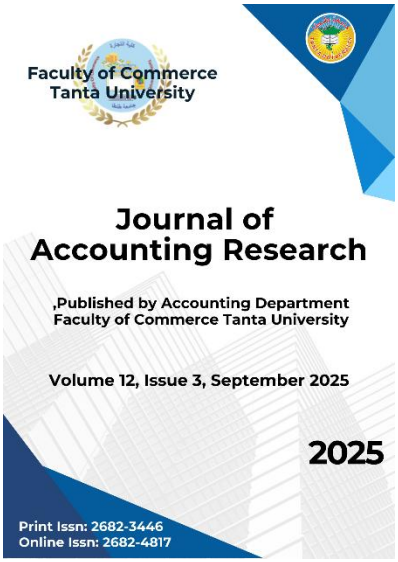

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A Proposed Model for Managing Green Costing: An Empirical study

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Abstract

Purpose
This study aims to examine the relationship between modern cost accounting methods—Activity-Based Costing (ABC), Life Cycle Costing (LCC), and Material Flow Cost Accounting (MFCA)—and green costing management within ISO 14001-certified manufacturing firms in Egypt. The objective is to assess the extent to which these methods support environmentally sustainable cost practices in an emerging market context.

Design/Methodology/Approach
Data were collected through a structured questionnaire collected from 150 respondents, including financial managers, cost accountants, and environmental management officers. The analysis involved descriptive statistics, reliability testing, correlation analysis, and multiple regression to evaluate the strength and direction of the relationships among the variables.

Findings
Results indicate that all three methods individually exhibit significant and positive relationships with green costing management, with LCC emerging as the strongest predictor. Collectively, these methods account for approximately 73% of the variance in green costing management.

Originality/Value
the study provides empirical insights into how modern cost accounting methods can support environmental management in an emerging economy context. The findings emphasize the need for organizations to integrate these methods to enhance environmental sustainability and cost management practices.

Keywords: Green Cost Management; Activity-Based Costing; Life Cycle Costing; Material Flow Cost Accounting; Environmental Management Accounting; ISO 14001; Egyptian Manufacturing Sector; Sustainability.

1.Introduction

Green costing is the identification, assessment, and allocation of environmental costs related to products, processes, or services produced (Jasch, 2003). Green costing is a significant component of business management today. Green costing is an advanced method of costs compared with "traditional" cost accounting practices, which often ignore or undervalue environmental effects of organizational behavior (e.g., Li et al., 2020). Traditional cost accounting leads to incomplete financial information that can be misinterpreted and can lead to poor strategic decisions. The task of green costing is to ensure organizations track, monitor, and manage long-term sustainability effectively.

In an age of heightened environmental awareness, and ever-changing and increasing regulations, the significance of green costing has grown beyond just legal protection for organizations. For organizations with an eye on sustainability, or simply improving their organizational image, competitive advantage and long-term sustainability, green costing has become more than just a legitimate part of environmental management (Paul et al., 2014). The evolution of green costing has been driven by several factors, including heightened public awareness of environmental issues, stricter environmental regulations imposed by governments worldwide, and the growing recognition that sustainable practices can lead to cost reduction and increase efficiency.

Green costing, characterized by new, modernistic costing models, but incorporating the models of traditional cost accounting (Taygashinova & Akhmetova, 2018), is embedded in substantial pressures to respond with accountability for environmentally damaging business practices.

The traditional cost accounting system often do not adequately a) capture and allocate any environmental costs and b) too often, lead to poor pricing and decision-making for organizations (Greenham, 2010; Taygashinova & Akhmetova, 2018).These traditional methods ignore the environmental costs absorbed in business processing, and therefore financial reporting and sustainable technologies may be recognized inaccurately (Greenham, 2010). This gap in the traditional cost accounting can lead to poorly informed business decisions since environmental costs associated with production, disposal of waste, and consumption of resources still remain misrepresented or unreported (Greenham, 2010).

