International Journal of Innovative Research and Scientific Studies, 8(6) 2025, pages: 714-725

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

The role of risk management in the sustainability of production facilities in Saudi Arabia

Sami A. Morsi

Applied College, Abqaiq Branch, King Faisal University, Al-Ahsa 31982, Saudi Arabia.

(*Email: Smorsi@kfu.edu.sa*)

Abstract

This study explores the importance of comprehensive risk management strategies for the continued operational sustainability of Saudi Arabia's industrial production facilities. The Kingdom faces multifaceted challenges such as operational risks, market risks, environmental risks, and ever-changing regulations as the Saudi Arabian Vision 2030 economic diversification plans continue. This research utilizes a mixed-method approach by quantifying the management performance metrics of risk management and the operational sustainability of 187 Saudi production facilities in the oil, gas, manufacturing, and petrochemical sectors, supplementing it with qualitative data from 42 industry executive participants. The results show that facilities with coordinated risk management principles scored operational sustainability on average 27.3% and 18.6% greater in financials than facilities with fragmented risk management approaches. This analysis emphasizes five focus areas of risk management pertinent to Saudi Arabia, which are: (1) climate resilience and water security, (2) rule of law foresight, (3) supply chain resilience, (4) technology acceptance, and (5) human capital. To conclude, risk management in Saudi Arabia's adaptive economy should transcend mere compliance frameworks; policies should be an organizational culture system to safeguard sustained industrial activity.

Keywords: Economic production, Environment, Industrial sustainability, Risk management, Saudi Vision 2030.

DOI: 10.53894/ijirss.v8i6.9671
Funding: This work is supported by Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia (Grant number: KFU 253012).
History: Received: 14 July 2025 / **Revised:** 15 August 2025 / **Accepted:** 18 August 2025 / **Published:** 4 September 2025

Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.
Transparency: The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

The Kingdom of Saudi Arabia is undergoing unparalleled changes in its economy due to the ambitious Vision 2030 initiative. It seeks to diversify income from oil revenues and grow other industrial sectors. This shift offers both opportunities and challenges for industrial production facilities within the Kingdom [1]. While facilities are met with new opportunities due to emerging markets and accelerated technological shifts, they also face greater uncertainty, increased competition, and evolving regulatory frameworks. In this scenario, effective risk management has shifted from being an administrative formality to a key requirement for an economy in transition.

This study aims to fill the aforementioned gap by analyzing the relationship between operational risk management and maintaining the competitiveness of production facilities in Saudi Arabia's industrial ecosystem. For operational sustainability Al-Shammari and Al-Khateeb [2] this study consider not only environmental concerns but also the ability of facilities to operate under a dynamically shifting environment for an extended period. This study attempts to fill a gap in the literature where risk management practices grounded in the context of Saudi Arabia's industrial environment with rapid modernization and traditional organizational cultures, as well as unique environmental constraints, have yet to be explored [3].

This study aims to find out the answers to the following research questions:

1. What is the relationship between practiced risk management, operational, and financial sustainability indicators in the production facilities in Saudi Arabia?
2. What risk management parameters are most critical for the sustainability of the facility in Saudi Arabia?

What is the best way to design the risk management system for the industrial policies of Saudi Arabia?

Fulfilling these questions is meant to assist facility operators, policymakers, and other relevant industry players in understanding how to sustain and increase the resilience of Saudi Arabia's industrial infrastructure. The results aid an emerging economy's understanding of risk management in sustaining facility operations and the region's operational facility logic.

2. Literature Review

2.1. Development of Risk Management in Industrial Contexts

Aspects of risk management dealing with the industrial setting developed from the focus of insurance, financial instruments to insurance, liability reduction, and asset protection. The earlier versions confined the focus of risk management to a lower level of broader strategy integration [4]. The more recent structures have shifted to an overarching abstract level, which balances different categories of risks [5]. This shift was regarded as an evolution from individual approaches to integrated enterprise risk management (ERM) Aven and Zio [6] underscore this trend towards modern frameworks which strive for resilience instead of avoidance of risk, which illuminates the attention given to risks in the industry.

The evolution of industrial risk management has emerged from the need to address safety, operational continuity, and reputation strategically Macdonald et al. [7]. This change is evident with the growing need for technology within production facilities, as risk management is increasingly becoming important. Macdonald et al. highlight this evolution in their work, showing how industrial risk management is concerned with safety beyond protective measures, expanding to consider operational continuity, reputational impacts, and strategic positioning.

2.2. Risk Management in Middle Eastern Industrial Contexts

There is considerable literature on risk management in the Western world; however, the same cannot be said for the Middle Eastern context. Al-Hammad [8] posts concern what he perceives as overly focused area dependency sectors. Other factors, like the GCC region's rapidly changing political climate, also pave the way for new risk management landscapes.

What Al-Mansouri and Morgan observe in 54 industrial facilities across the GCC is exposure to extremely diverse levels of risk management maturity, corresponding chronologically to how early they implemented it [9]. A number of cultural variables affecting risk management perception, alongside gaps in the GCC's tolerance for centralized decision-making, emerged from this. The South Pacific Islanders do not describe focus on the Saudi Arabian context nor do they link risk and sustainability practices.

2.3. Risks Related to Saudi Arabia's Industry

The industrial risk profile of Saudi Arabia reflects the Kingdom's socio-political context, geographic features, as well as the Saudi Arabia economic transition. The primary concern is still the lack of water, especially industrial water, which is expected to increase by 40% by 2030. This, along with the impact of climate change, poses greater challenges as Saudi Arabia is considered one of the most water-stressed countries in the world [10]. Average temperatures in industrial zones are already 1.5 times greater than global averages, and this trend will only worsen in the future. This is particularly problematic since Saudi Arabia's water institutes are pouring funds into systems to mitigate climate change impacts rather than funding research on water scarcity issues facing the country [11].

Additional uncertainties to production facilities are caused by the move to economically diversify the region. In Saudi Arabia, where investments are heavily regulated, Al-Otaibi [12] explains, the rapid shifts in policy come with regulatory risks because facilities scramble to meet new localization requirements, environmental benchmarks, and industrial licensing frameworks. Changes to foreign investment policies, as well as privatization drives, shift competitive factors in all industrial areas of focus.

