



Article

The Role of Green Accounting in Reducing Operational and Environmental Risks of Extractive Companies: An Analytical Study Using Financial Resilience and Feasibility “Indicators”

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Abstract: This study aims to explore the role of green accounting in reducing operational and environmental risks in industrial companies and to achieve this goal, the descriptive-analytical approach was adopted to root the intellectual framework of the variables, and the applied mathematical approach was adopted through a hypothetical case study of an industrial company (Al-Rafidain Construction Industries Company) for three consecutive years (2023-2025). The study relied on the method of ratios, mathematical indicators, and flexibility coefficients to measure the extent to which risk losses respond to changes in the volume of expenditure on green accounting. The study concluded that there was a clear inverse relationship, as increasing the intensity of environmental expenditure contributed to reducing the losses of operational and environmental risks by negative elasticity ratios of (-0.20) and (-0.27) respectively. The study recommends the need to integrate environmental costs into the accounting systems of industrial companies as a proactive tool to manage risks and avoid legal fines and production stoppages.

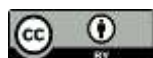
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Keywords: Green accounting, operational risks, environmental risks, industrial companies, mathematical elasticity indicators.

1. Introduction

The contemporary industrial environment is facing increasing challenges related to the need to strike a balance between maximizing economic profits and adhering to environmental responsibility. Industrial companies are one of the most influential sectors and affected by environmental problems due to the volume of waste and emissions resulting from their production processes, which imposes financial burdens and unplanned risks on them [1]. As a modern accounting and strategic tool that goes beyond the traditional role of financial accounting, to inventory, measure, and disclose environmental costs. The importance of green accounting is not only to improve the mental image of the organization, but also to be a preventive control system that provides management with the necessary data to predict and reduce risks. Ignorance of environmental costs consequently exacerbates operational risks (e.g., work accidents and damage to machinery) and environmental risks (e.g., legal fines and pollution costs). Based on this, this study provides a simplified application framework that links the volume of

expenditure on green accounting and the reduction of operational and environmental risks in industrial companies, which contributes to strengthening environmental accounting thought with clear practical measurement mechanisms [2].

2. Materials and Methods

The research methodology constitutes the procedural guide that links the hypotheses to the practical aspect.

1. Research problem:

The problem lies in the fact that traditional accounting systems in many industrial companies separate environmental spending decisions from risk management, which generates a weakness in estimating the size of the financial burdens resulting from the realization of operational and environmental risks. The research problem can be formulated in the main question: Does activating spending on green accounting contribute to reducing the operational and environmental risk losses of industrial companies.

2. The importance of the research :

This study will extend its importance from two main angles:

Scientific (theoretical) significance: Tech One in enriching the accounting literature by linking green accounting to risk management (operational and environmental), and providing a thought model that shows how environmental costs can be transformed from a mere financial burden into a proactive preventive tool to protect an enterprise's funds.

Practical (Application) Importance: It is manifested in the provision of a practical and simplified mathematical measurement framework (away from statistical complexities) for industrial/extractive companies, which helps decision-makers and financial management to assess the feasibility of environmental spending, and shows the extent to which each dinar spent on green accounting contributes to reducing direct financial losses resulting from environmental malfunctions, fines, and compensation.

3. Research Objectives:

The research sought to achieve the following main objectives : Intellectual and conceptual rooting of green accounting and operational and environmental risks in industrial and extractive companies

Measuring and determining the size of expenditure on green accounting (filter costs, waste treatment, and environmental maintenance) in the study sample company for years. (2023-2025) Calculating the Volume of Operational Risk Losses (Production Downtime and Breakdowns) and Environmental Risk Losses (Fines and Compensation) for the Years Under Study Applying the method of ratios, mathematical indicators and mathematical flexibility coefficients to verify the extent to which risk losses respond and be affected by the increase in green accounting spending Provide practical recommendations to financial management in industrial companies on how to integrate environmental costs within accounting systems as a bulwark against risks

4. Research Hypotheses:

To find solutions to the research problem, two main hypotheses of nullity have been formulated: The first hypothesis: There is no mathematically significant effect of spending on green accounting in reducing operational risk losses in the industrial company Study sample

