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Identification and Ranking of Early Warning Indicators for Managing Downstream Oil Industry Projects in Iran

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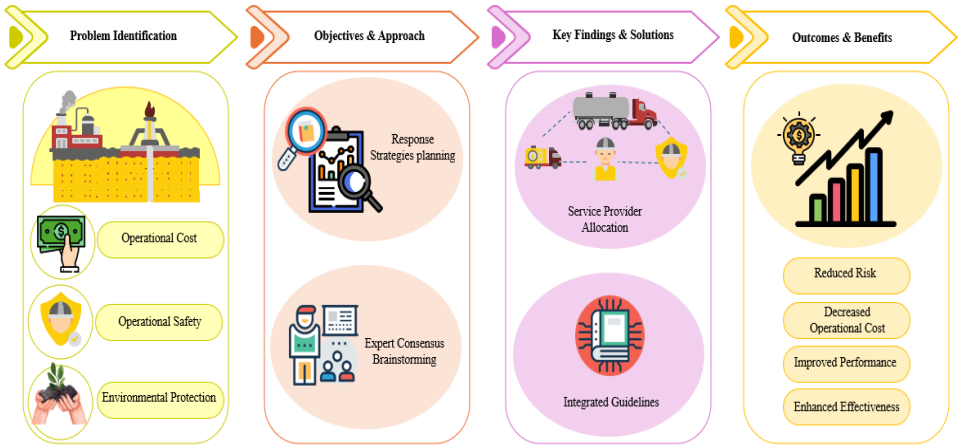
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A B S T R A C T

The research aims to identify and rank Early Warnings (EWs) for managing downstream oil industry projects in Iran. Due to the complexity and risks inherent in these projects, the need for a robust EW system is critical. The study addresses the challenges of project delays, cost overruns, resource shortages, and technical issues that can arise during the execution of oil industry projects. A combination of qualitative and quantitative methods, including expert interviews, questionnaires, and data analysis, was used to gather relevant data. The results identify the most significant EWs, which include delays in material delivery, unexpected cost increases, and project schedule disruptions. By ranking these indicators based on expert input, the research provides a framework for managers to take proactive measures and mitigate potential risks. The findings contribute to enhancing project management efficiency in the oil sector, offering practical tools for risk identification and early intervention. The study also provides a conceptual model for developing an EW system, which can be applied to similar industries facing complex operational challenges. Ultimately, this research offers valuable insights into improving the management of high-risk projects within Iran's oil industry.



1. Introduction

Downstream petroleum industry projects are categorized as high-risk endeavors due to their substantial capital investment, technical complexity, multi-stakeholder nature, and susceptibility to diverse economic, political, and technological factors. Delays, cost overruns, quality degradation, and deviations from project objectives represent the primary challenges facing these projects, a significant portion of which stems from the failure to timely identify the EWs of potential issues and risks. Therefore, the implementation of EW systems, as an effective project management approach, enables the detection of EW signs of deviation and the adoption of proactive measures before these anomalies escalate into crises. Although EW systems have been utilized across various global industries and projects as efficient tools for risk management and enhancing project success rates, a localized framework tailored to the specific economic, managerial, and organizational conditions of Iran's downstream petroleum projects has not yet been established to identify and prioritize EWs. The presence of financial constraints, international sanctions, energy market volatility, technological shifts, and the complexity of

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the project execution environment further underscores the critical necessity of developing such a framework.

Research Questions

1. What are the key EW Indicators that influence downstream petroleum projects in Iran?
2. How can the identified EWs in Iran's downstream petroleum projects be identified, classified, and ranked based on their significance?

Research Objectives

Primary Objective

To identify, classify, and rank EWs in Iran's downstream petroleum projects in order to assist project managers in timely risk detection, improve decision-making, and enhance project management effectiveness.

Secondary Objectives

- To identify key EW indicators influencing downstream petroleum projects in Iran.
- To classify EWs based on their nature and characteristics.
- To rank EWs based on their significance and impact on project performance.
- To present a practical framework that supports project managers' decision-making in timely risk identification and management.
- To lay the groundwork for mitigating delays, cost overruns, and other adverse consequences through the EW detection of warning signs.

An EW system comprises a set of technologies, policies, and processes designed to predict and identify adverse events particularly in business, financial, and economic contexts before they occur. Such systems may draw on quantitative and qualitative data and seek to mitigate potential losses and damages by providing signals of prospective crises or other adverse events [1].

More broadly, an EW system refers to any initiative that focuses on the systematic collection and analysis of data, as well as the provision of recommendations, including risk assessment and information exchange, regardless of whether the data are quantitative, qualitative, or a combination of both. These systems are designed to anticipate and respond to strategic surprises by identifying, analyzing, and acting upon EW signals [2]. In complex projects, the purpose of EW signals is to proactively identify and respond to potential positive or negative issues that may arise in the future. These signals serve as indicators of future changes or developments, enabling project professionals to take appropriate action before problems escalate into crises. A proactive approach to EW signals focuses on identifying and resolving issues before they intensify, thereby reducing the likelihood of strategic surprises and facilitating effective crisis management [3].