From a global labor force viewpoint, the complex nature of capital markets in Saudi Arabia's production facilities translates to distinct human capital risks. There are evident contradictions with the Saudization policies and the skills available. Al-Zahrani and Baig [13] explain that two-thirds of the managers in the region's industries are unable to hire skilled technical workers because they are in short supply, creating an uncertain operating environment in many facilities that depend on highly skilled workers.

2.4. Sustainability in Production Facilities

Sustainability in production facilities is now an interdisciplinary term that accounts for environmental, economic, social, and dynamic factors. Sustainable operations are defined by Khan and Al-Gahtani [14] as those which 'are functionally operational, competitive, socially valuable, consume resources efficiently, and minimize impact on resources and nature.' Such a definition works within the boundaries of triple-bottom-line frameworks that integrate economic, ecological, and societal considerations [15].

Sustainability issues are more pressing for resource-abundant regions like Saudi Arabia. Vásquez and Alicea-Planas [16] consider water efficiency as the main sustainability problem of Saudi industrial enterprises. Jubail Industrial City facilities alone spend an estimated 23.7 million cubic meters of desalinated water yearly. Another critical issue of sustainability is energy intensity, where industrial operations in the Kingdom contribute almost 18% of the total energy consumption of the Kingdom [17].

2.5. Connecting Risk Management to Sustainability Outcomes

The intersection of risk management practices with sustainability outcomes is an insufficiently explored topic in current literature, especially within Middle Eastern contexts. While there is Western research beginning to focus on these connections [18, 19], there are almost no studies examining these relationships within the unique industrial context of Saudi Arabia.

Preliminary work Ibrahim [20] indicates that there is a positive relationship between the more sophisticated structured risk assessment processes and the environmental compliance indicators in Saudi petrochemical plants. Al-Qahtani et al. [21] show the links between operational risk controls and production stability in oil and gas facilities without extending the analysis to the considerations of sustainability for the planning horizon.

The gaps in the literature highlight the absence of comprehensive frameworks integrating risk management efforts with the multifaceted sustainability dimensions of production facilities within the Saudi Arabian industrial ecosystem. These gaps justify the current research's aim to better articulate the relationships between risk management frameworks and sustainability, establishing important sub-questions regarding critical risk factors in the Saudi context.

3. Methodology

3.1. Research Design

For this study, both quantitative and qualitative methods were applied to fully capture the perception of the role risk management plays in facility sustainability. The data collection and analysis were carried out sequentially, first quantitative, then followed by qualitative components to explain the patterns, correlations, and relationships identified in the earlier data analysis [22].

This rationale responds to the combination of definable and abstract components within risk management and organizational sustainability. The integration of multiple approaches makes it possible to address most of the challenges arising from the use of a single approach. To deepen the investigation of complex organizational phenomena, using different types of data [23].

3.2. Sample Selection

In Saudi Arabia, the study was concerned with the production facilities in three major industries: oil and gas, manufacturing, and petrochemicals. There was a combination of stratified and simple random sampling for the different categories of industrial facilities in secondary cities like Jubail, Yanbu, Dammam, and in the capital city of Riyadh, which obtained access to all regions and all sizes of the facilities. As region and facility size increased, the number of facilities sampled also increased, so the level of balance in all regions across the various facility types was kept constant. Table 1 illustrates the distribution of sampled facilities across the sectors and size categories.

Table 1.
Distribution of Sampled Production Facilities.

Establishments	**Small (up to 100 employees)**	**Medium (100-500 employees)**	**Large (over 500 employees)**	**ALL**
Oil and Gas	14	23	31	68
Industry	27	32	18	77
Petrochemicals	12	19	11	42
Total	**53**	**74**	**60**	**187**

Table 1 shows for the qualitative part, purposive sampling was utilized to choose 42 risk management experts, senior managers from the participating facilities. The selection criteria were primarily focused on those having five years or more in the particular position in question, coupled with active participation in all risk management activities. The distribution of participants comprised 17 risk managers, 14 operations directors, and 11 executives.

3.3. Data Collection

3.3.1. Quantitative Data

Quantitative data collection began in November 2023 and continued through February 2024. The data was collected using the facility assessment protocol, which entailed:

1. Assessment of Risk Management Maturity: This involves a tailored 27 risk management practices framework within five areas: risk governance, identification, assessment methodologies, mitigation, and monitoring. Each practice was scored using a 7-point Likert scale based on evidence verified as embodying the practice. Documents scrutinized pertain to the in-place processes.
2. Metrics of sustainability performance: compilation of a set of standardized measures under three facets of sustainability:

- Operational sustainability: Production process efficiency, machine uptime, unscheduled outages, and incident frequency.
- Financial sustainability: Earnings relative to total assets, expense volatility, resource utilization, and spending trends
- Environmental sustainability: Resource energy intensity, waste production, emission concentration, and level of enforcement.

3. Facility Characteristic Data: Geographical data such as facility vintage, technological adoption, labor structure, output, and legal classification.

As part of data collection, trained research associates conducted on-site assessments using standardized checklists to maintain comparability across facilities. Full deployment of instruments was preceded by a pilot at six facilities, which was then adapted based on participant feedback.

3.3.2. Qualitative Data

Qualitative data were collected through semi-structured interviews from the 42 selected professionals between March and April 2024. Interview protocols sought to understand:

1. Existing connections between risk management activities and the sustainability of the given facility.
2. Principal risk concerns of Saudi production plants.
3. Strategies constituting organizational risk culture and governance.
4. Obstacles to effective implementation of risk management processes.
5. Strategies to adapt to the changing industrial environment of Saudi Arabia.

Each interview lasted an average of 74 minutes, conducted in English or Arabic based on the participant's preference. All interviews were recorded, transcribed, and translated if necessary before analysis.

3.4. Data Evaluation

3.4.1. Analysis Evaluation

For quantitative analysis, various statistical techniques were applied:

1. Descriptive statistics summarized the distribution of practices pertaining to risk management and sustainability within the sample.
2. Specific risk management elements and their respective sustainability indicators were evaluated using specific correlation calculations in correlation analysis.
3. Holding constant the characteristics of the facility, multiple regression modeling evaluated the impact of risk management practices on sustainability results.
4. Cluster analysis was performed regarding the sample to distinguish clearly identifiable profiles corresponding with various approaches to risk management.
5. Structural equation modeling assessed intermediary factors that exist within risk management practices and mediating factors within sustainability outcomes.

Using SPSS 28. 0 and AMOS 27. 0, the statistical analyses were performed at significance levels of $p < 0. 05$.