Assumption Two: There is nomathematically significant effect of spending on green accounting in reducing the losses of environmental risks in the industrial company Study sample

5. Research variables: Indicators and their measurement:

Independent Variable: Green Accounting, expressed in Total Environmental Expenditure Filter Costs, Waste Treatment, Environmental Maintenance For the first dependent variable: operational risk losses

Accidental maintenance of production interruption, maintenance of sudden breakdowns due to pollution or safety neglect)

The second dependent variable: Environmental risk losses: government fines, compensation for those affected by pollution

6-A The method of the proposed mathematical analysis

is based on the calculation of the environmental expenditure intensity index and then the calculation of the mathematical flexibility coefficients to indicate the extent of the response of the variables dependent to the change in the independent variable.

Second: Previous Studies

1- A Study (Al-Obaidi)

Title: The Impact of Green Accounting on Reducing Environmental Costs and Operational Risks: An Exploratory Study in Iraqi Industrial Companies.

Objective: The study aimed to measure the role of green accounting tools in reducing operational risks and reducing indirect environmental costs in the industrial sector.

Methodology and Application: The study relied on the descriptive-analytical approach and data collection through the questionnaire and financial analysis of a sample of industrial companies.

Key findings: The study found that accurate identification and disclosure of environmental costs directly contributes to avoiding sudden breakdowns of machines and reducing losses resulting from downtime of production lines

2-A Study (Al-Sharif & Al-Sayed, 2024)

Title: The Role of Environmental Accounting Disclosure in Reducing Environmental Risks and Conditional Obligations: An Applied Study on Extractive Companies

Objective: A Study of How Activating Environmental Disclosure and Green Accounting Reduces Government Compensation and Fines Resulting from Environmental Pollution.

Application: It relied on the analysis of the financial statements and supplementary reports of a number of extractive and oil companies and the use of financial and mathematical analysis indicators Conclusions: The study proved that there is an inverse relationship between the increase in the rates of environmental preventive spending and the volume of fines and financial compensation paid to government agencies and those affected

3-A Study Al-Daoud et al., 2021

Green Accounting Practices and Operational Risk Mitigation in Manufacturing Firms

Objective: To assess the impact of green accounting practices and environmental budget allocation in mitigating work accidents and operational risks.

Application: The study used the model of analysis of mathematical ratios and financial indicators for the time series data of manufacturing companies over a period of 5 years Conclusions: The results confirmed that companies that integrate environmental maintenance costs and filters into their accounting system have high rates of flexibility in reducing the costs of breakdowns and operational losses.

4-A Study Zhang & Wang, 2023

The Impact of Environmental Cost Accounting on Corporate Environmental Risk and Financial Feasibility.

Objective: To measure the extent to which environmental cost accounting contributes to improving financial viability and avoiding environmental risks in heavy industrial sectors.

Application: The mathematical analytical approach was applied to calculate the elasticity coefficients between the intensity of environmental expenditure and the reduction in fines and indirect costs.

Conclusions: The study showed that spending on waste treatment and proactive maintenance benefits the company's financial value through savings in reducing environmental losses

- What distinguishes current studies from previous studies

This study is consistent with previous studies in its treatment of green accounting and environmental and operational risks, but it is distinguished from it in providing a simplified mathematical measurement framework based on the mathematical flexibility coefficients and the net financial savings index without statistical complexities, and applying it to a sample of industrial/extractive companies to show the direct impact in absolute and relative numbers

Theoretical aspect:

3. Results and Discussion

The first topic:

1. Green Accounting Concepts:

Singh explained that the accounting and financial system aims to measure and record the environmental costs and benefits resulting from the operational activity, with the aim of improving the efficiency of the use of natural resources and providing reliable information that helps management reduce carbon footprints and promote environmental accountability.

Al-Madani & Hussain- It was found that an integrated coordination between the traditional accounting system and environmental management works to collect and compile data related to green investment costs (such as pollution prevention and waste recycling techniques) and link them directly to periodic financial reports to show their impact on financial performance and

An accounting methodology based on the identification and allocation of direct explicit and implied environmental costs and their financial measurement, for inclusion in the financial statements, enabling stakeholders to assess the natural capital risks and environmental liabilities of the company [3]

He explained that the modern branch of management and financial accounting focuses on tracking and documenting the environmental cost of a product throughout its life cycle, and linking environmental accounting practices to sustainable economic performance indicators and the organization's green capital

An advanced financial disclosure and evaluation tool based on the inventory of all financial and material flows related to the preservation of the environment, and the transformation of the environmental impacts of companies into accurate financial indicators and figures that can be compared and measured in the capital markets [4].

