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Occupational and Process Risk Assessment Methodologies in Offshore Oil Production: Structured Review and Integration Perspectives

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ABSTRACT

Offshore oil production involves high-pressure hydrocarbon systems, unpredictable weather, and complex organisations. This makes it one of the most challenging environments for safety management. The industry has developed many risk assessment methods over decades, but major accidents still occur. This indicates problems not with lacking methods, but with their selection, application, and integration. This paper reviews risk assessment methods in offshore oil production, covering occupational and process safety. It examines qualitative, semi-quantitative, quantitative, and dynamic probabilistic approaches in offshore settings. The review assesses their contributions and limitations in safety decisions. Key issues include: rare coherent use of qualitative and quantitative methods; marginal role of human and organisational factors in probabilistic models; and weak links between risk outputs and operations like barrier management and maintenance. A trend towards dynamic, real-time risk models better captures evolving risks. The paper proposes a framework to integrate methods across risk assessment stages, linking them to barrier management and organisational decisions.

1. INTRODUCTION

Offshore oil production has long been recognised as one of the most hazardous industrial environments in the world. High-pressure hydrocarbon systems, flammable substances, remote locations, and continuous operations allow a single failure to escalate rapidly with little warning [1]. Over the past two decades, the industry has formalized risk management, developing diverse methods from hazard identification to quantitative probabilistic models [2]. However, accident rates have not declined as expected, suggesting systemic issues beyond a lack of tools.

Part of the explanation lies in how methods are applied. Although offshore risk assessment has developed a wide range of methods, the literature still shows limited integration between qualitative screening, semi-quantitative prioritization, and quantitative modelling. As a result, the outputs of one method are rarely linked systematically to the next stage of decision-making. Qualitative methods dominate early design, quantitative ones come later, and links between them are uncommon. Human and organisational factors, key contributors to major accidents, are marginalised in probabilistic models despite evidence of incomplete risk pictures [3]. The result is a body of assessments that are individually rigorous but collectively fragmented, leaving gaps between what is analysed and what is actually managed at the operational level.

A further issue is the disconnect between risk assessment outputs and the safety barriers through which risk is actually controlled in practice. Barrier management is central to offshore safety, yet ties to formal assessments and performance tracking remain weak [4, 5]. Recommendations thus struggle to inform daily decisions on maintenance, operational limits, or change management.

These gaps drive this paper. It reviews risk assessment methods in offshore oil production across process and occupational safety, evaluating strengths, weaknesses, and integration paths. Rather than endorsing one method, it critically maps the landscape to foster effective combinations.

The remainder of the paper is structured as follows. Section 2 describes the methodology of the review, including the search strategy, selection criteria, and bibliometric overview. Section 3 examines the main categories of risk assessment methods as applied in offshore oil production. Section 4 provides a critical evaluation and identifies key integration gaps. Section 5 proposes a conceptual integrated framework, and Section 6 presents conclusions.

2. METHODOLOGY OF THE REVIEW

This study adopts a structured literature review approach to analyse risk assessment methodologies applied in offshore oil production, with particular emphasis on occupational and process safety integration. The review aims to examine methodological characteristics, analytical assumptions, practical applicability, and integration potential of existing assessment techniques within safety management systems.

2.1 Search strategy and selection criteria

The review was conducted through a systematic search of the Scopus database, selected for its broad coverage of engineering and process safety literature and its structured export functionality. However, relevant studies indexed exclusively in other databases (e.g., Web of Science, Engineering Village, ScienceDirect, and SPE OnePetro) may not have been captured. Therefore, the findings should be interpreted within the scope of the selected database. The search was restricted to English-language journal articles and conference papers published between 2000 and 2025, covering the Engineering and Energy subject areas.

The search string was constructed around three conceptual blocks: general risk assessment terminology, named methodological approaches, and offshore production context identifiers. This structure was intended to retrieve studies that explicitly combine a recognised method with an offshore application, rather than papers that mention risk only in passing:

TITLE-ABS-KEY (("risk assessment" OR "risk management") AND ("HAZOP" OR "HAZID" OR "QRA" OR "bow-tie" OR "FMEA" OR "fault tree" OR "event tree" OR "LOPA" OR "Bayesian network") AND ("oil platform" OR "offshore drilling" OR "petroleum" OR "offshore production"))

From an initial return of 314 records, 39 studies were retained following title, abstract, and full-text screening. The selection process is presented in Figure 1.

Inclusion criteria required that each study: (1) explicitly applied or evaluated at least one named risk assessment method; (2) addressed an offshore oil or gas production context, including drilling, well operations, production platforms, or floating production units; and (3) provided sufficient methodological detail to enable comparison and synthesis. Studies were excluded if they addressed purely structural or mechanical integrity without a risk assessment component, or generic industrial applications without offshore-specific content.