3.4.2. Analysis Evaluation

Thematic analysis is applied following a six-step framework notated as [24]:

1. Getting acquainted (Gain an understanding of the data by reading the transcripts multiple times)
2. Inductive and theoretical initial code creation (Start creating codes in an inductive approach or based on preconceived structures).
3. Narrative theme identification (Combine codes into their respective groups that add up into themes to identify them)
4. Iterative refinement theme examination (Review through multiple themes with the goal of refining them while achieving the purpose of their examination)
5. Creating themes step involves defining their names (Naming defined themes)
6. Make a report including quotes exemplifying the themes identified

The process of coding enabled quoting the themes identified to be supported using NVivo 14. To enhance reliability, two researchers were enlisted to encode a selection of transcripts independently (Cohen's k = 0. 83) of the reasoning underlying the themes identified, leading to enhanced reliability.

3.5. Research Quality and Ethical Considerations: Areas of Accuracy and Ethics

The quality of the research and its ethics were maintained using several measures, such as ensuring best practices concerning ethics and conduct:

1. Validity strategies utilized included triangulation, peer review of the analytical processes, and member checking, which involved verifying preliminary findings with some selected participants.

2. Reliability protocols involved the use of standard data collection instruments, comprehensive procedure documentation, and measurement of inter-rater reliability of the observational data.
3. Ethical safeguards include the use of informed consent for all participants, the protection of sensitive business information, and institutional review board approval of the research protocol.
4. Informed consent was included, but other ethical safeguards also extend to sensitive business information as well as the use of legal review boards.
5. These practices included the use of structured reflexive procedures as well as documentation of reasoning about qualitative frameworks for marking analytical decision points.

The described methodological set helped answer the posed questions regarding the Saudi production facilities concerning the intersection between risk management and sustainability practices.

4. Results

4.1. Risk Management Maturity in Saudi Production Facilities

Analysis of risk management practices in the sampled facilities has shown that there is a significant disparity in maturity levels among the 187 sampled facilities. Facilities scored within the range of 1.7 to 6.8, with a mean of 4.2 (SD = 1.3), using a composite Risk Management Maturity Index (RMMI) that was calculated from the 27 assessed practices. Table 2 displays the mean maturity scores across the different sectors and industries.

Table 2.
Risk Management Maturity Scores by Dimension and Industry Sector.

Risk Management Aspects:	Oil & Gas n=68	Manufacturing n=77	Petrochemicals n=42	Overall n=187
Risk Governance	5.3 (0.8)	3.7 (1.1)	4.6 (0.9)	4.5 (1.2)
Identification Processes	4.9 (1.0)	3.6 (1.2)	4.3 (0.8)	4.2 (1.2)
Assessment Methodologies	5.1 (0.7)	3.2 (1.3)	4.5 (1.0)	4.1 (1.3)
Mitigation Strategies	4.8 (0.9)	3.5 (1.1)	4.2 (1.1)	4.1 (1.2)
Monitoring Systems	5.0 (0.8)	3.4 (1.2)	4.3 (0.9)	4.1 (1.2)
Overall Risk Management Index	**5.0 (0.7)**	**3.5 (1.0)**	**4.4 (0.8)**	**4.2 (1.1)**

Note: Values represent means with standard deviations in parentheses

Table 2 shows that cluster analysis identified three distinct risk management approach profiles among sampled facilities:

1. Integrated Practitioners (32% of facilities): These facilities demonstrated the implementation of enterprise-wide systematic risk management, with robust executive sponsorship, multi-functional governance, and quantitative risk modeling at the facility level.
2. Compliance-Oriented (41% of facilities): These facilities emphasized adherence to laws and policies prescribed in standard operating procedures, with little to no linkage to higher-level strategic choices.
3. Reactive Responders (27% of facilities): These facilities exhibited opportunistic, ad hoc responses primarily shaped by inciting events or external forces, with no anticipatory risk evaluation.

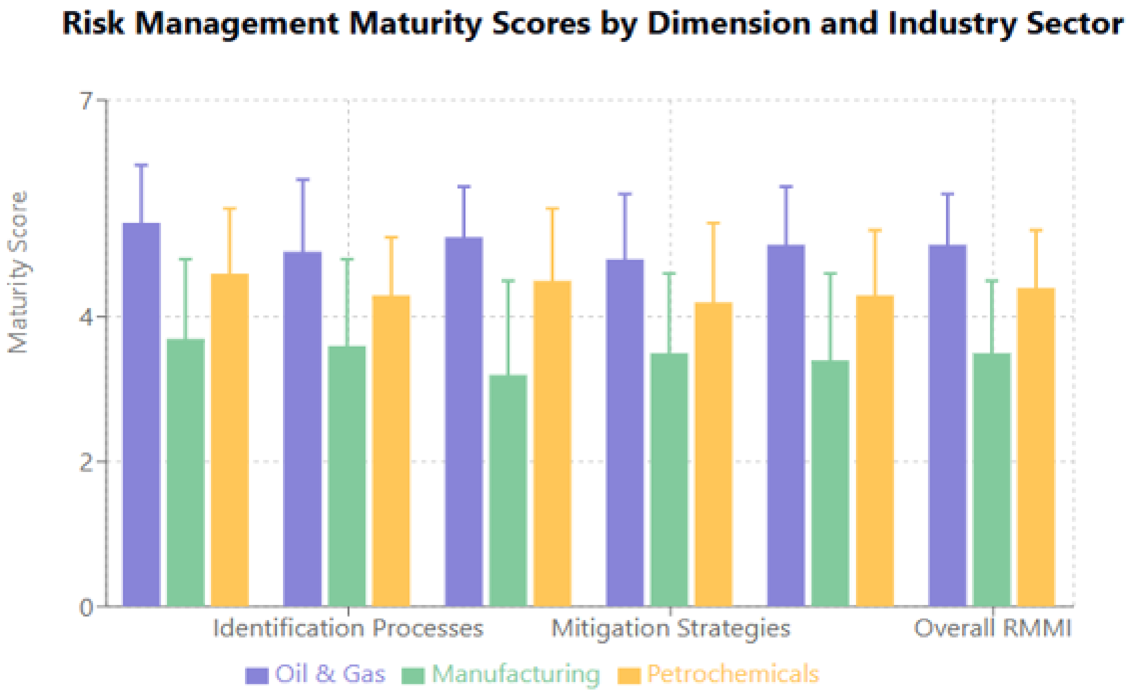

Figure 1.
Risk Management Maturity by Sector.