2. Types of Environmental Costs in Green Accounting

Green accounting relies on an accurate classification of costs to ensure that they are directly charged to productive activities

Direct costs: costs of technical equipment to prevent pollution and waste disposal

Indirect costs: Environmental inspection fees and training staff on green activities

Contingent costs: pollution fines and future legal settlements.

Social/external costs: Environmental damage to the community that is not directly borne by the company in its traditional listings

3. The basic components and objectives of the implementation of the green accounting system The

modern application of green accounting focuses on several strategic

objectives * Natural capital measurement: the consumption and depletion of natural resources as part of the company

's assets * Rationalization of investment decisions: directing investments towards projects with a dual

environmental and economic return*Reducing financial reporting risk: Reducing undisclosed environmental liabilities that may affect the market value of stocks [5]

4. Determinants and Constraints of Green Accounting:

Despite its importance, companies face difficulties in their field implementation

Difficulty of monetary measurement: The difficulty of accurately financial assessment of environmental damages such as carbon footprints and emissions.

Weakness of the Standard Accounting Standards: Lack of a binding international accounting standard that regulates green accounting independently

.5. Theories:

Legitimacy Theory Sharia Theory

is one of the most widely used theories in explaining the adoption of green accounting and environmental disclosure, as it assumes that the entity operates according to a social contract with the community, and uses green accounting to prove that its activities are compatible with the prevailing environmental values and standards to ensure its survival and continuity [6]

Stakeholder Theory Stakeholder Theory

This theory emphasizes that a company's management is accountable not only to the owners (shareholders), but also to all stakeholders affected by the activity (e.g., consumers, government agencies, and local communities). Green accounting is a means of providing financial and environmental information that meets the aspirations and needs of these multiple groups

Polluter Pays Principle The polluter principle

is an accounting and economic principle that the entity responsible for environmental pollution must bear all financial costs resulting from its prevention or treatment of the damages caused by it [7], [8]. This principle constitutes the legal and accounting basis for recording environmental obligations and costs in the company's books

The Environmental Precaution Principle

states that when there are threats of serious or irreparable environmental damage, complete scientific uncertainty should not be a reason to postpone taking preventive measures accounting, this principle obliges companies to recognize potential environmental allocations and liabilities early without waiting for direct damage to occur Corporate theory explains the ability of organizations to adopt green accounting systems as a result of pressures arising from the surrounding environment (government legislative pressures, professional normative pressures, or competitor simulation pressures) [9], [10]. It explains how companies are turning to the same green accounting applications to achieve institutional acceptance.

The second topic: Operational and environmental risks

1. The concept of operational risks :

Operational risks in this sector have been defined as the possibility of unexpected disruptions or losses resulting from malfunctions in internal systems and processes, human errors, or extreme conditions at exploration, drilling and extraction sites, leading to process disruptions affecting continuity [11].

2. Dimension of Operational Risks in Extractive Companies

Operational risks in mining and extraction operations are distributed across four basic dimensions

—human dimension : work injuries, poor technical efficiency, and errors during operation

—technical and equipment dimension : severe technical failures, maintenance failures, and cyber risks after procedures and operations: poor implementation of safety standards (HSE)

– supply chain disruptionAfter Events and the External Environment: Natural Disasters, Community Unrest, and Organizational Changes.

3 Operational Risk Management Objectives Risk

management systems in the extractive sector seek to achieve a set of key objectives:

- Ensuring continuity of production: Reducing technical downtime and unplanned delays. Protecting lives and the environment: Reducing occupational accidents, pollution and leakage accidents - Reducing costs and losses: Reducing expenses resulting from emergency maintenance and environmental fines

Promoting Social License: Building trust with local communities and maintaining company reputation

Second: Environmental Risks

1. The Concept of Risk

Environmental risks in the extractive sector are defined as the possibility of negative effects on the natural environment (soil, water, air, and biodiversity) as a result of extractive activities such as exploration, drilling, mining, or waste disposal, which entails legal responsibilities and financial and societal losses for the company [12].