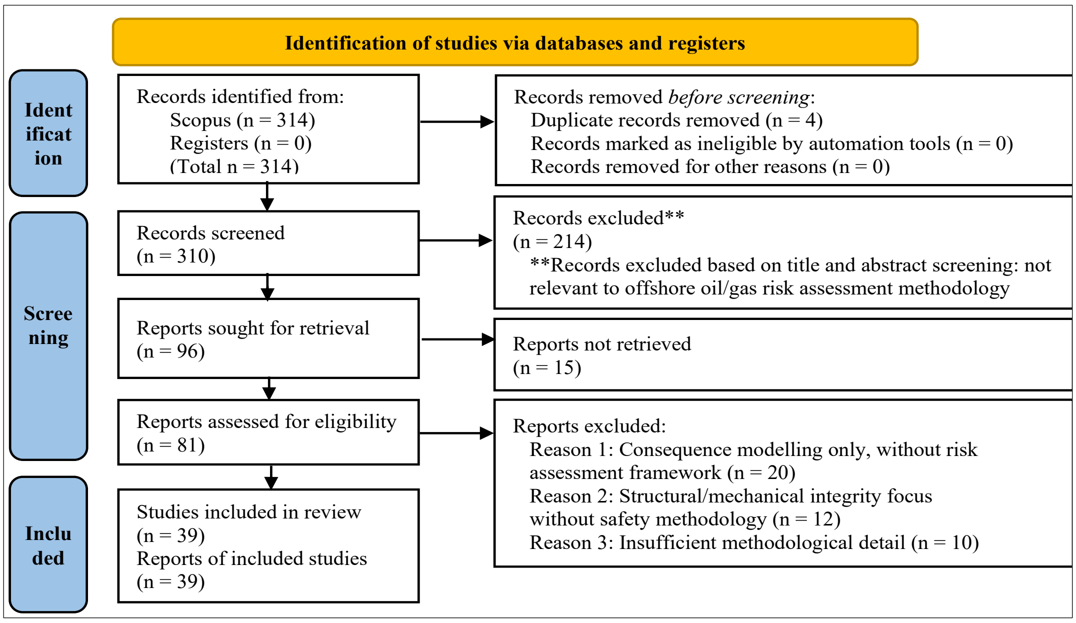

Figure 1. Flow diagram illustrating the literature search and study selection process

2.2 Data classification and synthesis

The 39 included studies were classified according to the primary risk assessment methodology applied, the operational context within offshore oil production, and the safety dimension addressed: process safety, occupational safety, or both. Four main methodological categories were identified based on analytical foundations: qualitative and semi-quantitative approaches; logical-probabilistic and quantitative models; Bayesian and dynamic methods; and human and organisational factor frameworks. This classification forms the basis for the review structure adopted in this paper.

Studies employing multiple methods (e.g., fault tree analysis (FTA) combined with Bayesian networks (BN)) were assigned to the category reflecting their primary analytical contribution. Barrier management studies were classified by the underlying method used to analyse barrier performance, rather than the barrier concept itself.

Data were extracted from each study across the following dimensions: methodology type, offshore application context, safety dimension, and key methodological findings or limitations. Subsequently, all 39 papers underwent a formal quality assessment, where their methodological quality and offshore relevance were rigorously appraised using a three-tier scale (High, Moderate, or Low). The complete study characteristics and resulting quality profiles are detailed in the Appendix Table A1.

2.3 Bibliometric overview

To contextualise the methodological landscape, a bibliometric analysis was performed using VOSviewer 1.6.20. Keyword co-occurrence analysis identified key themes and clusters from author and index keywords in the 314 initial records.

Figure 2 presents the keyword co-occurrence network constructed from the full search corpus. The central dominance of "risk assessment" and "offshore production" as co-occurring terms confirms the relevance of the search strategy. Peripheral clusters around "reliability analysis", "gas industry", and "blowouts" indicate the operational contexts in which risk methods are most frequently reported, while the relative absence of occupational safety terminology in the core of the map points to one of the key integration gaps that this review seeks to address.

Figure 3 presents a focused bibliometric map of method clusters derived from the included studies. Three distinct clusters are visible. The first, centred on BN and dynamic BN, reflects the growing dominance of probabilistic updating methods in recent offshore risk literature. The second cluster groups FTA and Event Tree Analysis (ETA), representing the established logical-probabilistic tradition that has underpinned offshore quantitative risk assessment (QRA) for decades. The third cluster connects QRA, hazard and operability (HAZOP), and layer of protection analysis (LOPA), illustrating the co-occurrence of quantitative and semi-quantitative approaches in process safety applications. The relative size of the Bayesian cluster compared to the others suggests a clear directional shift in the field toward dynamic and data-driven methods over the reviewed period.