This figure is based on the data contained in Table 2. The average risk management maturity ratings for the oil & gas, manufacturing, and petrochemicals industry sectors are presented. The figure includes error bar representation of standard deviations, as one would expect in SPSS output.

The distribution of these profiles varied significantly by industry sector ($\chi^2 = 21.8$, $p < 0.001$), with oil and gas facilities more likely to fall into the Integrated Practitioners category (52%) compared to manufacturing (18%) and petrochemicals (29%).

4.2. Sustainability Performance Metrics

Sustainability performance showed substantial variation across the sampled facilities. Composite indices were calculated for operational, financial, and environmental sustainability dimensions, each normalized to a 0–100 scale. Table 3 presents mean sustainability scores by facility size and industry sector.

Table 3.
Sustainability Performance Scores by Facility Size and Industry Sector.

Sustainability Axis	**Small Enterprises (n=53)**	**Medium Enterprises (n=53)**	**Large Enterprises (n=53)**	**Overall (n=187)**
Oil & Gas				
Operational Sustainability	63.7 (11.2)	71.4 (9.8)	76.2 (8.3)	71.6 (10.6)
Financial Sustainability	61.9 (12.3)	68.7 (10.4)	72.8 (9.1)	69.0 (11.2)
Environmental Sustainability	58.3 (13.5)	67.2 (11.3)	73.6 (8.7)	67.9 (12.4)
Manufacturing				
Operational Sustainability	54.2 (12.7)	61.5 (10.6)	68.1 (9.4)	60.8 (12.1)
Financial Sustainability	57.3 (11.9)	63.6 (10.1)	66.4 (9.7)	62.3 (11.0)
Environmental Sustainability	51.6 (14.2)	58.7 (12.6)	64.5 (10.3)	57.9 (13.2)
Petrochemicals				
Operational Sustainability	59.8 (12.3)	68.9 (9.5)	72.7 (8.6)	67.3 (11.3)
Financial Sustainability	60.2 (11.7)	67.4 (9.8)	70.9 (8.9)	66.2 (10.9)
Environmental Sustainability	56.9 (13.6)	65.8 (10.7)	71.3 (9.1)	64.7 (12.1)

Note: Values represent means with standard deviations in parentheses

Table 3 shows the analysis of specific sustainability indicators, revealing some significant patterns of interest. Average annual operational downtime across all facilities was 157 hours, with noticeable gaps between high RMMI score facilities (103 hours) and low RMMI score facilities (226 hours). In resource efficiency metrics, water consumed per unit produced was 27 percent greater in facilities with low resource management maturity compared to their high maturity peers. A similar 19 percent differential was observed in energy intensity between these groups of facilities.

Figure 2: Sustainability Performance by Facility Size and Sector

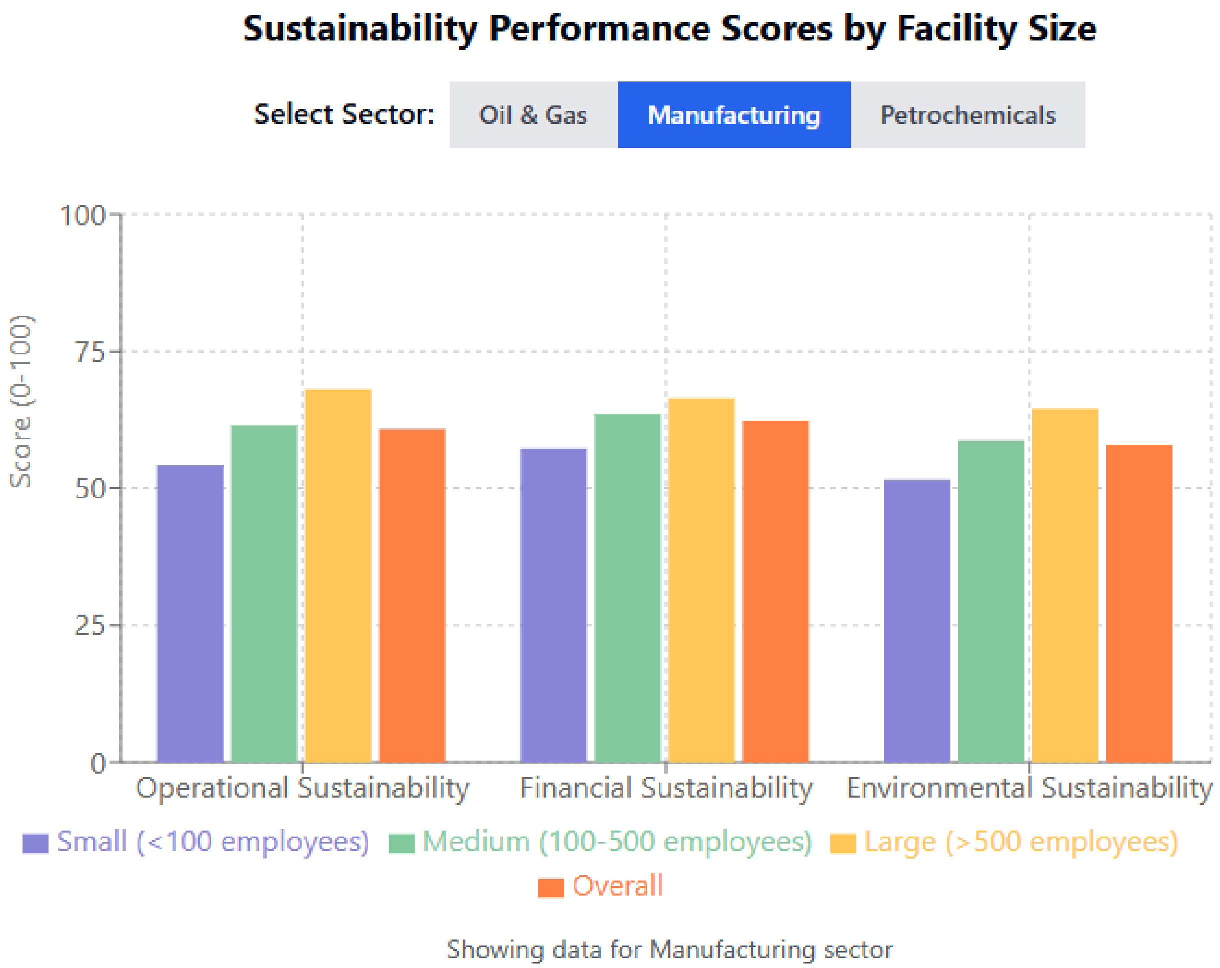

Figure 2.
This interactive graph provides a detailed breakdown of sustainability performance scores (operational, financial, environmental) for each sector according to facility size (small, medium, large). Selecting various sectors such as oil & gas, manufacturing, or petrochemicals will illustrate how facility size influences sustainability performance within the given industry.