EW system serves as key instruments for risk management and proactive decision-making. By identifying threats and uncertainties at an early stage, they enable organizations to implement corrective actions before a crisis materializes. Utilizing advanced analytical methods such as Bayesian networks and weak signal analysis these systems enhance predictive accuracy and play an influential role in optimizing resource allocation, mitigating schedule delays, increasing the probability of project success, and improving decision-making quality [4]. Beyond the domain of project management EW systems are of paramount importance in disaster risk management and natural hazard mitigation. By providing timely and precise information, they establish the foundation for preparedness, rapid response, and the minimization of human casualties and economic losses. Furthermore, they play a fundamental role in strengthening community resilience, reducing vulnerability, and supporting sustainable development, particularly when addressing climate change and extreme weather events [5].

The effectiveness of EWs depends on a variety of organizational, managerial, technical, and environmental factors. Among the most critical barriers to the effective utilization of these warnings are project complexity, managerial overoptimism, communication deficits, a lack of external perspective, organizational and political pressures, and the gradual acceptance of deviations (normalization of deviance), all of which reduce the speed and quality of response to warning signs [6]. Studies also indicate that integrating risk management with project control tools particularly Earned Value Management (EVM) and leveraging data analytics enhances the EW detection of time, cost, and performance deviations, thereby facilitating proactive decision-making [7]. Generally, EWs originate from three primary sources: technical, organizational/human, and environmental/external factors. Their ultimate efficacy depends on the execution of a systematic process encompassing identification, analysis, corrective action, and organizational learning. Recent research demonstrates that utilizing real-time data and decision-making models increases the accuracy and speed of identifying EWs, laying the groundwork for active risk management and performance improvement in complex [6-8].

The petroleum downstream industry encompasses refining activities, the production of petroleum products, storage, transportation, distribution, and the marketing of petroleum derivatives. Within this sector, crude oil is processed and converted into consumer products such as gasoline, diesel, and jet fuel before being supplied to the market. As the final segment of the oil and gas value chain, this industry plays a critical role in generating value added and meeting market demands. Furthermore, the efficient management of the transportation, storage, and distribution network is considered a key success factor in maintaining product quality, reducing costs, and responding to demand fluctuations [9-11].

Project management comprises a set of processes including planning, organizing, executing, controlling, and managing resources to achieve project objectives within the predefined constraints of time, cost, and quality. By managing requirements, controlling changes, and managing risk, this process plays a vital role in increasing the probability of project success [12]. Beyond technical aspects, project management is also influenced by behavioral and organizational factors. Cognitive biases, such as overoptimism and political biases, can lead to flawed decision-making, unrealistic estimations, and project deviations from established targets. Consequently, leveraging historical data, lessons learned from similar projects, and evidence-based approaches contributes to improved decision-making, risk mitigation, and enhanced project performance [13].

Esposito et al (2022), in an article titled "Recent Advancements in IoT-enabled Solutions for EW Systems," investigated the application of Internet of Things (IoT) technology in developing EW systems for natural disaster management. The findings of this study indicated that IoT-based architectures—specifically the three-layer architecture comprising the perception, network, and application layers—can significantly enhance the performance of EW systems. Furthermore, by reducing processing time and increasing the accuracy of data analysis, these systems play an effective role in mitigating disaster-induced losses[14].

Guo & Zhao (2021), in their paper titled "Research Analysis and Verification in EW Model via Support Vector Machine Algorithm," developed an EW model to predict corporate financial crises. Their results demonstrated that the Support Vector Machine (SVM) algorithm is capable of identifying crisis states with high accuracy, serving as an effective tool for predicting and preventing organizational financial distress [15].

Perera et al (2020), in an article titled "Identifying Social Challenges in Flood EW Systems," examined the social factors influencing the effectiveness of flood EW systems. The results of this study revealed that challenges such as poor warning communication, lack of preparedness, and limited response capacity are key factors reducing the efficiency of these systems. Additionally, the authors emphasized the critical role of civil society organizations in strengthening institutional capacity and improving the overall performance of EW systems [16].

Bai et al (2020), in a paper titled "Rapid Assessment and EW Models for COVID-19," evaluated assessment and forecasting models for the EW detection of infectious disease outbreaks. The findings showed that utilizing comprehensive assessment models and predictive analysis can enhance surveillance capacity, rapid detection, and timely response to health crises, thereby playing a vital role in public health event management [17].

Cremen & Galasso (2020), in an article titled "Earthquake EW: Recent Advancements and Future Perspectives," investigated Earthquake EW (EEW) systems. Their objective was to review recent progress in earthquake detection algorithms, magnitude estimation, seismic intensity prediction, and warning decision-making processes. They also addressed the limitations of existing methodologies, particularly the insufficient integration of engineering risk metrics into decision-making. The results indicated that current EEW systems focus predominantly on seismological aspects, while risk-based metrics and engineering consequences remain underutilized. Consequently, the authors proposed that the next generation of EW systems should be grounded in probabilistic, risk-based models to deliver more accurate, comprehensible, and actionable warnings, thereby facilitating more effective preventive actions [18].

Du et al (2021), in their research titled "Use of Innovative Risk EW Mode Under Big Data Technology in Internet Credit Financial Risk Assessment," developed a model for assessing and warning against financial risks in internet credit. By analyzing 450 financial data points from 90 companies and combining a Backpropagation (BP) neural network with a Genetic Algorithm (GA), they concluded that optimizing the model with the genetic algorithm increased the accuracy of financial risk prediction from 85% to 97% [19].

