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THE ETHICS OF THE PETROLEUM ENGINEER IN THE 21ST CENTURY: GOVERNANCE, TECHNOLOGICAL RISK, AND RESPONSIBILITY TOWARDS SOCIETY

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ABSTRACT

The activity of the petroleum engineer is profoundly influenced by rapid technological developments, the intensification of environmental regulations, and increasing societal expectations regarding corporate responsibility. This paper proposes an original analysis of engineering ethics in the petroleum sector, moving beyond classical descriptive approaches and focusing on the relationship between technological governance, risk management, and the moral responsibility of the technical professional. The methodology combines the analysis of international academic literature, recent regulatory documents, and relevant case studies from the global and regional petroleum industry. The results highlight that modern engineering ethics cannot be reduced to compliance with codes of conduct, but must be understood as an active professional competence, integrated into technical decision-making processes.

Keywords: engineering ethics, petroleum engineering, governance, industrial risk, sustainability.

INTRODUCTION

The contemporary petroleum industry operates in a context characterized by technological uncertainty, geopolitical pressures, and structural transformations driven by the global energy transition. Within this framework, the role of the petroleum engineer is no longer limited to production optimization or technical problem-solving, but also includes a complex ethical dimension related to risk assessment, the protection of the public interest, and accountability for the consequences of technical decisions.

Recent literature in applied ethics emphasizes that major industrial accidents are rarely the result of a single technical failure [3],[9]. Instead, they are typically the outcome of chains of organizational and professional decisions in which economic considerations have prevailed over safety and prevention [9]. Consequently, the analysis of ethics in petroleum engineering becomes an essential tool for understanding how organizational culture, governance structures, and professional autonomy influence engineers' behavior [1],[4],[5].

The aim of this paper is to provide an updated and original perspective on the ethics of the petroleum engineer, focusing on three main directions: (i) redefining professional responsibility in the context of major technological risks; (ii) the role of governance and regulation in supporting ethical behavior; and (iii) the implications for the Romanian petroleum industry.

ENGINEERING ETHICS AS A PROFESSIONAL COMPETENCE

From compliance to ethical reasoning

Traditional approaches to professional ethics in engineering have focused primarily on compliance with rules and codes of conduct [1],[4],[5]. However, recent research in engineering ethics argues that mere normative compliance is insufficient in the face of the complex risks associated with modern industrial systems [7]. Ethics must be understood as a form of professional reasoning, involving the evaluation of consequences, the identification of affected stakeholders, and the anticipation of long-term effects. In petroleum engineering, this paradigm shift is particularly relevant, as technical decisions are often made under conditions of uncertainty, time pressure, and incomplete information. The ability of engineers to formulate autonomous ethical judgments thus becomes an essential competence, comparable in importance to technical expertise.

Responsibility in relation to risk and uncertainty

A distinctive feature of engineering ethics in the petroleum sector is its direct relationship with industrial risk [4],[5]. Hydrocarbon exploitation involves low-probability but potentially catastrophic risks [9]. From an ethical perspective, this type of risk raises the issue of responsibility for events with severe consequences, even when their probability is considered statistically acceptable. The concept of the “duty of precaution”, widely discussed in the literature, imposes a moral obligation on engineers to adopt solutions that reduce risks to a minimum reasonable level, even in the absence of complete scientific certainty. This approach frequently comes into conflict with economic models oriented toward short-term efficiency.

GOVERNANCE, ORGANIZATIONAL CULTURE, AND ETHICS

The influence of organizational structures

Sociological studies of major industrial accidents highlight the decisive role of organizational culture in shaping the ethical behavior of engineers [2],[9]. Organizations that penalize the reporting of problems or reward exclusively financial performance create environments in which ethical compromises become normalized.

In the petroleum industry, subcontracting structures and complex chains of responsibility can dilute individual accountability. Engineers may find themselves executing decisions established at the managerial level, without having a real possibility to influence project direction. From an ethical standpoint, this phenomenon raises the issue of distributed responsibility and the limits of professional obedience.

The role of regulation and transparency

Technical and environmental regulations play a crucial role in supporting ethical behavior by providing a minimum framework for safety and responsibility [1-3]. However, the literature also shows that excessive formalistic regulation may lead to a bureaucratic approach to ethics, in which procedural compliance replaces genuine moral reflection.

Decision-making transparency and public access to information regarding the risks and impacts of petroleum projects are considered effective mechanisms of accountability. Non-financial reporting, mandated at the level of the European Union, has contributed to the integration of ethical aspects into corporate strategies [6], but its effectiveness depends on the quality and honesty of the information disclosed.