4.3. Relationship Between Risk Management and Sustainability

Sustainability outcomes were significantly related to risk management maturity in multiple regression analyses. Controlling for facility size, age, and sector, standardized regression coefficients for RMMI dimensions predicting sustainability indices are presented in Table 4.

Table 4.
Regression Analysis – The Influence of Risk Management Dimensions on Sustainability Outcomes.

Risk Management axis	Operational Sustainability	Financial Sustainability	Environmental Sustainability
Risk Governance	0.31	0.27	0.22
Identification Processes	0.26	0.19	0.24
Assessment Methodologies	0.33	0.21	0.18
Mitigation Strategies	0.37	0.34	0.29
Monitoring Systems	0.28	0.23	0.32
Overall Risk Management Index (RMMI)	**0.42**	**0.36**	**0.31**
R^2	0.37	0.31	0.28
Adjusted R^2	0.35	0.29	0.26

Note: $p < 0.05$, $p < 0.01$, $p < 0.001$.

Table 4 shows that these findings suggest that risk management maturity accounted for 37% of the variance in operational sustainability, 31% in financial sustainability, and 28% in environmental sustainability after controlling for benchmarking facility attributes. Among risk management dimensions, mitigation strategies had the strongest relationship with operational and financial sustainability, while monitoring systems showed the strongest correlation with environmental sustainability.

Analysis of sustainability outcomes based on risk management strategies used at the facilities showed remarkable differences. Integrated Practitioners demonstrated significantly higher operational sustainability, with a mean difference of

27.3% ($p < 0.001$). They also showed 18.6% improved financial sustainability (mean difference = 12.4, $p < 0.001$) and 23.1% better environmental sustainability (mean difference = 15.8, $p < 0.001$), compared to Reactive Responders.

Structural equation modeling pinpointed multiple mediating variables in the association between risk management and sustainability outcomes:

1. The organizational learning capacity varied the strength of the relationship between risk identification processes and operational sustainability (indirect effect = 0.14, $p < 0.01$).
2. Organizational-defined efficiency for resource allocation served as a mediating variable in the relationship between risk assessment methods and financial sustainability (indirect effect = 0.17, $p < 0.01$).
3. The mediation role of compliance management effectiveness on the monitoring systems and environmental sustainability link specifies an indirect effect of 0.19 at a p-value of less than 0.001.

4.4. Critical Risk Dimensions in the Saudi Context.

The qualitative analysis from the interviews also identified five risk dimensions that have particular relevance to the sustainability of production facilities in Saudi Arabia.

4.4.1. Climate Resilience and Water Security

The water-related risks were highlighted as key threats to facility sustainability by almost all interviewees. For example, one of the operations directors said:

Water security is existential for us. Our entire production model assumes reliable water access, but we are operating in one of the world's most water-stressed regions. Any risk management approach that does not prioritize water security is fundamentally incomplete.

Rising temperatures were also reported as operational risks by 78% of interviewees, which indicates the need for climate adaptation. Additionally, the average rate of heat-related equipment malfunctions increased by 14% from 2021 to 2023 across the sampled facilities. Facilities without specific protocols for resilience to heat experienced 2.3 times higher rates of failure.

4.4.2. Anticipatory Procedures for Compliance

The newly emerging rules in Saudi Arabia have caused significant uncertainty regarding the smooth operation of facilities. In nearly all cases, interviewees (93%) identified regulatory changes as a major risk factor that requires active attention. One of the risk managers provided the following comment:

Systems are changing at a pace that most facilities cannot keep up with. Facilities with a compliance continuity plan and active monitoring and scenario planning do well. Most are defaulted with continual disruptions with every additional prerequisite.

Formal processes for regulatory anticipation were associated with 76 percent fewer compliance citations, 82 percent lower compliance-related expenditures than those without such processes. These differences were particularly pronounced in the manufacturing sector, which underwent considerable regulatory changes.

4.4.3. Supply Chain Robustness

Supply chains possess weaknesses as a third critical risk dimension that is exacerbated by global disruptions and regional geopolitical conflicts. In the interviews, participants remarked how traditional just-in-time inventory systems have become obsolete in recent years:

"The premise of the stability of the supply chain has been profoundly proven wrong. Those companies that undertook detailed supplier risk evaluation and attended to the diversification of their suppliers were nursed through the recent shocks, unlike others who suffered dire production crippling impacts." (P31, Oil and Gas Sector)

From the quantitative metrics, it was evident that the facilities with advanced supplier risk management frameworks had 64% less severe disruption durations and a 47% lower financial impact from supply chain disruptions compared to basic practitioners.

4.4.4. Technological Adaptation

While digitalizing the industrial segments of Saudi Arabia, concerns regarding technological adaptation risks have escalated. The interview participants noted conflicts between the need for adoption and operational risks:

We suffer from an implementation paradox technologically; there are rapid changes and exposure risks or, alternatively, corporate inefficiency and competitive disadvantage. ‘Balanced’ pathways are possible, but only with advanced risk evaluation capabilities. (P22, Manufacturing Sector)

Those reporting formal technology risk assessment methodologies had 53% higher ROI on technology spending. They experienced 67% fewer implementation failures than peers with more informal methodologies. Additionally, these peers exhibited sustained operational health through lower technology-induced disruptions.

4.4.5. Workforce Development

The last significant risk dimension centered on human capital issues within the Saudi labor market. Given the ongoing changes in the labor market with the implementation of Saudization policies, technical skills are becoming increasingly important. Interviewees noted that talent management is essential for sustainability.

