culture (SM → SC) by making safety expectations visible, consistent, and supported through systems, routines, and leadership reinforcement, which supports reliable enactment in day-to-day operations (Cantu et al., 2021; Al Mazrouei et al., 2020). Second, Safety Culture is expected to enhance Operational Efficiency (SC → OE) by reducing operational variability, encouraging early detection and reporting of weak signals, supporting resilient response, and sustaining disciplined execution under pressure-mechanisms consistent with HRO theory and its application in high-hazard environments (Enya et al., 2018; Dingee, 2019). Third, Safety Measures are expected to directly improve Operational Efficiency (SM → OE) by preventing incidents and reducing disruption through better detection, preparedness, and protection, particularly when enabled by digital and technology-based interventions and operational effectiveness practices (Mudaa et al., 2026; Mondal et al., 2026). Finally, the model proposes that Safety Culture mediates the relationship between Safety Measures and Operational Efficiency, indicating that formal barriers and controls deliver sustained performance most effectively when embedded in cultural norms and leadership commitment that ensure consistent implementation under real

operational conditions (Glebova et al., 2023; Tayab et al., 2024).

### 3.2 Framework Testing Roadmap

This paper proposes an HRO-grounded mediation framework in which Safety Measures (SM) influence Operational Efficiency (OE) both directly and indirectly through Safety Culture (SC). All three constructs are modelled as higher-order constructs (HOCs) represented by lower-order components (LOCs): SM (AST, CWS, ER, PPE), SC (SA, MCS), and OE (PD, PI). To transition from conceptual development to empirical verification, Figure 2 presents a structured roadmap for testing, validating, and applying the framework in ADNOC-type high-hazard operational environments.

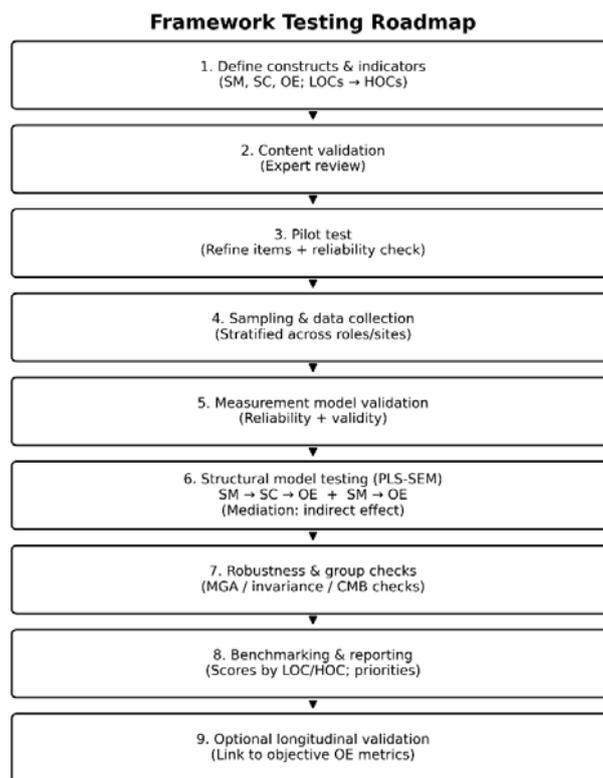


Figure 2. Testing procedure

As shown in Figure 2, framework testing follows a staged procedure that moves from measurement design to empirical validation and organisational use. The process begins with defining constructs and translating LOCs into ADNOC-relevant measurement indicators, including explicit specification of the HOC–LOC structure. Instrument quality is then strengthened through expert content validation and pilot testing to refine wording, confirm clarity, and establish preliminary reliability. After this, data are collected using a sampling approach that ensures representation across relevant roles and operational contexts.

Once data are obtained, the roadmap prioritises measurement model validation (reliability and validity checks) before interpreting structural relationships. The structural model is then tested using PLS-SEM, evaluating both the direct effect (SM → OE) and the mediated pathway (SM → SC → OE) through bootstrapped significance testing. To enhance credibility and generalisability within ADNOC-type settings, the roadmap recommends robustness procedures, including multi-group comparisons, measurement invariance assessment, alternative model evaluation, and common method bias checks. Following validation, the framework can be operationalised for benchmarking by generating LOC/HOC scores to identify improvement priorities. Finally, the roadmap proposes optional longitudinal validation linking construct scores to objective OE indicators to demonstrate sustained operational impact over time.