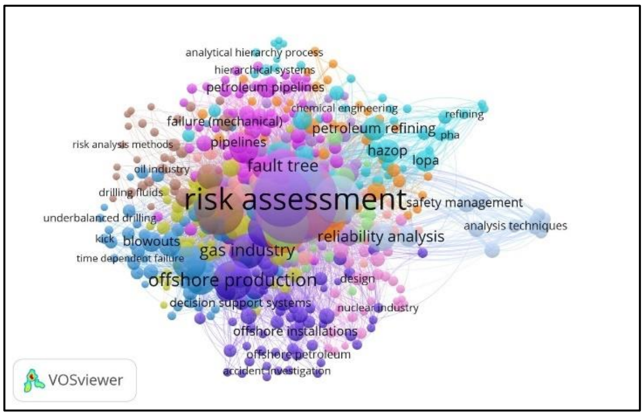

Figure 2. Keyword co-occurrence network

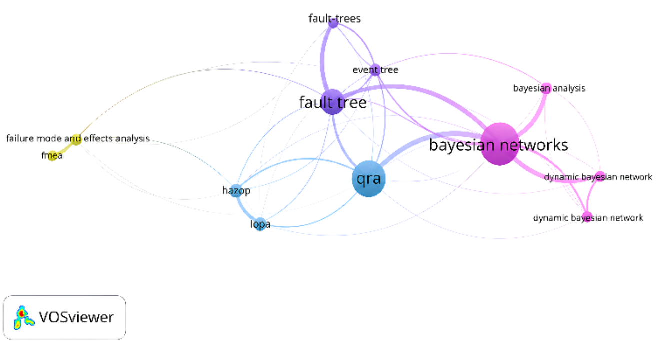

Figure 3. Bibliometric map of method clusters in oil production risk assessment

Taken together, the bibliometric analysis suggests that the literature has developed strongly in the direction of quantitative and probabilistic methods, with Bayesian approaches attracting the most recent attention. However, the limited co-occurrence of human factors and occupational risk terminology with mainstream methodological terms indicates that the integration of these dimensions remains an underexplored area.

Analysis of the full search corpus reveals clear temporal and geographical trends. Publication activity grew steadily from the early 2000s, peaking in 2020, and has remained high since, confirming the field's continued growth (Figure 4).

The United States, China, and Norway dominate geographically (Figure 5), reflecting established offshore industries and strong institutional research traditions.

At the author level, output is concentrated among a small group of researchers led by Khan, F. and Vinnem, J.E. (Figure 6).

Collectively, the bibliometric results show that offshore risk assessment is a mature and growing field, but one that remains methodologically concentrated around a limited set of approaches, countries, and authors. This supports the central argument of the review: the literature has expanded, yet integrated occupational-process risk assessment remains underdeveloped.

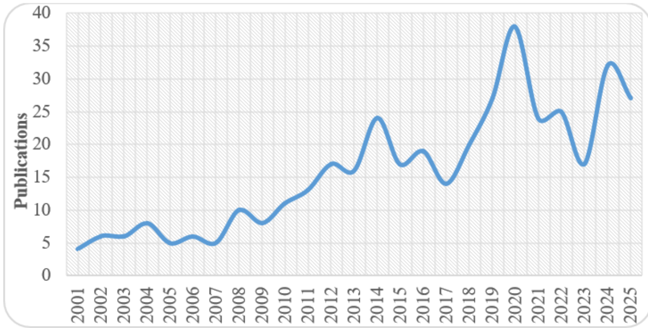

Figure 4. Annual publication trend (2001–2025)

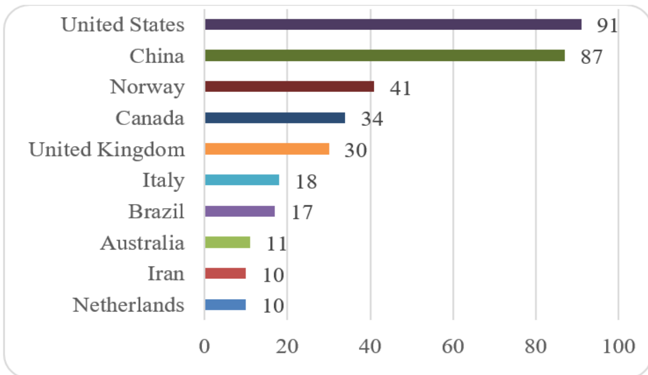

Figure 5. Geographical distribution of publications (top 10 countries)

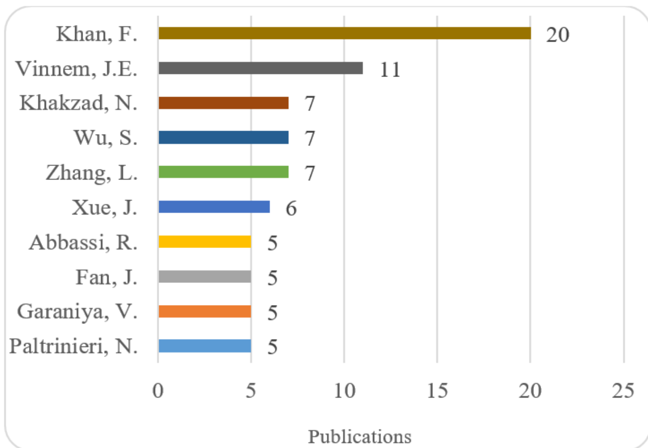

Figure 6. Most prolific authors in offshore oil production risk assessment research