Kim et al (2018), in a study titled "EW Performance Monitoring System (EPMS) Using Project Business Intelligence," designed an EW system to monitor and forecast project performance. Utilizing project progress data and establishing an information database, they proposed a theoretical model for performance measurement and an index for its monitoring. The findings demonstrated that the EPMS can objectively monitor project performance and effectively assist in the EW detection of performance deviations, especially under conditions of limited performance data [20].

Samitas et al (2020), in an article titled "Machine Learning as an EW system to Predict Financial Crises," leveraged global financial networks, financial data from 33 countries, and machine learning algorithms to develop a model for

predicting financial crises and contagion risks. The results of this study showed that the proposed model possesses exceptionally high predictive accuracy and can assist policymakers and investors in identifying and managing financial crises more effectively [21].

Javed & Liu (2017), in their study titled "Evaluation of Project Management Knowledge Areas Using Gray Incidence Model and AHP," evaluated and prioritized project management knowledge areas in both manufacturing and service industries. Utilizing the absolute grey incidence analysis model and the Analytic Hierarchy Process (AHP), they found that in the manufacturing industry, quality, time, and integration are of paramount importance, whereas in the service industry, cost, communication, quality, and time are given higher priority. Overall, the results indicated that knowledge areas related to quality, communication, cost, and time are the most critical domains [22].

Haji-Kazemi et al (2015), in an article entitled "Barriers to Effective Responses to EW Signs in Projects," investigated the organizational and project-related factors influencing managers' responses to EW signs. Utilizing a quantitative survey and an inductive reasoning approach, they demonstrated that factors such as project complexity, managerial optimism, organizational openness, and effective communication significantly impact the efficacy of responses to EW signs. The study also highlighted that optimism bias, the normalization of deviance, and a lack of external perspective represent major barriers to reacting appropriately to EWs [6].

Williams et al (2012), in their research titled "Identifying and Acting on EW Signs in Complex Projects," examined how EW signs are identified in complex projects from the project owner's perspective. Utilizing qualitative methods, interviews, document analysis, and case studies from Australia, Norway, and the United Kingdom, the study revealed that formal project assessments alone are insufficient for the effective identification of EW signs in complex projects. Instead, it is crucial to look beyond "hard" technical and financial indicators and pay close attention to "soft" issues, cultural signals, lack of transparency, and organizational misalignments [3].

2. Materials and Methods

The research process is conducted through the following steps:

Step 1: Literature Review and Desk Study

At this stage, relevant academic articles, books, reports, and available documents concerning EWs and related concepts in Iran's downstream oil industry projects are reviewed. This step involves identifying and extracting EWs relevant to such projects from library-based and online sources.

Step 2: Data Collection

In addition to the literature review, interviews with experts and managers in Iran's oil industry are conducted to identify and collect EWs related to downstream oil projects. Data are also collected through instruments such as questionnaires and checklists.

Step 3: Data Analysis

The collected data are analyzed using ranking methods. The purpose of this stage is to rank and prioritize EWs according to their importance in downstream oil industry projects. These analyses assist project managers in identifying the most critical warning signs and adopting the most appropriate preventive actions.

Step 4: Finalization and Development of Recommendations

At this stage, the results obtained from the analyses are finalized through consultation with and validation by experts. Subsequently, effective recommendations for managing EWs in Iran's downstream oil industry projects are developed and presented.

The flowchart of the research methodology is presented in Figure 1.



Figure 1. Research flowchart

2.1. Data Collection Methods

To obtain accurate, reliable, and comprehensive data, the data collection process in this study is conducted in two complementary phases: desk (library) research and field research. This dual approach ensures that the study is supported by a robust theoretical and scientific foundation while simultaneously gathering empirical findings and real-world data from the domestic industrial environment, thereby securing the practical applicability of the research findings.

- **Desk Research Phase:** The primary focus is on identifying and analyzing scientific literature, research articles, theses, specialized national and international reports, and project management standards within the oil and gas sector. At this stage, effort is directed toward identifying gaps in both global and domestic literature regarding "EWs in downstream oil industry projects." Furthermore, the theoretical foundations including key concepts such as EW systems, risk management, project success, and proactive decision-making approaches are reviewed and analyzed to establish a solid theoretical framework for the subsequent stages of the research.

- **Field Research Phase:** Data are gathered using tools such as semi-structured interviews with experts and experienced oil project managers, alongside specialized questionnaires. The objective of this phase is to extract the practical insights of professionals regarding the most critical challenges and warning signs in downstream projects. The participation of these experts ensures that the initial model derived from the literature is validated, refined, and localized according to the actual operational conditions of the Iranian oil industry.

Ultimately, integrating the results of both the desk and field research phases leads to the precise identification and classification of the most critical vulnerabilities, risks, and EWs in oil and gas projects. This synthesis of theoretical and empirical data forms the basis for developing the study's analytical framework and enables the formulation of scientific and practical recommendations to enhance project management effectiveness in the country's oil sector.

2.2. Data Collection Instruments

The data collection instruments consist of conducting interviews with experts and administering questionnaires structured in alignment with the chosen data analysis methodologies.

2.3. Target Population, Sample, and Sampling Method

The target population for this study comprises all experts, specialists, and professionals active in the downstream sector of the petroleum industry. Purposive sampling is utilized, meaning that participants are selected specifically based on their professional expertise, experience, and capability to address the research questions.