Moreover, this gap in cost accounting practices hinders the integration of environmental considerations into corporate strategy, impeding progress toward sustainability goals and potentially harming long-term profitability (Debnath, 2017).

It is critical to develop new cost accounting methods to accurately identify, assign and allocate environmental costs so business can make appropriate decisions, improve eco-efficiency, and meet the growing expectations of their stakeholders' stewardship and responsible environmental impact (Greenham, 2010).

The integration of modern cost accounting techniques into green cost accounting is crucial for companies to enhance environmental sustainability and financial performance (Shank & Govindarajan, 2013).

To effectively address these shortcomings, companies must adopt modern cost accounting techniques that capture the full spectrum of environmental costs and benefits. Environmental costs impact product selection, design and pricing, capital budgeting, and future strategic direction (Russell et al., 1994).

By implementing modern cost accounting methods such as Activity based costing; life cycle costing; and material flow costing, businesses would be able to gain a more comprehensive understanding of their environmental impact and identify opportunities for improvement (Taygashinova & Akhmetova, 2018).

This paper aimed to develop a comprehensive model that integrates modern cost accounting techniques into green costing management, providing organizations with a robust framework for accurately identifying, measuring, and allocating environmental costs. This model aims to provide a more accurate and transparent view of the environmental impact of business operations, enabling better decision-making and promoting sustainability. This proposed model will allow organizations to strategically manage green costs, promote eco-efficiency, and achieve a competitive advantage in an increasingly environmentally conscious market.

The specific objectives of this study include

- Developing a comprehensive model for integrating modern cost accounting methods into green costing management, which allows businesses to develop environmentally friendly strategies
- Examining the impact of the proposed comprehensive model on the green costing management

The study addresses the following research questions

- What are the key components and processes of a comprehensive model for integrating modern cost accounting methods into green costing management?
- How can organizations effectively implement the proposed model to improve environmental sustainability and financial performance?

By answering these research questions this research will provide valuable insights into how companies can enhance their green costing practices through the integration of modern cost accounting techniques, ultimately contributing to improved environmental sustainability and financial performance.

In order to achieve the objectives of the research paper, the paper is organized as follows : Section 2 provides a background of the existing literature, establishing the traditional costing methodologies and their limitations in terms of capturing environmental costs, and offering

up-to-date costing models -these being Activity-Based Costing, Life Cycle- Costing, and Material Flow Cost Accounting- suitable for managing environmental costs. Section 3 provides the proposed model for integrating these costing methodologies into green costing management, including a brief discussion of the conceptual framework and its components. Section 4 provides the research design of the study, including the survey process, sampling techniques, and data analysis methods utilized in the research project. Section 5 discusses the empirical result of the study, including descriptive statistics, reliability analysis, correlation analysis, and simple and multiple regression analyses. Section 6 discusses the results of study in the context of the literature. Finally, Section 7 summarizes the key tentative conclusions of the study, including implications and contributions of the study, the implications for future research, and limitations of the study.

2.Background of the research

In recent decades, there has been an increasing of interest in integrating environmental considerations into accounting (Brooks & Schopohl, 2020). Traditional cost accounting system does not account for all environmental costs associated with business operations (Srivastava, 2020). This leads to inaccurate product pricing, poor decision-making, and a lack of incentive for companies to implement sustainable practices. Traditional cost accounting methods fail to track and allocate environmental costs for resource consumption, waste disposal, and environmental cost to ecosystems. These shortcomings result in an incomplete picture of the true costs of business, hindering the integration of environmental factors into strategic decision-making (Gibson & Martin, 2004; Oshiole *et al*., 2020).