3. RISK ASSESSMENT METHODOLOGIES IN OFFSHORE OIL PRODUCTION

The following section examines the principal categories of risk assessment methodologies identified in the reviewed literature. The analysis is organised into four groups reflecting distinct analytical traditions: qualitative and semi-quantitative approaches, logical-probabilistic and quantitative models, Bayesian and dynamic risk assessment methods, and human and organisational factor integration frameworks. This categorisation is not intended to imply that these approaches are mutually exclusive. In practice, many studies combine elements from more than one group. Rather, it reflects the primary analytical logic of each methodology and provides a basis for structured comparison. For each category, the review considers how the methods have been applied in offshore oil production contexts, what they contribute to safety decision-making, and where their limitations lie.

3.1 Qualitative and semi-quantitative approaches

Qualitative and semi-quantitative methods represent the foundational layer of risk assessment in offshore oil production, primarily serving hazard identification and early-stage risk prioritisation during design reviews, pre-startup evaluations, and periodic operational assessments.

HAZOP study remains one of the most widely used qualitative techniques in offshore settings, particularly for mobile drilling units and production facilities [6]. Its strength lies in a facilitated, team-based structure that draws on tacit operational knowledge difficult to capture through purely analytical means.

Bow-tie analysis is similarly prominent because it provides a clear visual representation of threats, preventive barriers, consequences, and mitigative barriers around a central hazardous event [7, 8]. In offshore practice, this makes the method especially useful for communicating risk control logic to operational teams. A conceptual bow-tie representation of an occupational accident scenario is presented in Figure 7.

Semi-quantitative methods extend this early-stage layer by adding structured prioritisation under uncertainty. Fuzzy multi-criteria approaches have been used to improve risk ranking where expert judgment is uncertain or incomplete [9]. FMEA-based approaches are also common, including hybrid versions that combine fuzzy logic, Bayesian updating, and multi-criteria decision tools for offshore installation risks, FPSO explosion assessment, and other offshore applications [10-12]. Overall, these methods are practical and accessible, but they remain largely static, depend heavily on subjective scoring, and do not fully quantify barrier effectiveness or organisational influences.

The principal qualitative and semi-quantitative methods identified in the reviewed literature are summarised in Table 1.

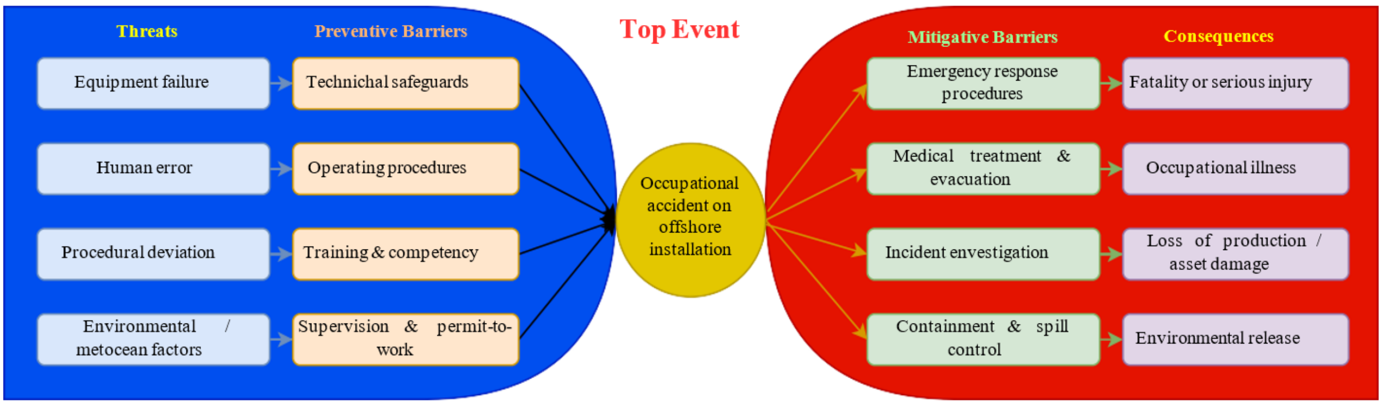

Figure 7. Conceptual bow-tie representation of an occupational accident scenario in offshore oil production, based on established barrier-based risk analysis approaches

Table 1. Role of qualitative hazard identification methods in early-stage occupational risk assessment in offshore oil production