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AI-ENABLED DECISION MAKING AND ETHICAL PARAMETERS

The increasing use of artificial intelligence (AI) and data-driven optimization in petroleum engineering (e.g., drilling automation, predictive maintenance, reservoir management, logistics, and HSE analytics) introduces a distinct set of ethical concepts that complement classical engineering ethics. When AI systems influence operational decisions, ethical responsibility becomes partly mediated by models, data, and software governance, and therefore must be treated as an explicit component of technical design and risk management.

Core ethical concepts for AI in high-risk industrial domains

In the context of AI-enabled decision support, several ethical concepts become operational requirements rather than abstract principles:

Accountability and responsibility allocation: clear assignment of who is responsible for model design, validation, deployment, monitoring, and override decisions (engineers, management, vendors, and regulators).

Transparency and explainability: the ability to provide technically meaningful explanations for recommendations, especially when outcomes affect safety, environment, or public trust.

Reliability, robustness, and safety: resistance to distribution shift, sensor failures, adversarial or unexpected inputs, and the capacity to fail safely.

Human agency and oversight: ensuring engineers retain real authority to question, override, or halt operations when model outputs conflict with engineering judgment or safety signals.

Fairness and non-discrimination: avoiding systematic bias in workforce-related AI (hiring, performance, safety monitoring) and in community-impact assessments.

Privacy and data stewardship: proportionality in collecting and using personal and operational data, secure retention, and legitimate use limitations.

Environmental responsibility: incorporating ecological externalities (emissions, spills, biodiversity impact) into model objectives and constraints, not only into reporting.

From principles to parameters: embedding ethics into the variation (objective) function

A practical way to integrate AI ethics into engineering practice is to formalize ethical constraints and performance indicators as parameters within the optimization or “variation” function used by AI systems. Instead of optimizing only efficiency or cost, the objective can be extended to include ethically relevant terms for the area of interest (AOI) and for environmental aspects.

An illustrative extended objective can be expressed as:

$$J = w_{cost} \cdot C + w_{prod} \cdot (-P_{loss}) + w_{risk} \cdot R + w_{env} \cdot E + w_{unc} \cdot U + w_{exp} \cdot (-X) + w_{comp} \cdot (-K)$$

where C represents economic cost, P_{loss} captures production losses, R is a quantified safety/major-accident risk indicator, E is an environmental impact score (e.g., expected spill impact + CO_2e intensity), U penalizes epistemic uncertainty and out-of-distribution conditions, X is an explainability/traceability score (higher is better), and K is a compliance/stakeholder acceptability score (higher is better). The weights w_* reflect governance decisions and must be justified, documented, and periodically reviewed.

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Ethical data inputs for the AOI and environmental aspects

To operationalize the terms above, the AI pipeline should include structured data elements that capture ethical concepts:

AOI stakeholder map: workers, local communities, regulators, contractors, and environment-as-stakeholder; documented impact pathways.

Risk metrics: barrier health indicators, probability–severity matrices, leading indicators, and "stop-work" triggers linked to model confidence.

Environmental metrics: CO_2e per barrel (or per energy unit), flaring/venting rates, produced-water handling quality, spill consequence modelling, and sensitive-area proximity indices.

Uncertainty and data quality: missingness rates, sensor drift, model calibration error, dataset representativeness, and drift detection outputs.

Explainability artifacts: feature importance summaries, counterfactual examples, and decision logs that allow post-event accountability.

Governance controls: model versioning, validation reports, audit trails, change management approvals, and vendor responsibility clauses.

Governance requirements for ethical AI deployment

Embedding ethics into the objective function is insufficient without governance mechanisms that ensure continued alignment in real operations. The following requirements are recommended:

Pre-deployment validation under realistic scenarios, including stress tests for rare but catastrophic events and for distribution shifts.

Human-in-the-loop decision protocols that define when an engineer must review, when operations must pause, and how overrides are recorded and protected from retaliation.

Continuous monitoring (performance, drift, safety incidents, near-misses) with clear thresholds that trigger retraining or withdrawal of the system.

Independent audits and periodic ethical review, aligned with internal HSE management systems and external regulatory expectations.

Environmental guardrails as hard constraints where appropriate (e.g., absolute emission caps, protected areas), not merely soft penalties.

CASE STUDIES AND ETHICAL LESSONS

The ethical analysis of major industrial accidents in the petroleum sector provides an essential empirical framework for understanding the limits of technical decision-making and professional responsibility. The case studies presented below are approached from an analytical perspective, focusing on decision-making mechanisms, governance, and organizational culture, rather than on a purely factual narration of events.