#### **4. Potential Application of the Framework**

The proposed SM-SC-OE mediation framework as Figure 1 can be applied in ADNOC-type operations as both a diagnostic tool and a roadmap for targeted improvement. Practically, the model enables ADNOC leaders to assess whether operational efficiency outcomes are being constrained by gaps in Safety Measures (such as insufficient technology enablement, weak compliance control, limited emergency readiness, or PPE system weaknesses) or by the cultural mechanism that determines how consistently those measures are enacted under operational pressure. This is consistent with operational excellence and process safety integration approaches that emphasize strengthening barriers and disciplined execution to prevent incidents across upstream and downstream assets (Tayab et al., 2022; Tayab et al., 2024), as well as ADNOC's emphasis on integrated work management to standardize execution and improve governance (Saleem, 2024).

At an implementation level, the framework supports a structured cycle of baseline assessment → intervention design → performance monitoring. First, ADNOC can conduct a baseline maturity assessment using survey-based measurement of the framework's lower-order components-AST, CWS, ER, PPE for Safety Measures; SA and MCS for Safety Culture; and PD and PI for Operational Efficiency-allowing comparison across sites, functions, or contractor-intensive areas. Such diagnostic use aligns with HRO evaluation approaches that emphasize measuring reliability conditions rather than relying solely on lagging incident metrics (Cantu et al., 2021). Second, results can guide targeted interventions. For example, where SM scores are strong but OE outcomes remain weak, the framework suggests prioritizing cultural levers-such as leadership visibility, reinforcement, learning routines, and near-miss reporting quality-because culture is the proposed pathway translating measures into stable performance (Glebova et al., 2023; Al Mazrouei et al., 2020). Conversely, where cultural commitment is high but disruptions persist, interventions may focus on closing specific measure gaps (such as upgrading detection systems, strengthening compliance verification, or improving drill realism and response readiness), supported by the growing role of advanced technology and digitalization in improving both safety and operational performance (Mudaa et al., 2026; Mondal et al., 2026).

The framework can also be embedded into ADNOC's operational governance by linking each

construct to measurable leading indicators and management routines. Safety Measures can be tracked through indicators such as audit closure rate, barrier verification outcomes, emergency drill performance, and PPE readiness. Safety Culture can be reinforced and monitored through indicators such as near-miss reporting quality, safety communication frequency, leadership safety walk participation, and responsiveness to workforce safety suggestions-dimensions consistent with safety culture management logic (Glebova et al., 2023). Operational Efficiency outcomes can be monitored through both perceptual measures (as used in this study) and objective operational metrics such as unplanned downtime hours, recovery time, schedule adherence, and productivity stability, recognizing that reliability-based efficiency is critical in high-hazard systems (Tayab et al., 2024). In addition, the framework provides a basis for evaluating transformation initiatives-such as integrated work management-by testing whether improvements in work governance strengthen culture and, in turn, improve efficiency (Saleem, 2024). Overall, by applying the framework, ADNOC can move from broad safety investment decisions toward evidence-based prioritization-identifying which safety measures deliver the highest operational return when the cultural mechanism is strengthened in parallel.

## 5. Conclusion

This study developed an HRO-based mediation framework (Figure 1) to explain how safety interventions translate into operational performance outcomes in high-risk oil and gas environments. The framework conceptualizes Safety Measures as a higher-order construct formed by Advanced Safety Technology, Compliance with Safety, Emergency Response, and Personal Protective Equipment, and proposes that these measures influence Operational Efficiency both directly and indirectly through Safety Culture, represented by Safety Awareness and Management Commitment to Safety. By positioning Safety Culture as the central mechanism, the framework highlights that safety systems deliver stronger and more sustainable performance when they are embedded into daily routines, reinforced by leadership, and consistently enacted under real operational pressures.

Practically, the framework offers a structured approach for diagnosing performance gaps, designing targeted interventions, and tracking improvement. It enables organizations to distinguish whether operational disruption is primarily driven by weaknesses in safety measures, limitations in cultural adoption, or both. In doing so, it supports more evidence-based prioritization of safety and operational excellence initiatives, ensuring that investments in technology, compliance, preparedness, and protection are matched by the cultural conditions needed for reliable execution. Future research can empirically test the proposed mediation relationships across operational settings and strengthen the model by integrating objective reliability and productivity indicators alongside perceptual measures.

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