Method	Primary Function	Offshore Application	Key Strength	Key Limitation
HAZOP	Process deviation identification	Drilling units and production platforms [7]	Systematic; multidisciplinary team review	Resource-intensive; static output
HAZID	High-level hazard identification	Early design stage of offshore facilities	Fast; broad hazard coverage	Lacks analytical depth
What-If Analysis	Scenario-based brainstorming	Operational safety reviews	Flexible; adaptable	Less systematic; facilitator-dependent
Risk Matrix	Likelihood-consequence prioritisation	Risk ranking across hazard scenarios [3]	Simple; accessible	Subjective; limited uncertainty handling
Bow-Tie Analysis	Barrier mapping around top event	Offshore production platforms [8, 9]	Visual; communicates risk control structure to operations	Static; barrier effectiveness not quantified
FMEA / Fuzzy FMEA	Failure mode identification and effect analysis	FPSO explosion assessment; offshore installation risk [10-14]	Structured; extensible with fuzzy methods	Does not capture systemic or organisational failures

3.2 Logical-probabilistic and quantitative models

FTA, ETA, and QRA form the classical backbone of probabilistic risk assessment in offshore oil production. FTA traces failure combinations leading to a top event, while ETA maps outcomes after an initiating event. Together, they underpin most formal QRA studies. The reviewed studies show that these methods have been applied to FPSO fire and explosion assessment, blowout frequency estimation, vapour cloud explosion modelling, and major incident frequency estimation [13-16]. They have also been adapted into offshore-specific tools such as QRA interfaces for fixed platforms and fuzzy ETA models for drilling barrier assessment [17, 18]. More recent work has extended QRA to drone-assisted personnel safety and to innovative subsurface well completion systems [19, 20].

These methods are analytically rigorous and transparent, but they commonly assume static system parameters and limited interaction between events. This is a serious limitation in offshore environments, where barrier performance changes over time and operational conditions evolve continuously. Xue et al. [21] showed that barrier performance changes over time in ways that static models cannot capture, motivating the shift toward dynamic approaches.

3.3 Bayesian and dynamic risk assessment

BN dominate recent offshore risk studies. They update probabilities with new evidence and model complex dependencies better than fault trees. Early studies introduced hybrid causal logic as a bridge between probabilistic reasoning and offshore risk analysis, followed by Bayesian approaches to offshore drilling risk quantification [22, 23]. Subsequent work extended these ideas into dynamic safety risk analysis, managed pressure drilling, and time-dependent failure modelling [24, 25]. More recent studies have applied BN to deepwater drilling, barrier warnings, real-time risk diagnosis, blowout analysis, and barrier performance under different maintenance strategies [26-35]. This body of work shows a clear shift from static estimation toward dynamic updating and operational monitoring.

The main strength of these methods is their ability to capture conditional dependencies, uncertainty propagation, and evolving risk profiles. Their main limitation is dependence on expert elicitation when historical data are scarce, together with the computational and practical complexity of implementing dynamic models in real offshore operations. FRAM- and NK-based extensions also show promise, but they remain more difficult to operationalise than conventional QRA or barrier-based tools [31, 32].

3.4 Occupational and human-factor integration

Despite the sophistication of probabilistic and dynamic methods reviewed in the preceding sections, human and organisational factors remain inadequately integrated into most offshore risk assessment frameworks. The majority of quantitative models treat human error as a fixed probability input rather than a dynamic variable shaped by workload, fatigue, organisational culture, and situational context.

Beyond human error probability estimation, occupational safety in offshore oil production also involves worker exposure to multiple interacting hazards, including confined spaces, simultaneous operations, lifting activities, high-pressure equipment, adverse weather conditions, fatigue, and extended shift work. Unlike process safety, which primarily focuses on preventing major accident hazards, occupational safety requires continuous assessment of individual worker exposure, behavioural factors, supervision quality, permit-to-work implementation, safety culture, and organisational learning. However, these aspects remain only partially represented in existing offshore risk assessment methodologies and are rarely integrated into probabilistic risk models.

The reviewed studies show that Human Reliability Analysis can be incorporated into offshore risk assessment, but the integration remains inconsistent. Petro-HRA work highlights conceptual differences between nuclear and petroleum risk perspectives, which directly affect the treatment of human error probabilities in QRA [36]. Graph-based and fuzzy approaches have also been proposed for offshore operational safety and barrier reliability when historical data are limited [37].

Collectively, these studies confirm that HRA integration into offshore risk assessment is possible but remains methodologically inconsistent, with no established standard for incorporating human error probabilities into broader quantitative and dynamic frameworks.

Future methodological developments should therefore move beyond treating human error as an isolated probability parameter and instead incorporate organisational factors, workforce competence, safety culture, permit-to-work effectiveness, and dynamic worker exposure into integrated offshore risk assessment frameworks. Such integration would provide a more comprehensive representation of occupational risk throughout the operational lifecycle.

4. CRITICAL EVALUATION AND IDENTIFIED GAPS

The review of qualitative, quantitative, Bayesian, and human-factor methodologies reveals a field that has advanced considerably in technical sophistication but remains fragmented in practice. Three persistent gaps emerge consistently across the literature.