Sustained facility risk is now a part of our business reality. The greatest operational risk we face isn't equipment failure or supply disruption; it's the talent capability gap, which is a looming risk. This gap exists between our workforce capabilities and operational requirements along the continuum. Efforts toward proactive talent risk management are now a necessity for any sustainable facility. (P14, Petrochemical Sector)

Such facilities equipped with workforce risk assessment and development programs had 37% lower average vacancy durations for critical positions, and 42% higher retention rates of technical specialists compared to those lacking such programs. These are some pace-setting human capital benefits that directly resulted in operational sustainability metrics of skill-related incidents and disruptions by 28% fewer.

4.5. Implementation Barriers and Success Factors

Qualitative analysis identified four barriers to the implementation of effective risk management in Saudi production facilities:

1. Organizational siloing: 76% of interviewees mentioned gaps across the functional interplay of technical, financial, and strategic arms of risk management.
2. Short-term operational focus: 69% noted conflict between spending for immediate production needs and long-term investments for risk mitigation.
3. Data limitations: 64% considered lack of adequate risk data collection and analysis capabilities as implementation constraints.
4. Cultural Issues: 57% of respondents remarked on organizational cultures that suppressed reporting and risk assessment.

In contrast, successful implementations showed several common factors:

1. Executive sponsorship: 88% of high-performing facilities reported vigorous executive participation in risk governance.
2. Alignment with business strategy: 73% of organizations integrated risk management strategies into the overall performance evaluation processes at organizational and functional levels.
3. Resource commitment: 81% provided dedicated funding for risk management systems, associated technologies, and relevant training.
4. Integrative approaches: 77% created multi-disciplinary risk committees with authority to make managerial decisions.

These results are helpful in explaining the variation in the level of risk management sophistication of Saudi production facilities, as well as drawing attention to the particular organizational variables that affect the success of implementation.

5. Discussion

5.1. The Interaction of Risk Management and Sustainability

This study illustrates a strong connection between the multifunctional practices of risk management and the sustainability of production facilities in Saudi Arabia. The literature was enriched by demonstrating how such relationships exist within the context of an industrialized country in the Middle East. It also explores how risk management affects sustainability through specific pathways.

The gap in the literature explaining the relationship between advanced risk management systems and operational sustainability, where R2 = 0.37, helped sustain some level of operational resiliency as explained by Pettit et al. [25]. Systematic risk management does help create some level of adaptive capacity so that disruptions do not turn into permanent shutdowns of operations. This idea is not new to the Western world; however, we argue this is more pronounced in Saudi Arabia's industrial context due to high uncertainty and rapidly changing economic conditions.

The weak to moderate findings on the integration of risk management and planning in an organization's financial sustainability, where R2 = 0.31, corroborate resource-based theories of organizational performance [26]. These theories have long claimed that competitive advantage emerges from capabilities that are valuable, rare, and difficult to replicate. In the transforming industrial landscape of Saudi Arabia, this advantage appears to be more significant for plants and factories that operate within new economic, cost, investment, and market-driven dynamics.

Perhaps most remarkably, the link between risk management and environmental sustainability ($R^2 = 0.28$) provides an alternative explanation regarding the contradictions between performance in the environment and operational concerns. Rather, our findings propose that advanced risk management allows facilities to foresee environmental issues, resource control, compliance management, or eco-sustenance vernaculars. These systems strategically align with the operational goals without undermining the objectives.

5.2. Contextual Factors in Saudi Risk Management

The five critical risk dimensions identified in this research, climate resilience, regulatory anticipation, supply chain robustness, technological adaptation, and workforce development, demonstrate the primary focus of risks in Saudi Arabia due to the specific industrial context. These dimensions epitomize the blend of global industrial movements with the particular features of the region that are unique.

Considering the harsh environmental conditions of Saudi Arabia, climate resilience and water security are particularly crucial. With industrial zone temperatures rising by approximately 0.2°C per year [27] and groundwater reserves are depleting unsustainably. Production facilities face challenges that are no longer purely operational in nature. This aligns with the argument made by Al-Zahrani and Baig [13] that industrial sustainability in arid regions requires a fundamentally different approach to risk management compared to water-rich environments.

The focus on regulatory expectation as a crucial risk dimension shows the Kingdom's acceleration of policy developments under Vision 2030. Although all industries face the risk of regulatory change, no other country appears to impose as much intense adaptation strain as Saudi Arabia does through the volume and speed of reforms. This also builds on Al-Otaibi [12] work on regulatory uncertainty by providing evidence on the economic rivalry sustainability benefits to facilities that possess developed regulatory intelligence skills.

Also, the workforce development dimension highlights some of the distinctive gaps in human capital for Saudi Arabia's industrial areas. As the labor market is undergoing Saudization and other technical skills are changing, the facilities are confronted with heightened acute talent risks that impact the operational sustainability of the facility. This finding adds to the emerging human capital risk management literature [28] by illustrating the mechanisms through which workforce risks undermine industrial sustainability in a workforce nationalizing environment.

5.3. Maturity Variation Across Industrial Sectors

Greater attention should be given to the notable differences in the level of development of risk management systems across different industrial sectors. The oil and gas facilities appear to have substantially higher maturity (RMMI = 5.0) than manufacturing (RMMI = 3.5) and petrochemicals (RMMI = 4.3). Other reasons for this are the relatively longer history of the oil and gas sector in Saudi Arabia, its exposure to high-consequence risks, and its dependence on multinational partnerships for the oil and gas industry.

The lower risk management maturity of the manufacturing sector indicates an area of development focus, particularly as this sector emerges within the context of Saudi Arabia's economic diversification strategy. Manufacturing plants showed notable gaps in assessment processes (mean = 3.2) and control mechanisms (mean = 3.4), which may limit their capability to identify risks and evaluate mitigation strategies. This supports Ibrahim and Hassan's [29] viewpoint that informal risk evaluation practices, prevalent within Saudi manufacturing firms, may become increasingly problematic with rising levels of operational intricacy.

The mid-level position of petrochemical facilities probably represents a mixed position for this sector that combines elements of process industries like oil and gas with some manufacturing features. This finding helps to address the gaps [30] work on the construction and development of organizational capabilities in Saudi industrial contexts by demonstrating the impact of industry features on the respective trajectories of risk management development.

5.4. Organizational Factors in Risk Management Implementation

The identified implementation barriers and success factors reveal organizational dynamics that are critical for understanding risk management effectiveness. The existence of organizational siloing as an implementation barrier (cited by 76% of those interviewed) indicates that deep-seated functional boundaries pose major impediments to risk management integration in production facilities in Saudi Arabia. This supports Al-Rasheed and Naguib [31]'s explorations of organizational structure impediments in Saudi enterprises, albeit extending their work by elucidating the implications for risk management.