2. Dimensions of Environmental Risks

The dimensions of environmental risks are represented in four main

axes-Pollution of water resources: Chemical and oil spillage into groundwater and surface waters-Air pollution and emissions : emission of greenhouse gases (e.g., methane and carbon dioxide) and toxic dust-Soil and vegetation degradation: land dredging and accumulation of solid and mining wastes Threat to biodiversity : destruction of natural habitats and decline of living populations in areas of urban areas ExtractC

3. Environmental Risks Objectives Extractive companies' environmental risk management systems aim to achieve the following

objectives: Compliance with legislation: Adherence to local and international environmental standards to avoid penalties and

prosecutions-Pollution and waste reduction: Carbon emissions reduction and industrial waste treatment before discharge

-Sustainability: Reduce the environmental footprint of projects and apply green extraction technologies [13], [14]. Reputation Protection and Confidence Building: Gaining the Support of Surrounding Communities and Environmental Organizations (Obtaining the Social Environmental License) Al-Mansour: 2020

4. Principles of Environmental Risk Management:

Successful environmental risk management is based on 4 basic principles
Precautionary Principle

- Taking immediate preventive measures even in the absence of full scientific certainty about the magnitude of the environmental risk
Polluter Pays Principle: - The company bears full financial responsibility for pollution removal and rehabilitation
EIA Principle

-Conducting comprehensive environmental impact : assessment studies before starting any extraction project

-Mitigation & Restoration: -Seeking to minimize damage during operation while committing to rehabilitating the site naturally after the completion of the extraction operations

The theoretical aspect between the independent and dependent variables is that green accounting is an extension and strategic development of the traditional financial accounting system, as accounting is no longer limited to tracking and proving the financial and economic transactions under investigation, but has extended to include inventory, measurement, and disclosure of environmental costs and liabilities resulting from the operational and production activities of industrial and extractive

companies [15]. Accounting Objective: This system provides management with accurate financial and environmental data that helps predict future burdens and convert environmental costs from mere "expendable expenses" to a proactive preventive investment aimed at protecting the company's assets and reducing resource

wastage
Environmental Costs Classification: Environmental costs within the green system are divided into three main tabs

Prevention costs: such as investment in filter installation, periodic environmental maintenance, and emission reduction

technologies
Costs of assessment and control: such as pollution checks and environmental safety monitoring

Treatment costs: includes management and recycling of industrial waste and waste treatment
Since. Nature and Classification of Risks in Industrial and Extractive Companies
Industrial and extractive companies are exposed to a set of direct financial and operational risks due to the nature of emissions-intensive and waste-intensive production processes [16]. These risks are classified in the study into two main types, namely operational and environmental
Operational is the risks associated with daily internal operations, and its losses are the costs of sudden breakdowns of machinery and equipment, the costs of production lines shutting down and the increase in the percentage of damaged or perishable production resulting from the mismanagement of safety and environmental maintenance within the facility, while the environmental is the risks resulting from the negative impact of the company's operations on the external environment and the surrounding space, and its direct losses are crystallized in government fines and financial penalties resulting from the violation of laws and legislation [17]. The conceptual framework of the research is based on the idea of the preventive inverse relationship between the volume of expenditure on green accounting and the size of risk losses and the mechanism of influencing operational risks: when the company allocates sufficient budgets for environmental maintenance and filters (green spending), this is directly reflected in raising the efficiency of equipment and reducing bottlenecks and internal pollution, which leads to the reduction of production stoppages and mechanical failures
Impact on environmental risks: The company's commitment to measuring, disclosing environmental costs and treating waste on a first-come, first-served basis contributes to compliance with environmental laws and regulations, which incapacitates the facility from incurring high legal fines and emergency financial damages
The theoretical aspect of the

research concludes that the integration of green accounting within the accounting structure of companies is not technical or merely an improvement of the mental image of the enterprise, but rather a proactive control and financial tool that achieves financial savings for the company and prevents the leakage of profits in the form of fines or emergency maintenance costs, which supports the economic feasibility and financial sustainability of industrial and extractive companies [18], [19].