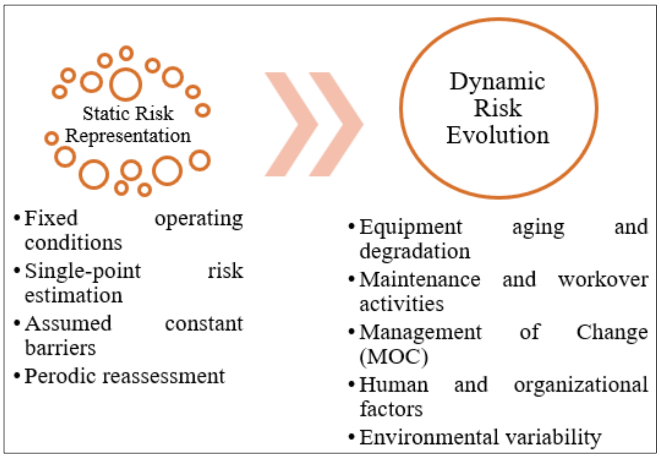

Figure 8. Conceptual comparison between static and dynamic risk representations in offshore oil production systems

The majority of methods produce point-in-time assessments that do not reflect how risk evolves during operations. Barrier performance degrades with equipment ageing, procedural drift, and changing operational conditions, yet most QRA models assume fixed failure rates. Perez and Tan [38] identify this limitation directly in proposing the accident precursor probabilistic method (APPM) framework: conventional QRA methods do not incorporate risk influencing factors or current operational conditions, meaning their outputs cannot be updated as conditions change. The shift toward dynamic Bayesian approaches partially addresses this, but dynamic models remain computationally intensive and difficult to implement at operational scale. This static-dynamic distinction is illustrated conceptually in Figure 8.

Qualitative and quantitative approaches are also rarely applied in a coordinated sequence. HAZOP and bow-tie studies are conducted at design stage and seldom updated; QRA models are built separately and rarely reference the hazard register produced by earlier qualitative work. The principal characteristics, strengths and limitations of the reviewed methods are summarised in Table 2.

Risk assessment in offshore settings has traditionally been a compliance-driven activity, producing documentation rather than operational tools. Reis et al. [39] demonstrate a practical response through real-time monitoring of LOPA-based bow-tie barriers on offshore drilling units, showing that continuous barrier integrity monitoring significantly improves decision-making visibility and enables preventive maintenance, representing precisely the kind of operational connection that most conventional risk assessments fail to establish.

Table 2. Comparative overview of occupational risk assessment methods applied in oil production

Method Category	Representative Methods	Primary Output	Key Strength	Key Limitation in Offshore Context
Qualitative	HAZOP, HAZID, What-If	Hazard register, deviation list	Team-based; captures system interactions early	Static; no probability estimation
Semi-quantitative	Risk matrix, Bow-tie, FMEA, LOPA	Risk ranking, barrier map	Accessible; links hazards to barriers	Subjective scoring; barrier effectiveness not quantified
Logical-probabilistic	FTA, ETA, Fuzzy FTA/ETA	Failure probability, accident sequence	Systematic causal analysis; combinable with QRA	Assumes static parameters and event independence
Quantitative (QRA)	Individual/societal risk metrics	Risk metrics vs. acceptance criteria	Regulatory compliance; design-stage decision support	Relies on generic databases; does not update with operations
Bayesian and Dynamic	BN, DBN, HCL	Updated probabilities, dynamic risk profile	Models dependencies; enables real-time risk updating	Expert elicitation dependency; computational complexity
Human and Organisational	HRA, Petro-HRA, FRAM	Human error probabilities, functional model	Addresses human contribution to risk	Methodologically fragmented; inconsistent integration with QRA

5. TOWARD AN INTEGRATED RISK ASSESSMENT FRAMEWORK

The gaps identified in the preceding section point toward a common need: a structured way of connecting different assessment approaches across the lifecycle of offshore oil production rather than applying them as isolated exercises. The conceptual framework proposed here, illustrated in Figure 9, addresses this through three interconnected blocks.

The left block represents a staged assessment process in which qualitative, semi-quantitative, and quantitative methods are applied in sequence. Qualitative approaches identify hazards and define critical scenarios; semi-quantitative methods prioritise risks and define required protection layers; quantitative and probabilistic models then provide numerical estimates drawing on outputs of earlier stages. This staged logic reflects the analytical progression from broad hazard identification to specific risk quantification that effective offshore safety management requires.