3. Results and Discussion

This study was conducted with the objective of identifying and prioritizing EWs in Iran's downstream oil industry projects. To achieve this objective, a hybrid approach was adopted. First, the problems and warning signs associated with the risks of these projects were identified in the initial stage of the research. Subsequently, these warnings were prioritized by industry experts using the Direct Rating (Doyle, 1979) method. The final weight of each EW sign was calculated using the geometric mean.

3.1. Target Population and Data Collection Method

The demographic profile of the participating experts reflects a balanced and credible cross-section of professionals actively engaged in Iran's downstream petroleum sector. Among the respondents, approximately 80 percent were male and 20 percent female, indicating the male-dominant yet gradually diversifying composition of the industry. The largest age group was between 40 and 50 years old (40 %), followed by 30–40 years (27 %) and above 50 years (20 %), while only 13 percent were under 30 years. In terms of education, bachelor's degree holders accounted for 47 percent, master's degree 33 percent, and Ph.D. 20 percent, showing a highly educated professional base. Regarding job positions, senior experts represented the majority (47 %), followed by experts (27 %), middle managers (20 %), and senior managers (7 %). Work-experience analysis revealed that most respondents had over 20 years of professional experience (33 %), with another 27 percent having 16–20 years, confirming their deep industry familiarity. This demographic composition ensures that the collected data are grounded in substantial practical expertise and represent the institutional diversity of stakeholders involved in downstream petroleum project management.

Results of the First Questionnaire: Identification of Key Issues

The first questionnaire was designed to systematically identify the critical issues and corresponding EW indicators that influence the performance of downstream petroleum projects. Through the participation of fifteen domain experts representing project management, engineering, finance, and procurement the study aggregated expert insights into a coherent diagnostic dataset. The open-ended structure of the instrument allowed respondents to not only select from predefined problem categories but also to add new issues based on their professional experience. As a result, the questionnaire captured a broad spectrum of internal and external risk factors, spanning cost control, scheduling efficiency, material supply, equipment reliability, workforce management, and environmental protection. This approach ensured that the list of identified problems was not constrained by theoretical assumptions but reflected the practical realities of Iran's petroleum project environment.

Analysis of the responses revealed that three main dimensions of risk resource supply, cost control, and project scheduling received the highest priority ratings among participants. The indicator "delay in delivery of equipment and raw materials" ranked first, obtaining 14 votes, strongly highlighting the vulnerability of supply-chain operations under sanctions and logistic restrictions. Next in importance were "unexpected cost increases relative to the baseline budget" and "delays in project progress versus the planned schedule," each with 13 votes.

These results indicate that project performance in the downstream petroleum sector is profoundly affected by material availability, funding stability, and schedule adherence [23,24]. Furthermore, safety-related and environmental warning signs such as equipment failure, safety incidents, and leakage hazards were frequently cited as secondary but nevertheless critical indicators, especially in maintaining operational integrity and regulatory compliance.

Conversely, issues with administrative or regulatory roots, such as managerial reshuffling, currency fluctuations, or licensing delays, received limited attention and were classified as supporting or peripheral risks. This suggests that while such factors can compound project complexity, their impact is often indirect compared to direct operational challenges. The findings of the first questionnaire thus provide a validated foundation for the next analytical phase the weighting and prioritization of identified key issues through the Direct Rating (Doyle) method. Overall, the results underscore the necessity of designing an EW model focused on anticipating supply, cost, and time deviations, while integrating complementary safety and political-risk indicators to ensure comprehensive risk management in downstream petroleum projects.

Results of the Second Questionnaire: Weighting Indicators

The second questionnaire aimed to quantify the relative importance of each key issue and its associated EW indicators that had been identified in the previous stage. Using the Direct Rating (Doyle, 1979) method, each expert independently assigned a value between 0 and 100 to each indicator, reflecting its perceived significance in contributing to project risk emergence. This method was selected because it avoids the cognitive overload of pairwise comparisons while maintaining consistency and transparency in expert judgment. After collecting all scores, the raw values were normalized so that the sum of the weights equaled 1. This normalization allowed for cross-comparison between indicators of differing natures financial, technical, logistical, and safety-related and ensured that the aggregated results accurately represented the collective perception of the expert panel. The formula for this calculation is as follows:

$$\left(\prod_{i=1}^{n}\alpha_i\right)^{\frac{1}{n}} = \sqrt[n]{\alpha_1\alpha_2\alpha_3\ldots\alpha_n} \quad (1)$$

The weighted results revealed a distinct prioritization among the major risk domains. Indicators related to cost escalation received the highest normalized mean weight (0.178), followed by schedule slippage and procurement delays (0.162 and 0.153 respectively). These findings confirm that deviations in cost and time serve as the earliest and most visible symptoms of systemic distress in downstream projects. Technical performance indicators such as frequent equipment breakdowns (0.124) and low material quality (0.118) occupied the intermediate tier, indicating their indirect but compounding influence on cost and schedule control. Meanwhile, administrative and organizational issues, including leadership turnover and weak coordination among contractors, showed lower weights (below 0.08), signifying that experts perceived them as secondary factors whose impact is manifested through other operational variables rather than directly generating EWs.