Practical aspect:

Introduction

After the theoretical and conceptual review of the study variables represented in green accounting and operational and environmental risk variables, this research seeks to embody these theoretical concepts within a direct applied and analytical framework through a case study of (Al-Rafidain Construction Industries) Company for the period from (2023 to 2025).

Operational and environmental risks (as dependent variables)

In order to ensure the clarity and accuracy of the results away from statistical complexities, this aspect relies on the method of time series analysis and financial indicators by calculating ratios, mathematical flexibility coefficients, and financial savings indicators, to test the hypotheses of the study and determine the extent of the actual response to risk losses when increasing green accounting allocations, in order to draw accurate financial results that help decision-makers in financial management to assess the feasibility of environmental spending as a proactive preventive tool [20].

1. Structure of the Environmental Cost Classification

Before the financial analysis, it is preferable to include how to measure and classify the green accounting variable within the company to verify the integrity of the accounting entry: Practical Research Vocabulary

Purchasing and Maintaining Filters Environmental Impact Studies Proposed Accounting Tab Air & Water Quality Measurement Periodic Environmental Inspection Environmental/Operational Fixed Assets Industrial Waste Treatment and Maintenance of Environmental Faults Environmental Quality Control Expenses Maintenance and Operating Expenses

2. Net Environmental Financial Availability Index:

To prove that environmental spending is not just a burden but also a good investment financially, the net financial savings resulting from the reduction of loss is calculated compared to the increase in expenditure.

Savings in operational and environmental risks (2023-2025)

$180,000 = 80,000 + 100,000$

$132,000 = 80,000 + 52,000$

$180,000 - 132,000 = 48,000$

Increase in environmental spending:

$100,000 - 50,000 = 50,000$

Sports Environmental Investment Return

$ROI_{Enu} = -48,000 \div 50,000 = 96\%$

Explanation: Every additional dinars invested by the company in green accounting was recovered from the company 96% in the form of protection and direct redemption to save money to avoid losses [21].

Adding an applied paragraph that includes a recommendation on how to record the accounting costs of environmental costs to ensure the sustainability of measurement in the company

Allocating an environmental cost measurement center: Opening an independent cost center under the name of (Environmental Cost and Responsibility Center) within the Manual of Accounts

Financial Statement Disclosure: Showing the environmental costs within the financial statements with a special appendix (sustainability report or financial environmental disclosure report) to indicate the efficiency of risk management before external and regulatory bodies

*The applied mathematical approach used to analyze digital time series and indicators of change [22].

Mathematical Measuring Instruments

Percentage Change Rate

$$\Delta x\% = \frac{x_t - x_{t-1}}{x_{t-1}} \times 100$$

Elasticity Coefficient

$$E = \frac{\Delta x\%}{\Delta y\%}$$

Mathematical presentation and analysis of data (study case hypothetical)

Table No. (1)

Operational Risk Losses Y and Disruptions production stoppages	Environmental expenditure (Independent variable costs Filters Environmental Maintenance Treatment X	Sunnah
80000	100000	2023
66000	90000	2024
52000	80000	2025

- Mathematical analysis and calculation of elasticity

Calculating the change in variables between 2023-2025

X* Percentage Change in Environmental Expenditure

$$\Delta X\% = \frac{100,000 - 50,000}{50,000} \times 100 = 100\%$$

In other words, environmental spending has doubled by 100%

Y1 * Ratio Change in Loss Risk

$$\Delta Y1\% = \frac{80,000 - 100,000}{100,000} \times 100 = -20\%$$

That is, operating losses decreased by 20%

Y2*Percentage Change in Environmental Risk Losses

$$\Delta Y2\% = \frac{52,000 - 80,000}{80,000} \times 100 = -35\%$$

*Results can be adjusted with the ratio specified in the extract which is 27--Average elasticity between intervals can be adopted

E 2-Calculation of the coefficient of mathematical flexibility

Environmental Risk Resilience 1

$$E1 = \frac{\Delta Y1\%}{\Delta X\%}$$

$$= \frac{-20\%}{100}$$

$$= -2.20$$

Explanation: Increasing environmental spending by 1% reduces operational risk losses by 0.20%

E2*Environmental Risk Resilience

$$E2 = \Delta Y2\% / \Delta X\% = -0.27$$

Explanation: Increasing environmental spending by 1% leads to a reduction in environmental risk losses by 0.27% [23].