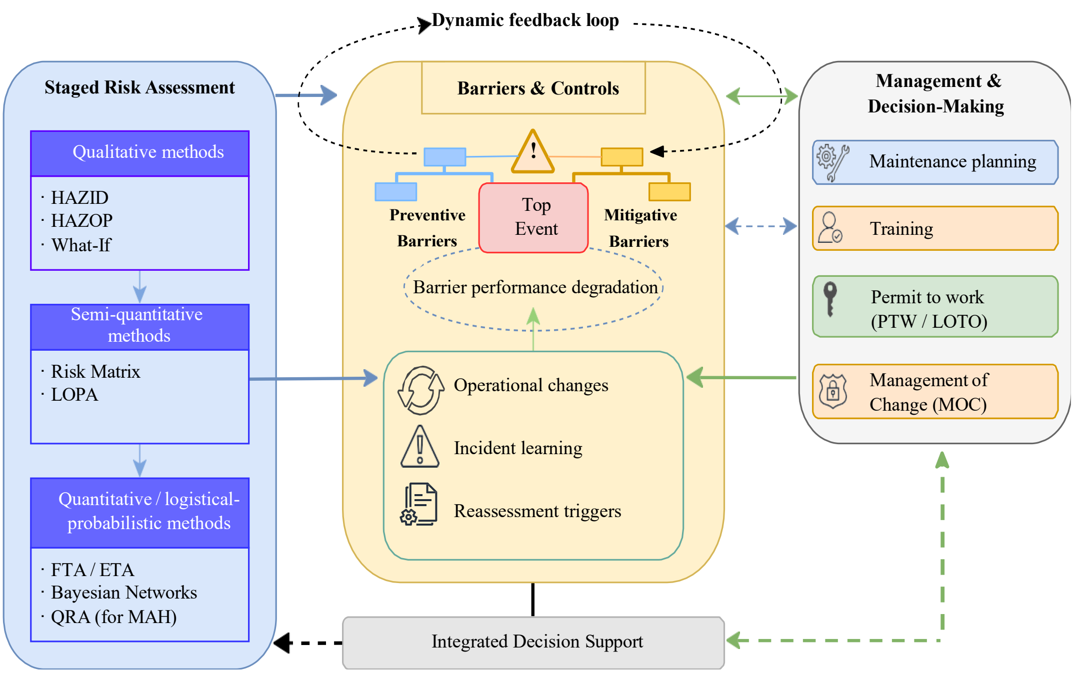

Figure 9. Conceptual integrated framework for occupational and process risk assessment in offshore oil production

The central block addresses barrier management. Preventive barriers reduce the likelihood of the top event; mitigative barriers limit its consequences. Barrier performance is not static: equipment degrades, procedures drift, and organisational conditions change. The framework represents this explicitly through a barrier performance degradation loop, which feeds information back into the assessment process and triggers reassessment when barrier integrity falls below acceptable thresholds.

The right block represents the management functions that maintain barrier integrity in practice: maintenance planning, training and competency, permit-to-work controls, and management of change. These are the operational translation of risk assessment outputs. A dynamic feedback loop connects all three blocks, and an integrated decision support function consolidates their outputs into a unified basis for operational decisions.

The framework does not introduce new methods. Its value lies in providing a conceptual structure for how existing methods can be sequenced, connected, and translated into operational action.

6. CONCLUSIONS

This paper has presented a structured review of risk assessment methodologies applied in offshore oil production, examining qualitative, semi-quantitative, quantitative, Bayesian, and human-factor approaches across a systematically selected corpus of peer-reviewed literature.

Several conclusions emerge from the analysis. First, the offshore industry has a strong set of risk assessment methods, but their use is fragmented. Qualitative and quantitative methods are rarely combined, and human and organizational factors are inconsistently included in probabilistic models. Second, literature increasingly favors dynamic Bayesian models that capture time-varying risks. However, these models are computationally intensive and hard to apply operationally. Third, the key limitation is the gap between risk assessments and operational decisions, especially barrier management and maintenance planning.

The framework offers a conceptual synthesis of these issues. It sequences complementary methods, links assessments to barrier management, and integrates operational functions like maintenance planning, training, and management of change. It builds on existing methods while providing a conceptual basis for future empirical testing and operational validation. Future research should focus on three directions: the development of standardised protocols for integrating HRA outputs into offshore QRA models; the operational validation of dynamic Bayesian frameworks under real field conditions; and the design of decision support interfaces that translate risk assessment findings into actionable barrier management decisions in real time.

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NOMENCLATURE

HAZID	Hazard identification
HAZOP	Hazard and operability
LOPA	Layer of protection analysis
ETA	Event tree analysis
FTA	Fault tree analysis
FMEA	Failure mode and effects analysis
OMT	Organizational, human, and technical
FPSO	Floating production, storage and offloading
MPD	Managed pressure drilling
UBD	Underbalanced drilling
SPAR-H	Standardized plant analysis risk-human
HRA	Human reliability analysis
APPM	Accident precursor probabilistic method
MOC	Management of change
QRA	Quantitative risk assessment
HCL	Hybrid causal logic
MAH	Major accident hazards
PTW	Permit-to-work