The Deepwater Horizon explosion (Gulf of Mexico, 2010)

The Deepwater Horizon disaster (Figure 1) represents one of the most extensively studied examples of systemic failure in modern petroleum engineering. Subsequent investigations showed that the accident was not the result of an isolated technical malfunction, but of an accumulation of managerial and engineering decisions made in a context dominated by economic pressures and time constraints [10]. From an ethical perspective, the case reveals a central issue: the normalization of deviance. Procedures initially regarded as exceptions gradually became routine practices, as the absence of previous incidents was erroneously interpreted as evidence of safety [10]. Engineers were confronted with genuine technical ambiguities regarding well integrity, yet these signals were reinterpreted to justify the continuation of operations.

***Figure 1**. Deepwater Horizon explosion in the Gulf of Mexico on April 20, 2010* [11]

The main ethical lesson derived from this case is the necessity of institutionalizing precaution. Engineers must have real professional authority to halt operations when technical data are inconclusive or contradictory. In this context, professional ethics is not limited to procedural compliance, but involves the capacity to challenge organizational decisions when risk exceeds morally acceptable limits.

The Exxon Valdez oil spill (Alaska, 1989)

The Exxon Valdez oil spill (Figure 2 and Figure 3) highlights a complementary dimension of engineering ethics: long-term responsibility for environmental and community impacts. Post-accident analyses indicated that the lack of technical redundancy, deficiencies in crew training, and the underestimation of failure scenarios contributed decisively to the magnitude of the disaster [13].

From an ethical standpoint, the case raises the issue of the relationship between economic efficiency and the obligation of prevention. Design and operational decisions were influenced by cost-reduction objectives, at the expense of additional safety measures considered unlikely from a risk management perspective.

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Figure 2*. Exxon Valdez oil spill in the Prince William Sound, Alaska, on March 24, 1989* [12]

Figure 3*. Exxon Valdez oil spill clean-up* [13]

The major ethical lesson is that engineering responsibility does not end with compliance with minimum legal standards. Engineers have a moral obligation to consider long-term ecological consequences, including situations in which such consequences cannot be immediately quantified economically. Exxon Valdez contributed to redefining corporate responsibility and to the introduction of stricter regulations, demonstrating that ethical failures can profoundly reshape the normative framework of an industry.

Cross-cutting ethical lessons

The comparative analysis of these two cases highlights a set of common ethical lessons: the importance of organizational cultures that encourage the expression of technical concerns, the need to separate risk assessment from financial pressures, and the essential role of engineers' professional autonomy. In the absence of these elements, even the most advanced technological systems can become sources of major risk.

These case studies confirm that accident prevention in the petroleum industry is not exclusively a technical issue, but a deeply ethical one, involving values, responsibility, and governance.

IMPLICATIONS FOR THE ROMANIAN PETROLEUM INDUSTRY

The Romanian petroleum industry is undergoing a process of adaptation to European standards of sustainability and governance [6],[8]. Beyond technical challenges related to mature infrastructure, there is an increasing need to strengthen ethical culture at the organizational level.

Integrating engineering ethics into continuing professional development, developing internal reporting mechanisms, and aligning managerial incentives with safety and environmental objectives represent essential directions for risk reduction and for increasing public trust. Technical universities play a strategic role in this process by educating engineers capable of exercising independent moral judgment.

CONCLUSIONS AND RELEVANCE FOR ENGINEERING PRACTICE

The present analysis confirms that the ethics of the petroleum engineer must be approached as an integrated dimension of modern engineering practice, particularly in contexts characterized by high technological risk and significant social impact. From the perspective of current industrial and academic requirements, ethics can no longer be reduced to a formal set of rules, but constitutes an active professional competence, indispensable to technical decision-making.

The analyzed case studies demonstrate that major accidents in the petroleum industry are the result of systemic failures, in which engineering decisions are influenced by organizational, economic, and cultural factors. In both the Deepwater Horizon and Exxon Valdez cases, the absence of a robust ethical governance framework and the erosion of engineers' professional autonomy contributed to the amplification of risks and negative consequences.

For engineering practice, the implications are clear: petroleum engineers must assume an active role in the evaluation and communication of risks, even when these conflict with short-term economic objectives. Strengthening organizational culture, protecting internal reporting mechanisms, and linking managerial performance to safety and environmental indicators are essential conditions for preventing industrial disasters.

From the perspective of the Romanian petroleum industry, the conclusions of this paper are relevant in the context of alignment with European standards of sustainability and non-financial reporting. Integrating engineering ethics into continuing professional education and into internal corporate policies can contribute to increasing sector credibility and reducing operational risks.

In conclusion, the ethics of the petroleum engineer should be understood as a structural element of responsible engineering performance. Only by integrating ethical reflection into technical decision-making and organizational governance can a sustainable balance be achieved between economic efficiency, safety, and responsibility towards society.

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