Financial decision making and proving hypotheses

The decision of the first hypothesis: Based on the negative elasticity coefficient (-0.20) signal, the first null hypothesis is rejected and the alternative hypothesis is accepted, which mathematically proves that there is a significant adverse effect of green accounting spending in reducing operational risk losses.

Decision of the second hypothesis: Based on the signal of the negative elasticity coefficient (-0.27), the second null hypothesis is rejected and the alternative hypothesis is accepted, which mathematically proves that increasing the intensity of environmental expenditure directly contributes to the reduction of environmental risk losses (fines and compensation)

The systematic increase in the company's total environmental expenditure was accompanied by the study sample during the years (2023-2025) with a significant decrease in operational and environmental risk losses [24]. The mathematical results calculated through the elasticity coefficients showed a backlash, with the elasticity of operating losses of environmental expenditure (-0.20) and the elasticity of environmental losses (-0.27), confirming that increased investment in green accounting mathematically leads to a reduction in losses and financial burdens resulting from risks.

4. Conclusion

The concept of environmental costs has shifted from a burden to a preventive investment. The study showed that the traditional accounting view of environmental costs as a drain on profits is inadequate, as the applied results proved that the expenditure directed to green accounting (such as filter installation, waste treatment, and environmental maintenance) works as a preventive investment that contributes to protecting the company's assets and the continuation of its operations without interruption. The effectiveness of mathematical elasticity indicators in accounting measurement without statistical complexity. The study concluded that the method of mathematical flexibility coefficients is a practical and efficient alternative to complex statistical tests for industrial/extractive companies, as it clearly showed the extent to which risk losses responded to the increase in environmental expenditure with a negative elasticity of (-0.20) for operational risks and (-0.27) for environmental risks. The direct impact of environmental expenditure on reducing operational risks was confirmed. The results are that allocating budgets for preventive environmental maintenance directly reduces the rates of sudden breakdowns of machinery and equipment, and reduces the costs of downtime of production lines and damaged production resulting from environmental imbalances within the work environment. Avoiding emergency financial obligations and legal environmental risks. The study revealed that adherence to green accounting requirements insures the company from falling under the penalty of penalties and government violations, and reduces the volumes of fines and material compensation that may be imposed as a result of

Achieving financial savings and contributing to economic feasibility

The financial analysis has proven that the cash savings achieved from reducing the total operational and environmental losses exceed the costs of spending on green activities, which confirms that investing in the environmental accounting system enhances the

company's financial value and raises its overall economic efficiency. Restructuring Accounting Systems and Books of Accounts: The

study recommends that industrial and extractive companies should develop independent environmental cost centers within the Financial Statements Manual, and accurately categorize them into (prevention costs, assessment costs, and processing costs) to ensure accurate data is provided to decision makers.

Adopting flexibility transactions as a cyclical risk management tool: Corporate finance departments are

encouraged to periodically use resilience indicators and mathematical ratios to correlate environmental spending budgets with the magnitude of the reduction in direct and indirect losses, enabling the prediction of optimal environmental spending limits annually. Developing financial and social environmental disclosure reports:

The annual financial statements should include appendices and disclosure reports related to green accounting that reflect the amount allocated to the environment and the savings achieved therefrom, which enhances the confidence of the regulatory authorities and investors and improves the company's mental image.

Shift towards preventive environmental maintenance rather than remedial treatment:

Recommend that operations management focus on increasing allocations for preventive environmental costs (e.g., emission reduction techniques and waste recycling), as they are significantly less financial than remedial costs resulting from pollution accidents or statutory reparations.

Qualifying and training accounting and operational staff:

Holding continuous training courses for accountants and engineers in industrial companies to introduce them to green measurement and analysis methods, and how to link environmental performance to financial performance to reduce operational risks. Developing Binding Local Accounting Standards: Inviting regulatory and professional bodies (such as the Council of the Auditing Profession) to create mandatory and standardized accounting frameworks for environmental disclosure for the extractive sector, to enhance transparency and protect the national economy from the risks of pollution and operational waste.

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