In addition to quantitative weighting, expert qualitative comments provided further insight into contextual drivers behind these priorities. Many experts stressed that chronic underfunding, complex procurement chains under sanctions, and delays in customs clearance amplified the effect of cost and time-related warnings. Moreover, they emphasized the interdependence among indicators particularly how procurement delays trigger cascading effects on scheduling, safety, and cost performance. The integration of both statistical weights and qualitative interpretations thus delivered a nuanced understanding of the hierarchical structure of EW indicators. These weighted results laid the foundation for the subsequent analytical step, where composite geometric means were computed to produce the final normalized importance scores and the ultimate ranking of EW indicators across all project dimensions.

3.2. Target Population and Data Collection Method

The findings derived from the data analysis indicate that risks in downstream projects are heavily concentrated around key themes: resource procurement and supply chain management, cost management, and project scheduling. In total, 15 major problem categories were identified, each associated with several EW signs. Based on the weighted calculations, the most critical and impactful EW signs in these projects were prioritized as follows Table 1:

Table 1. The most critical EW signals in Iran's downstream petroleum projects

Row	Major Problems	EW Signals	Overall Weight
1	Delay in equipment and resource procurement	Delay in the delivery of equipment and raw materials	0.0688
2	Cost variance	Unexpected project cost overruns compared to the initial budget	0.0648
3	Schedule variance	Project schedule delays compared to the baseline	0.0607
4	Insufficient budget	Unexpected cost increases leading to budget deficits	0.0564
5	Cost variance	Frequent changes in supplier contracts and agreements	0.0548
6	Safety and environmental (HSE) risks	Occurrence of safety incidents or environmental spills	0.0481
7	Insufficient budget	Budget deficit compared to initial forecasts	0.0470
8	Schedule variance	Emergence of obstacles impacting the project schedule	0.0467
9	Political tensions	Emergence of political crises affecting operations	0.0433
10	Substandard quality	Poor results from quality tests and inspections	0.0422
11	Political tensions	Increased political tensions in key oil-producing regions	0.0354
12	Shortage of skilled labor	Decrease in the number of skilled project personnel	0.0348
13	Shortage of skilled labor	Inability to recruit new staff with required skills	0.0348
14	Technical complexity	Increased frequency of technical problems and maintenance needs	0.0316
15	Delay in equipment and resource procurement	Reduced inventory of critical equipment and resources	0.0246
16	Technical complexity	Implementation challenges regarding new technologies	0.0226
17	Safety and environmental (HSE) risks	Increased safety and environmental regulation violations	0.0218
18	Oil price volatility and demand fluctuations	Sudden changes in market demand for petroleum products	0.0168
19	Substandard quality	Increased number of customer and end-user complaints	0.0141
20	Oil price volatility and demand fluctuations	Severe volatility in global oil prices	0.0126
21	Cost variance	Exchange rate fluctuations	0.0050
22	Cost variance	Changes in international conditions and sanctions	0.0050
23	Cost variance	Contractor's errors in initial project cost estimation	0.0050
24	Insufficient budget	Impact of sanctions on procurement	0.0047
25	Substandard quality	Use of substandard materials and frequent design changes	0.0047
26	Schedule variance	Local content requirements and technological limitations of domestic suppliers	0.0047
27	Schedule variance	Changes in requirements or execution policies by the operator	0.0047
28	Schedule variance	Unrealistic estimation at the project onset	0.0047
29	Delays in customs clearance	Increased lead time for material delivery to the site	0.0046
30	Safety and environmental (HSE) risks	Failure to calibrate equipment on time	0.0044
31	Safety and environmental (HSE) risks	Failure to hire personnel with recognized certifications	0.0044
32	Delayed decision-making	Frequent personnel turnover (at management levels)	0.0043
33	Delayed decision-making	Short tenure of managers	0.0043
34	Delayed decision-making	Misalignment of managers' experience/education with their leadership roles	0.0043
35	Changes in government regulations or processes	Delays in implementing or complying with new requirements	0.0043
36	Foreign exchange (Forex) constraints for procurement	Inability to place purchase orders	0.0042
37	Foreign exchange (Forex) constraints for procurement	Increased procurement costs	0.0042
38	Oil price volatility and demand fluctuations	Scope and design changes	0.0042
39	Shortage of skilled labor	Increased number of complaints	0.0040
40	Shortage of skilled labor	Increase in unpaid leaves	0.0040
41	Shortage of skilled labor	Organizational tensions	0.0040

Source: Research finding

Note: The weights presented in the table are derived from final calculations and averaging based on the research methodology.

The cumulative findings of the analytical phase present a coherent and empirically validated hierarchy of EW indicators governing the performance of Iran's downstream petroleum projects. Through a two-stage methodological process first identifying critical issues and then weighting them via the Direct Rating (Doyle) method the study established a structured model of risk precursors. The results showed that cost escalation, delays in equipment and material delivery, and schedule deviations are the dominant EW indicators with the highest

normalized importance weights. These were closely followed by factors such as technical equipment failures, quality deficiencies, and weak contractor coordination. Together, these indicators form a multi-layered EW profile that integrates both operational and strategic dimensions of project management. The consistency between expert opinions and geometric-mean-based weight normalization confirmed the robustness and logical coherence of this ranking process, ensuring that the resulting hierarchy accurately represents industry-wide expert consensus.