Therefore, the literature focuses on green costing, which is a broader environmental management accounting notion that tracing, measuring, identifying, and allocating environmental costs to an organization's activities, products, and services (Ayabaca & Vila, 2020). This includes pollution prevention, waste management, resource depletion, environmental remediation and other environmental costs. Green costing method is often linked to the life cycle assessment (LCA) which evaluates the environmental impacts of service or products throughout its life cycle from raw material extraction through end-of-life disposal (Ayabaca & Vila, 2020). Unlike traditional costing methods, environmental impacts are often ignored or underestimated, green costs provide a more accurate and comprehensive picture of true production costs (Ayabaca & Vila, 2020). Green costing drives businesses toward sustainable practices by integrating environmental costs into decision-making, thereby enhancing environmental performance (Ayabaca & Vila, 2020). Additionally, modern organizations emphasize adherence to ISO 9000, viewing quality management as a system of related processes directed toward meeting consumer demands and improving efficiency through continuous improvement techniques (Aleksakhin *et al*., 2019).

The strategic alignment of environmental preservation with corporate financial objectives, known as "environmental controlling," involves the integration of environmental expenses into accounting systems (Taygashinova & Akhmetova, 2018).

Accounting for environmental costs, may take several forms and differ in level of integration with traditional accounting systems and frequency of accounting (Taygashinova & Akhmetova, 2018). Environmental Management Systems provide organizations with the data to set objectives and measure objectives over time (Russell *et al*., 1994).

Contemporary cost accounting methods including activity-based costing, life cycle costing, and material flow costing, provide an opportunity to mitigate the shortcomings of the traditional cost accounting system, and can use many accurate and comprehensive methods that relate to how organizations will be able to identify, trace, measure, and allocate environmental costs. Implementation of described contemporary costing methods can help organizations make informed decisions about operations, eco-efficiency and combine their financial and environmental performance to keep up with the evolving demand for sustainability in business and social expectations.

3.Development of the Model and Hypotheses

The proposed model for integrating modern cost accounting techniques into the green costing management is a multi-dimensional approach that provides a comprehensive way for organizations to implement holistic environmental cost management (Jing & Li, 2011). The purpose of the proposed model is to overcome the limitations of traditional cost accounting system by incorporating modern cost accounting techniques that accurately capture and allocate environmental costs, enabling informed decision-making and improved environmental sustainability. This can be achieved by integrate the appropriate modern cost accounting methods to manage green costing, which is the correct identification, measurement and allocation of environmental costs to products, services and processes (Tamburini *et al*., 2015). The proposed methods are: the activity-based costing, life cycle costing, and material flow costing methods as part of the overall green costing management.

3.1 Model Development

3.1.1The use of activity-based costing to manage the green costing

Activity-based costing is a costing methodology which identifies the activities in the organization, and assigns the costs of each activity to all products and services based on the actual consumption by each (Pope & Perkins, 2008). Activity-based costing offers a refined methodology for allocating costs by tracing resources to activities and then activities to cost objects, providing a more accurate and nuanced understanding of cost drivers (Baines, 1992). Traditional costing systems that primarily rely on volume-based allocation methods have been shown to have difficulties in product costing and may not reflect resources consumed in subsequently completed activities (Tuncel et al., 2005). Activity-based costing mitigates these weaknesses by considering the activities that cause costs, offering a better way to allocate overheads and indirect costs correctly and transparently (Staubus, 1990). By identifying and analyzing activities, businesses can gain insights into the true costs associated with each product or service, and enhance their decisions on pricing, product mix, and

process improvements. Activity-based costing was demonstrated as a system to analyze cost and effectiveness of activities, products, and services based on the resources they use to produce the product or services (Tran & Tran, 2022). Activity-based costing provides a structured way to allocate overhead costs by identifying and linking costs to corresponding activities (Roztocki *et al*., 2004; Graybeal *et al*., 2018). In addition, it can help identify non-value-added activities to improve operations and reduce costs (Alsayegh, 2020). This process called activity-based management which uses the information from an activity-based costing system for decision making involving recurring and non-repeating management decisions (Kaciuba & Siegel, 2009). The two stages can be referenced as the steps required for successful implementation of Activity Based Costing where the identification of the activities, assignment of costs to activities, and assigning costs drivers for each activity (Alsayegh, 2020).