The prominence of executive championship as a success factor (present in 88% of the high-performing facilities) highlights how leadership commitment shapes the influence of risk management implementation. In Saudi organizational contexts, where command-and-control structures are still quite pronounced, this leadership commitment remains crucial for effective risk management [32] there is a credible assumption that senior leadership delegations concerning risk management are likely to influence organizational uptake, resource allocation, and organizational adoption levels significantly.

That integration with performance management systems was a strong predictor of implementation success. It adds depth to the debate on how risk management is assimilated within organizational processes and routines. By aligning risk management activities with performance appraisal systems, facilities establish accountability mechanisms that make enduring implementation possible beyond mere initial adoption. This contributes to the work of Abdullah and Valentine [33] on governance mechanisms in Saudi organizations by detailing how risk governance principles are operationalized through specific practices that actually transform organizational realities.

5.5. Implications for Practice

These results offer a few insights regarding practice for stakeholders in the industrial domain in Saudi Arabia.

For facility managers, these outcomes suggest that there are clear sustainability advantages associated with investing in risk management capabilities, especially along the five pivotal dimensions. The sheer performance gaps between Integrated Practitioners and Reactive Responders are striking – the former significantly outperforming the latter, compelling one to consider more 'evolved' stages of risk management. Specifically, they need to focus on:

1. Forming integrated governance frameworks that capture the tactical, financial, and strategic views on risk.
2. Applying relevant quantitative risk assessment procedures for their context.
3. Designing robust monitoring frameworks for all metrics of risks and their mitigation.

For policymakers, the results reveal ways to enhance industrial sustainability through investment in risk management capacity development. The existing regulatory approaches focus more on verifying compliance with limits set by regulations rather than fostering capabilities. Other approaches could be more effective, such as:

1. Designing adequate sector-specific risk management frameworks targeting the five pivotal dimensions.
2. Establishing cross-sectoral industrial risk management forums for sharing and advancing practices.
3. Evaluating risk management competencies as a requirement for granting industrial licenses.

For industry associations, these findings highlight the benefits of launching collaborative risk information sharing initiatives. Gaps in proactive regulation and the adoption of advanced manufacturing technologies contribute to the creation of collaborative approaches to information gathering and assessment tools across various entities.

For educational organizations, the results highlight the acute gap in targeted professional training programs dealing with risk management specific to Saudi Arabia's industrial setting. Most offered advanced training programs use plans developed in different regions with little or no modification to local realities.

5.6. Shortcomings and Other Considerations

These shortcomings of the work may be taken as reasons to conduct further research. To begin with, the sampling frame, which consists of 187 facilities, is rather large; it constitutes only 14 percent of the major production facilities in Saudi Arabia. Later studies should have broader sampling scopes, especially with younger, newer facilities set up in industrial hubs like the King Abdullah Economic City.

On the other hand, the cross-sectional approach used here is not helpful in explaining the likely relationships that could exist between sustainability and risk management practices. Following the facilities longitudinally would deepen knowledge about how investment in risk management is converted into sustainability through several processes.

Lastly, the study was primarily concerned with formal practices of risk management, leaving little room for informal risk strategies that might be embedded in the day-to-day activities of the organization. Other studies using ethnographic techniques might add important aspects of the phenomenon of risk management that were missed by this study.

Fourth, while the study identified critical risk dimensions, it did not comprehensively assess risk interactions and systemic effects. Further research utilizing system dynamics modeling could build on these findings by exploring the interconnections of risks and their potential system-wide impacts in production systems.

Finally, the scope of research was limited to facility-level outcomes while ignoring the impact across the supply chain or ecosystem. Other studies might explore the cascading effects of risk management practices through industrial networks and onto regional industrial resilience in Saudi Arabia.

6. Conclusion

This study illustrates how risk management strategies impact the operational, financial, and environmental sustainability of production facilities in Saudi Arabia. Integrated risk management frameworks enhanced operational sustainability scores by 27.3% and improved financial resilience by 18.6% compared to facilities adopting fragmented approaches. These findings are arguably most salient relative to the context of Saudi Arabia's growing industrial economy, which increasingly faces new challenges where traditional risk management strategies are insufficient.

The analysis notes five risk areas that are specifically important to Saudi production facilities. climate and water security, anticipation of legal frameworks, supply chain strength, technological change, and human capital. These areas show the unique set of risks shaped by Saudi Arabia's geography, economic transformation drives, and socio-political environment. Management of these areas is more effective when tailored to the context rather than using international approaches. tends to be the case for many countries.

The mismatch in the degree of sophistication in risk management across different Saudi industrial sectors provides opportunities for development. Within the Kingdom's economic diversification strategy, there is increasing focus on manufacturing, which is relatively less mature and therefore presents greater opportunities. Alongside factors such as the integration of leadership roles and performance management, investment in capabilities, team structures, and organizational processes tend to enable effective risk management.

While operational facilities have unprecedented opportunities, under Hyperreality, there are complex challenges everywhere as the kingdom continues its aggressive economic transformation plans under Vision 2030. The reliance on outsourcing complicates effective supply chain management in dealing with these unprecedented opportunities. This study advocates evolving risk management from merely ensuring compliance, at best, to becoming deeply embedded into organizational culture. Those that succeed in this shift secure operational sustainability balanced amidst fierce competition over profitability, environmental, and social value.

In the context of Saudi Arabia, further studies on how risk management impacts industrial sustainability would benefit from broadening sample coverage, employing longitudinal designs, exploring informal risk practices, evaluating inter-systemic risks, and studying wider ecosystem impacts.

References

[1] Saudi Arabia, *Vision 2030: National transformation for a diversified and sustainable economy*. Riyadh, Saudi Arabia: Council of Economic and Development Affairs, 2016.

[2] N. Al-Shammari and M. Al-Khateeb, "The effect of economic diversification on the industrial risk scape in Saudi Arabia," *Journal of Gulf Economics*, vol. 23, no. 2, pp. 187–204, 2023.

[3] S. M. Ibrahim, "A comparative analysis of risk management practices across industrial sectors in Saudi Arabia," *International Journal of Production Economics*, vol. 201, pp. 273–289, 2022.