In terms of validation, the results were subjected to both qualitative and quantitative verification. Expert panels reviewed the ranked indicators to confirm their content and construct validity, affirming that the identified EW indicators adequately reflect the real-world causes of delay and cost deviation frequently experienced in Iranian downstream projects. Cross-checking the outcomes with previous research and project case reports further strengthened external validity, showing a high degree of alignment between modeled expectations and historical incident data. Moreover, the internal consistency coefficients (Cronbach's $\alpha > 0.85$) indicated reliable measurement of expert judgment across the sample. This dual validation expert corroboration and statistical reliability demonstrated that the developed EW framework is context-sensitive, statistically sound.

4. Conclusions

This study was conducted to identify, classify, and prioritize EW indicators relevant to the management of Iran's downstream petroleum projects, where complexity, capital intensity, and environmental uncertainty create high systemic vulnerability. The integrated analysis combining literature review, expert interviews, and two successive questionnaires resulted in the extraction of a well-defined set of critical indicators spanning financial, technical, scheduling, managerial, and external dimensions. Among these, financial shortages, delays in equipment procurement, and coordination weaknesses among stakeholders consistently emerged as the top-ranked EW indicators, each exerting direct influence on project performance outcomes such as cost, time, and quality. The data demonstrated that financial and logistical indicators act as the earliest and most detectable precursors of project distress, while managerial and environmental indicators function as secondary amplifiers that often reinforce the impact of primary risks.The findings further revealed that the interrelationship among categories of EW indicators forms a complex but predictable network of cause-and-effect patterns. Cost overruns, scheduling disruptions, and technical inefficiencies rarely occur in isolation; rather, they manifest as linked phenomena that evolve through the project lifecycle. This confirms that a functional EW system in the Iranian context must adopt an integrated monitoring perspective, capturing not only quantitative deviations in budget and progress metrics but also qualitative changes in human, regulatory, and supply-chain conditions. Overall, results provided both descriptive and inferential evidence for building a localized, data-driven EW system. The set of validated indicators constitutes the empirical backbone of the framework proposed in this thesis one that can support proactive risk management and enhance decision-making efficiency in the downstream petroleum industry.

4.1. Comparison with Previous Research

The comparative review demonstrated a high degree of alignment between the findings of this study and leading international research on EW system in project and financial risk management. Similar to the results of Kim et al [25], this study confirmed that financial instability, equipment procurement delays, and weak monitoring mechanisms are among the most critical precursors to performance failure. It also echoed the conclusions of Haji-Kazemi et al [6], emphasizing that organizational and cultural barriers significantly weaken timely responses to detected warning signs. Furthermore, in congruence with Williams et al [3], this research underlined the necessity of integrating "hard" indicators (technical and financial) with "soft" indicators (managerial and communication-related) to ensure a holistic risk-detection mechanism. Likewise, consistency was observed with Javid and Liu [22], whose models placed project time, quality, and communication among the top risk criteria elements reflected directly in the present study's ranking of EW indicators related to scheduling and stakeholder coordination. Nevertheless, several important divergences were observed when comparing the current outcomes with international experiences. Unlike Samitas et al [21], who prioritized machine-learning-based prediction of macro-financial crises, the present research found that limited data infrastructure and inconsistent record-keeping in Iran's petroleum projects impede the wide adoption of automated analytical tools. Similarly, in contrast to Prabheesh and Padhan, whose models concentrated on systemic financial contagion across economies, this study expanded the perspective to include technical, process-oriented, and environmental risks, thereby localizing the EW system within the contextual realities of industrial projects under sanctions. These differences underline the context-specific innovation of the current research: rather than replicating generic financial-risk models, it integrates multiple technical and managerial dimensions to form a hybrid, adaptive EW architecture suited to the operational and geopolitical complexities of Iran's downstream petroleum sector [26].

4.2. Research Innovation Compared to Previous Studies

The core innovation of this study, in comparison to previous research, lies in the simultaneous integration of qualitative data from expert interviews, quantitative questionnaires, and multi-criteria evaluations to rank EW signs within the specific operational context of Iran's downstream petroleum projects. Furthermore, unlike the majority of international studies that focus single-dimensionally on a specific category of warning signs (such as purely financial, technical, or environmental aspects), this research designs a comprehensive, multidimensional framework capable of prioritizing indicators to facilitate managerial decision-making.

4.3. Practical Implications for Project Management

Considering the prioritization of EW signs and the demographic characteristics of the surveyed population in the Iranian oil industry, the findings of this study can serve as a foundation for developing and improving project management processes in similar industries. The most significant practical implications include:

Prioritizing Financial Warning Signs as the Top Priority: The identification of "financial resource deficits" as the most critical EW sign indicates that project managers must activate cash-flow monitoring mechanisms, cost control protocols, and alternative financing strategies from the very inception of the project.

Managing the Import Equipment Supply Chain: The second highest priority corresponds to "challenges in procuring imported equipment." This highlights the urgent need to establish domestic alternative solutions, engage in long-term negotiations with suppliers, and incorporate flexible scheduling for equipment delivery.

Establishing Inter-Contractor Coordination Mechanisms: Poor coordination among contractors emerged as one of the three key warning signs. Mitigating this risk requires establishing regular coordination meetings, utilizing integrated Project Management Information Systems (PMIS), and clearly defining scopes of work.

Preparing for Sudden Regulatory and Macroeconomic Shifts: The fourth and fifth priorities namely, "sudden changes in laws and regulations" and "severe exchange rate fluctuations" underscore the necessity of establishing dedicated regulatory and economic monitoring units, as well as designing rapid-response scenarios within macro project planning.