APPENDIX

Table A1. Primary characteristics of included studies

No.	Author (Year)	Country	Application Context	Method Used	Offshore Relevance	Methodological Quality	Study Type
[1]	Brandsaeter (2002)	Norway	Offshore QRA general	QRA review	High	High	Journal
[2]	Vinnem et al. (2006)	Norway	Norwegian offshore sector	Risk indicators, barriers	High	High	Journal
[3]	Ramos et al. (2020)	USA	Oil and gas operations	HRA methods review	Moderate	Moderate	Conference
[4]	Bubbico et al. (2020)	Italy/Norway	Offshore O&G (Goliat platform)	Dynamic BN, barrier assessment	High	High	Journal
[5]	Pitblado (2013)	Australia	Offshore developments	Barrier management, bow-tie	High	Moderate	Conference
[6]	Jones (2014)	USA	Mobile offshore drilling units	HAZOP	High	Moderate	Conference
[7]	Grant et al. (2017)	Australia	Offshore production platforms	Bow-tie	High	Moderate	Conference
[8]	Jones & Israni (2012)	USA	Offshore platform design	Bow-tie	Moderate	Moderate	Conference
[9]	Nabizadeh et al. (2021)	Iran	Oil industry HSE	Fuzzy FMEA-VIKOR	Moderate	Moderate	Journal
[10]	Gran et al. (2012)	Norway	Offshore process equipment	Risk OMT, BBN, FTA, ETA	High	High	Journal
[11]	Sun et al. (2016)	China	FPSO topsides	FMEA + CFD	High	Moderate	Conference
[12]	Yu et al. (2025)	China	FPSO anchor pile installation	Hybrid FMEA + spherical fuzzy	High	High	Journal
[13]	Suardin et al. (2009)	USA	FPSO fire and explosion	QRA + bow-tie	High	High	Journal
[14]	Borello et al. (2011)	Italy	Offshore blowout events	QRA (RAINBOW)	High	Moderate	Conference
[15]	Das & Weinberg (2012)	Canada	Offshore production platform	QRA (VCE modelling)	High	High	Journal
[16]	Emery et al. (2013)	UK	Offshore assets (FPSO, fixed)	QRA (major incident frequencies)	High	Moderate	Conference
[17]	Wang et al. (2020)	Malaysia	Fixed offshore platforms	QRA interface	High	High	Journal
[18]	Ramzali et al. (2015)	Iran	Offshore drilling system	Fuzzy ETA + FTA + RBD	High	High	Journal
[19]	Leong et al. (2025)	Malaysia	Offshore production platforms	QRA + drone technology	High	Moderate	Journal
[20]	Zhen et al. (2018)	China/Norway	Subsurface well completion (UDS)	QRA + ALARP	High	Moderate	Journal
[21]	Xue et al. (2013)	China/Norway	Offshore drilling blowouts	Barrier model + ETA + FTA	High	High	Journal
[22]	Røed et al. (2009)	Norway	Offshore operational phase	HCL + BBN	High	High	Journal
[23]	Khakzad et al. (2013)	Canada	Offshore drilling operations	BN + bow-tie	High	High	Journal
[24]	Abimbola et al. (2014)	Canada	Offshore drilling (UBD)	Dynamic bow-tie + BN	High	High	Journal

[25]	Abimbola et al. (2015)	Canada	Managed pressure drilling	BN	High	High	Journal
[26]	Bhandari et al. (2015)	Australia	Deepwater MPD and UBD	BN	High	High	Journal
[27]	Zhang et al. (2018)	China	Offshore MPD phases	DBN + uncertainty analysis	High	High	Journal
[28]	Chang et al. (2019)	China	Deepwater drilling riser	BN + evidence theory	High	High	Journal
[29]	Wu et al. (2019)	China	Offshore downhole drilling	Real-time BN	High	High	Journal
[30]	Bijay et al. (2020)	India	Offshore drilling (kick scenario)	BN + real-time barrier monitoring	High	High	Journal
[31]	Pezeshki et al. (2020)	Italy/Norway	Offshore drilling	FRAM + event tree	High	Moderate	Conference
[32]	Liu et al. (2022)	China	Subsea blowout accidents	DBN + NK model	High	High	Journal
[33]	Wu et al. (2022)	China	Offshore well safety barriers	Hybrid DBN + Markov	High	Moderate	Journal
[34]	Chen et al. (2021)	China	Offshore drilling blowout	BN + operational data	High	High	Journal
[35]	Yin et al. (2021)	China	Offshore well blowout	BN + SPAR-H HRA	High	High	Journal
[36]	Bansal et al. (2019)	Norway	Norwegian oil and gas industry	Petro-HRA	Moderate	Moderate	Conference
[37]	Jaculli et al. (2019)	Brazil	Offshore oil wells	Graph-based methodology + BIS	High	Moderate	Conference
[38]	Perez & Tan (2018)	Brazil	Offshore drilling blowouts	APPM + BN + RIF	High	High	Journal
[39]	Reis et al. (2023)	Brazil	Offshore drilling units	LOPA + bow-tie monitoring	High	Moderate	Conference