[4] T. Aven, "The risk concept—historical and recent development trends," *Reliability Engineering & System Safety*, vol. 99, pp. 33-44, 2012. https://doi.org/10.1016/j.ress.2011.11.006

[5] M. Arena, M. Arnaboldi, and G. Azzone, "The organizational dynamics of Enterprise Risk Management," *Accounting, Organizations and Society*, vol. 35, no. 7, pp. 659-675, 2010. https://doi.org/10.1016/j.aos.2010.07.003

[6] T. Aven and E. Zio, "Some considerations on the treatment of uncertainties in risk assessment for practical decision making," *Reliability Engineering & System Safety*, vol. 96, no. 1, pp. 64-74, 2011. https://doi.org/10.1016/j.ress.2010.06.001

[7] D. Macdonald, J. Smallwood, and T. Basson, "Perceptions of contractors of the impact risk has on construction projects," *Journal of Construction*, vol. 12, no. 2, pp. 21-35, 2019.

[8] A. Al-Hammad, "Risk assessment for petrochemical facilities in GCC countries," *Engineering, Construction and Architectural Management*, vol. 27, no. 7, pp. 1603-1624, 2020.

[9] K. Al-Mansouri and R. Morgan, "Risk management maturity in Gulf industrial organizations: A comparative study," *Risk Management*, vol. 16, no. 4, pp. 233–251, 2019.

[10] World Resources Institute, "Aqueduct water risk atlas: An overview," 2023. https://www.wri.org/aqueduct

[11] H. Al-Zawad and B. Aksakal, "Mortality benefit of building adaptations to protect care home residents against heat risks in the context of uncertainty over loss of life expectancy from heat," *Climate Risk Management*, vol. 32, p. 100307, 2021.

[12] Y. Al-Otaibi, "Regulatory uncertainty and industrial investment decisions in Saudi Arabia," *Saudi Journal of Economics and Management*, vol. 5, no. 3, pp. 67–89, 2022.

[13] K. H. Al-Zahrani and M. B. Baig, "Water in the Kingdom of Saudi Arabia: sustainable management options," *The Journal of Animal & Plant Sciences*, vol. 21, no. 3, pp. 601-604, 2011.

[14] S. Khan and M. Al-Gahtani, "Industrial systems with sustainable operations in water-scarce regions: Saudi Arabia case studies," *Journal of Cleaner Production*, vol. 286, p. 125432, 2021.

[15] J. Elkington, "Partnerships from cannibals with forks: The triple bottom line of 21st-century business," *Environmental Quality Management*, vol. 8, no. 1, pp. 37-51, 1998. https://doi.org/10.1002/tqem.3310080106

[16] W. F. Vásquez and J. Alicea-Planas, "Unbundling household preferences for improved sanitation: A choice experiment from an urban settlement in Nicaragua," *Journal of Environmental Management*, vol. 218, pp. 477-485, 2018. https://doi.org/10.1016/j.jenvman.2018.04.085

[17] Saudi Energy Efficiency Center, "Report on industrial energy consumption," 2023. https://www.seec.gov.sa/ar

[18] W. S. Lee and D. L. K. Chuen, "Risk management and sustainability: Theoretical framework and empirical verification," *Sustainability*, vol. 13, no. 2, p. 781, 2021.

[19] A. Rostami and C. J. Sommerville, "Risk management for building sustainable infrastructure," *Proceedings of the Institution of Civil Engineers – Engineering Sustainability*, vol. 168, no. 4, pp. 161-172, 2015.

[20] A. Ibrahim, "Environmental compliance alongside operational risk controls in Saudi petrochemical facilities," *Saudi Journal of Engineering and Applied Sciences*, vol. 12, no. 3, pp. 243–262, 2022.

[21] S. Al-Qahtani, M. Al-Gahtani, and A. Al-Yami, "Operational risk control effectiveness in Saudi oil and gas operations," *Journal of Risk Research*, vol. 24, no. 9, pp. 1112–1131, 2021.

[22] J. Creswell and V. Plano Clark, *Designing and conducting mixed methods research*, 3rd ed. Thousand Oaks, CA: SAGE Publications, 2018.

[23] A. Bryman, "Integrating quantitative and qualitative research: How is it done?," *Qualitative Research*, vol. 6, no. 1, pp. 97-113, 2006. https://doi.org/10.1177/1468794106058877

[24] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77-101, 2006. https://doi.org/10.1191/1478088706qp063oa

[25] T. J. Pettit, K. L. Croxton, and J. Fiksel, "Ensuring supply chain resilience: Development and implementation of an assessment tool," *Journal of Business Logistics*, vol. 34, no. 1, pp. 46-76, 2013. https://doi.org/10.1111/jbl.12009

[26] J. Barney, "Firm resources and sustained competitive advantage," *Journal of Management*, vol. 17, no. 1, pp. 99-120, 1991. https://doi.org/10.1177/014920639101700108

[27] A. H. Ahmed and A. S. Al-Amri, "Challenges and sustainable industrial opportunities in Saudi Arabia's groundwater depletion," *Water Resources Management*, vol. 35, no. 8, pp. 2523–2541, 2021.

[28] S. Bhattacharya and P. Wright, "Human resource management and the bottom line: Is there a real connection?," *Human Resource Management Journal*, vol. 15, no. 3, pp. 3–26, 2005.

[29] B. Ibrahim and M. Hassan, "A study of current practices regarding risk assessment methodologies in Saudi manufacturing organizations," *International Journal of Industrial Engineering*, vol. 29, no. 4, pp. 312–331, 2022.

[30] A. Al-Ahmari, "Capability development trajectories in Saudi industrial organizations," *International Journal of Operations & Production Management*, vol. 41, no. 7, pp. 1128–1152, 2021.

[31] K. Al-Rasheed and R. Naguib, "Organizational structures and innovation in Saudi enterprises: Barriers and opportunities," *Saudi Journal of Business Management*, vol. 6, no. 2, pp. 87–106, 2021.

[32] A. Al-Swidi and A. Mahmood, "Styles of leadership and performance of firms in Saudi Arabia: The moderating impact of culture," *Saudi Journal of Management Studies*, vol. 3, no. 1, pp. 45–63, 2019.

[33] H. Abdullah and B. Valentine, "Corporate governance and Saudi Arabian corporations: Governance mechanisms and issues," *Corporate Ownership & Control*, vol. 15, no. 4, pp. 8-21, 2018.