Leveraging the Tacit Knowledge of Experienced Personnel: Given that 33% of the target population possesses over 20 years of work experience and 47% hold bachelor's degrees, strategically leveraging the practical experience and tacit knowledge of this cohort can significantly accelerate the detection of and response to warning signs.

Fostering an Organizational Culture of Rapid Response to Warnings: The findings emphasize that an EW system must not only be designed but also integrated into the organizational culture and formal project management processes to ensure timely responses. By focusing on these identified priorities, these applications can play a vital role in enhancing project resilience, reducing operational and financial risks, and increasing the success rate of projects within the petroleum sector and related industries. To further operationalize the research findings, Table 2 details the practical applications of the identified EW signs in project management. In addition to proposing strategic approaches for each warning sign, this table delineates the expected impacts and outcomes of implementing these approaches.

Table 2. Proposed Approaches for Managing EW Signals and Their Impacts on Projects

Row	Identified EW Signal	Suggested Project Management Approach	Expected Effect
1	Shortage of financial resources	Designing a liquidity monitoring system, cost control, and securing alternative funding sources	Reduced likelihood of project stoppage and improved financial stability
2	Difficulties in procuring imported equipment	Using domestic suppliers, entering into long-term contracts, and applying flexible scheduling	Reduced supply delays and increased operational independence
3	Weak coordination among contractors	Holding regular coordination meetings, using integrated project information systems, and clearly defining responsibilities	Improved execution efficiency and reduced conflicts
4	Sudden changes in laws and regulations	Establishing a legal and regulatory monitoring unit and developing rapid-response scenarios	Reduced impact of legal shocks on project planning
5	Severe exchange rate fluctuations	Continuously monitoring exchange market conditions, using hedging instruments, and building flexibility into contracts	Reduced financial risk arising from exchange rate fluctuations
6	High level of human resource experience	Leveraging tacit knowledge and the practical experience of senior staff in decision-making	Improved quality of warning identification and response

Source: Research findings

4.4. Research Innovations and Theoretical Contributions

This study, which focuses on identifying and prioritizing EW signs in the management of downstream oil industry projects in Iran, offers substantive, methodological, and analytical innovations, as outlined below.

Methodological Innovations

- **Application of multi-criteria decision-making methods:** The study employs multi-criteria decision-making techniques to evaluate and rank EW signs, thereby enabling the simultaneous analysis of both quantitative and qualitative criteria.
- **Development of an adaptable evaluation structure:** The proposed evaluation structure can be adapted to other high-risk industries, particularly those exposed to severe environmental volatility, economic uncertainty, and sanctions-related constraints [28-29].

Innovations in Comparative Analysis

- **Comparison of localized and international findings:** The study compares localized findings derived from field data and expert opinions with the results of international studies. This comparison identifies both similarities and differences while taking into account the specific characteristics and constraints of Iran's petroleum industry.
- **Development and localization of a conceptual model:** A localized conceptual model is developed that can serve as a foundation for designing and implementing EW systems in other comparable projects.

Theoretical Contributions

- **A localized conceptual framework:** The research presents a localized conceptual framework for identifying, classifying, and prioritizing EW signs in downstream oil projects.
- **Enrichment of the theoretical foundations of EWs:** By integrating domestic field evidence with theoretical discussions and international literature, the study enriches the theoretical foundations of the EW field.
- **A practical and flexible final model:** The study proposes a final model that can be directly applied by managers of downstream oil projects. At the same time, the model maintains sufficient flexibility to be adapted for use in other industries.

4.5. Recommendations for Future Studies

Future research should aim to expand the analytical and technological depth of EW system in project management by integrating advanced data-driven and comparative approaches. Building on the findings of this thesis, subsequent studies could employ machine learning algorithms, neural networks, and big-data analytics to enhance the precision and timeliness of risk detection. Moreover, comparative analyses across other high-risk sectors such as petrochemicals, power generation, and transportation would help identify cross-industry patterns and transferable best practices. Researchers are also encouraged to explore the institutional and cultural dimensions influencing EW system adoption, particularly under regulatory uncertainty and sanction-driven constraints. Finally, developing localized digital platforms capable of real-time indicator monitoring and predictive modeling would transform EW systems from theoretical constructs into actionable management instruments, thereby increasing their effectiveness in complex, high-volatility environments.

Author Contributions

All authors contributed equally to the conception, preparation, and writing of this manuscript.

Conflict of Interest

M.A. Hatefi, in the capacity of Editor-in-Chief, had no involvement in the selection of reviewers or the management of the peer-review process, and the other authors, while observing publication ethics in referencing, declare the absence of any conflict of interest.

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References

[1] I. Klopotan, J. Zoroja, M. Meško, *International Journal of Engineering Business Management*, 2018, **10**, 241-250. https://doi.org/10.1177/1847979018797013

[2] M. Sjekavica Klepo, M. Radujković, *Journal of Civil Engineering and Management*, 2019, ***25*(6)**, 531–550. https://doi.org/10.3846/jcem.2019.10404

[3] T. Williams, O. Jonny Klakegg, D. H. T. Walker, B. Andersen, O. Morten Magnussen, *In Project Management Journal*, 2012, **43(2)**, 37–53. https://doi.org/10.1002/pmj.21259

[4] I. O. Nikander, *Helsinki University of Technology*, 2002.