Integrating activity-based costing into green costing improve the relevance and accuracy of environmental cost allocation, and assist with decision making and improve environmental performance (Jing & Li, 2011). Activity based costing allows a more accurate allocation of environmental costs to products or processes by determining the activities that created the environmental cost. This differs from the traditional costing approach, which would instead allocate the environmental cost based on volume or direct labor hours, which could misrepresent the environmental cost of a particular product or service (Reyhanoğlu, 2004). By determine the activities associated with environmental costs, organizations can start the effort to improve those activities, implement change strategies to reduce waste and/or emissions, and resources consumption. Activity-based costing assist management to achieve cost ascertainment, which facilitate in making pricing decisions, cost reduction, and enhance profitability, time and resource savings, and improved production quality (Saeed *et al*., 2023). In other words, it exposes the misuse of resources that is not accurately represented in traditional costing. For example, an activity-based costing analysis may reveal that a particular product requires a disproportionate amount of energy or generates excessive waste, prompting the business to redesign the product or modify the production process.

Several benefits arise when integrate activity-based costing into green costing. These include improved decision making, using a systems perspective to follow the impacts with improved environmental performance, and establishing better credibility in environmental reporting. The use of ABC lead to a better understanding of environmental costing associated with different products or services, enabling businesses to make informed decisions about pricing, product design, and process improvements). In addition, by identifying the activities that drive environmental costs, businesses can target these activities for improvement, implementing strategies to reduce waste, emissions, and resource consumption (Tsai *et al.*, 2012). This ultimately leads to management effort being directed toward activities that generate environmental costs and allow businesses to implement strategies to reduce waste and/or emissions. Improving environmental costing will potentially lead to cost savings, ultimately better environmental performance. In addition, the credibility and transparency of environmental reporting is improved because it is based on actual environmental costing. Environmental management systems also require relevant data since organizations want to

establish future goals and check their movement towards the goal (Russell *et al*., 1994). Having a better understanding of environmental costs also allows businesses to prioritize environmental projects, identify any cost improvement project, and identify what products are carrying any environmental costs (Carrera & Iannuzzi, 1998).

There are several strategies can be used to successfully integrate activity-based costing into green costing. These strategies include gaining support of top management, involving employees in the process, and using appropriate software and tools. One of the key strategies for the integration of activity-based costing into green costing is to gain management support. Top management can provide the resources and leadership needed to ensure the success of the project. Employee involvement is another strategy because it will reduce the likelihood of employee resistance and ensure that the system is implemented effectively (Haddock-Millar *et al*., 2015). Utilizing suitable software for activity based costing and ongoing success is another strategy that can facilitate the implementation and maintenance of activity-based costing (Benevene & Buonomo, 2020). Moreover, green training could provide organizational performance improvements per training that would increase job satisfaction per increased skills and employee development in their respective green initiatives (Martins *et al*., 2021).

3.1.2 The use of life cycle costing in managing green costing

Life cycle costing is the process of compiling all of the costs incurred by stakeholders associated with a product or service over the life cycle. It is an assessment of all the costs throughout entire lifespan of the product or service, including research and development, production, marketing, distribution, use, maintenance, disposal, and recycling (Olubodun *et al.,* 2010, Heralová, 2017). Life cycle costing offers a complete view of the total cost of ownership, which allows for making informed decisions by determining which decision option is the most cost-effective option in the long run (Kale *et al*., 2016). Life cycle costing remains an invaluable tool for assessing the long-term economic feasibility of design options, materials, and maintenance plans (Ho & Rahman, 2012). At the planning stages of a project, life cycle costing can help maximize investment costs, incorporating all maintenance costs of technical equipment, illustrating the importance of preventive maintenance to the life cycle of systems and components (Petroutsatou *et al.*, 2021). The decisions made at the planning and designing a project can have a significant effect on costs incurred later in the life cycle, this is especially true for durable consumer goods where design decisions can have an impact on productive efficiency and usage costs (Testa *et al*., 2011).