[5] I. Kelman, M. H. Glantz, *Early warning systems defined.* In Reducing disaster: Early warning systems for climate change, Dordrecht: Springer Netherlands, 2014, pp. 89–108. https://doi.org/10.1007/978-94-017-8598-3_5

[6] S. Haji-Kazemi, B. Andersen, O. J. Klakegg, *International Journal of Project Management*, 2015, ***33*(5)**, 1068–1083. https://doi.org/10.1016/j.ijproman.2015.01.002

[7] E. Soliman, K. A. Alrasheed, S. Alghanim, E. Morsi, *Journal of Engineering Research (Kuwait)*, 2024, **13(3)**, 2109-2116. https://doi.org/10.1016/j.jer.2024.05.029

[8] S. A. Razavi, E. Ordoei, *Journal of Environmental Economics and Chemical Processes*, 2025, **2(4)**, 129-133. https://doi.org/10.22034/jeecp.2025.735022

[9] S. Ramos, H. Veiga, (n.d.). *Lecture Notes in Energy 54 The Interrelationship Between Financial and Energy Markets*, 2014, **4**, 3-32.

[10] S. A. MirHassani, A. Nikbakht, *International Journal of Applied Management Science*, 2010, ***2*(4)**, 321–334. https://doi.org/10.1504/IJAMS.2010.036589

[11] S. A. Razavi, A. K. Manshad, L. Kashani, *Energy Strategy Reviews*, 2026, **65**, 1022261-30. https://doi.org/10.1016/j.esr.2026.102226

[12] L. R. Yang, J. H. Chen, C. F. Huang, *Journal of Civil Engineering and Management*, 2012, **18(1)**, 114–124. https://doi.org/10.3846/13923730.2012.657340

[13] B. Flyvbjerg, *Project Management Journal*, 2021, **52(6)**, 531–546. https://doi.org/10.1177/87569728211049046

[14] M. Esposito, L. Palma, A. Belli, L. Sabbatini, P. Pierleoni, *MDPI*, 2022, **22(6)**, 1451-1500. https://doi.org/10.3390/s22062124

[15] L. Guo, Y. Zhao, *International Conference on Electronic Technology, Communication and Information, ICETCI* , 2021, **1**, 211–213. https://doi.org/10.1109/ICETCI53161.2021.9563374

[16] D. Perera, J. Agnihotri, O. Seidou, R. Djalante, *International Journal of Disaster Risk Reduction*, 2020, **51**,1017941-9. https://doi.org/10.1016/j.ijdrr.2020.101794

[17] Z. Bai, Y. Gong, X. Tian, Y. Cao, W. Liu, J. Li, *In Virologica Sinica*, 2020, **35(3)**, 272–279. https://doi.org/10.1007/s12250-020-00219-0

[18] G. Cremen, C. Galasso, *Earth-Science Reviews*, 2020, **205(5)**, 1031841-46. https://doi.org/10.1016/j.earscirev.2020.103184

[19] G. Du, Z. Liu, H. Lu, *Journal of Computational and Applied Mathematics*, 2021, **386**, 1132601-11. https://doi.org/10.1016/j.cam.2020.113260

[20] C. W. Kim, W. S. Yoo, H. Lim, I. Yu, H. Cho, K. I, Kang, *International Journal of Project Management*, 2018, **36(5)**, 730–743. https://doi.org/10.1016/j.ijproman.2018.03.010

[21] A. Samitas, E. Kampouris, D. Kenourgios, *International Review of Financial Analysis*, 2020, **71**, 1015071-64. https://doi.org/10.1016/j.irfa.2020.101507

[22] S. A. Javed, S. Liu, *Technological and Economic Development of Economy*, 2017, **26(3)**, 621–641. https://doi.org/10.1109/GSIS.2017.8077684

[23] S. A. Razavi & H. Motavali, Journal of Industrial Engineering and Management Studies, 2023, 10(2), 106-115. https://doi.org/10.22116/jiems.2023.399150.1516

[24] H. Mofid, M. R. Khosravi-Nikou, S. A. Razavi, M. Mohammadian, Applied Thermal Engineering, 2024, 245, 122810. https://doi.org/10.1016/j.applthermaleng.2024.122810

[25] C. W. Kim, W. S. Yoo, H. Lim, I. Yu, H. Cho, K. I. Kang, International Journal of Project Management, 2018, **36(5)**, 730–743. https://doi.org/10.1016/j.ijproman.2018.03.010

[26] R. Padhan, K. P. Prabheesh, *Buletin Ekonomi Moneter Dan Perbankan/Monetary and Banking Economics Bulletin*, 2019, **22(4)**, 457–484. https://doi.org/10.21098/bemp.v22i4.1188

[27] S. A. Razavi & M. Nasr Esfahani, Political Strategic Studies, 2020, 9(35), 101-134. https://doi.org/10.22054/qpss.2020.42777.2320

[28] S. A. Razavi & S. Pirani, Petroleum Business Review, 2019, 3(4), 28-36. https://doi.org/10.22050/pbr.2019.119151

[29] S. A. Razavi, A. Tarnian, *Journal of Environmental Economics and Chemical Processes*, 2026, **3(1)**, 29-33. https://doi.org/10.22034/jeecp.2024.735000