The relationship between environmental costs and life cycle costing has emerged more recently, due to growing environmental consciousness and more pervasive regulations The integration of life cycle costing within green costing frameworks is a major step forward in understanding and assessment the genuine environmental and economic impacts of products, processes and services. Life cycle costing looks at the whole-of-life cost of an asset from inception to disposal and provides a basis for comparison of design options, and value for money (Olubodun *et al*., 2010). Green costing, on the other hand, considers the identification,

quantification and allocation of environmental costs, generally with the intention of reducing negative environmental impact and/or encouraging sustainable practices (Backes *et al.,* 2021). The integration of these two approaches allows for a more holistic evaluation, where both the direct financial costs and the environmental burdens are considered in decision-making processes (Tamburini *et al.*, 2015). By employing a cradle-to-grave methodology, the whole life cycle is assessed, from extraction of raw materials, manufacture, distribution, use and end-of-life management (Haouat *et al.,* 2025). This approach facilitates the identification of cost drivers and opportunities for optimization, allowing businesses to eliminate environmental damage and financial costs.

Life Cycle Assessment can be integrated into current cost accounting system to assess the environmental impacts of products and services during their entire life cycle (Backes *et al*., 2021). This approach not only ensures compliance with internationally recognized standards, it also improves the robustness and dependability of the methodology (Haouat et al., 2025). Calculating a product carbon footprint provides an organization with different parameter effects through a product life cycle (Song *et al*., 2016).

Integrating and applying life cycle costing as part of green costing provides a life cycle framework for companies to assess both sustainability and financial performance (Kambanou, 2020). This is critical to developing a sustainable product strategy since environmental and economic objectives must be addressed, and decisions are made with a greater understanding of their long-term impacts (Fava *et al*., 2000). By incorporating environmental costs into life cycle costing context, organizations can develop a more accurate picture of the actual cost of their products and services and use this information to support sustainable decisions. The use of life cycle costing framework also can lead to improvements to product development, process efficiency, and supply chain management, as firms strive to reduce costs while minimizing their environmental impacts (Buxel et al., 2014). Furthermore, integrating life cycle costing will help facilitate the development of green supply chains as environmental factors will be considered at every step, from obtaining raw materials to delivering final products (Lin *et al.*, 2011).

In order to effectively incorporate life cycle costing with green costing, there must be a robust framework that incorporates all relevant cost elements and all the environmental impacts to facilitate strategic environmental management (Russell *et al*., 1994). This framework will also include an adequate definition of the assessment scope, identification of relevant cost categories, quantification of the environmental impacts, and, importantly, their valuation, all in monetary terms. This comprehensive assessment should allow a more accurate, and more holistic, view of the true costs and benefits of alternatives that will lead to more informed, sustainable decision-making.

Life cycle assessment is a valuable tool for facilitating holistic assessment of trade-offs and opportunities to generate positive impacts on the economy, environment and society (Lapeña, 2012; Khan *et al.,* 2025). Life cycle assessment is an analytical method that is established to evaluate the environmental balance of a product, process or service, (Horvath,

2004; Rebitzer *et al.*, 2004; Sala, 2019). It identifies and quantifies the use of energy and materials, and the environmental releases into air, water, and land (Hollberg *et al*., 2019).

A life cycle management approach requires the effective integration of different disciplines to achieve sustainable development in the manufacturing industry (Brent, 2005). Integration requires that cross-functional teams be established that incorporate team members from engineering, environmental science, finance and marketing, among other disciplines. Furthermore, stakeholder interactions will be important to ensure that all relevant perspectives be considered, and that the final decisions are aligned with societal values and expectations (Thabrew *et al*., 2008). Systematic assessment of the environmental impacts of product and service systems will directly impact the decisions organizations make with respect to resources consumpiton, waste minimization, and pollution prevention (Chubbs & Steiner, 1998).

3.1.3 The use of Material flow costing in managing green costing

Material Flow Cost Accounting is a powerful cost accounting approach specifically designed to trace and quantify the flow of materials within an organization and to identify costs associated with each step of the production process (Dierkes & Siepelmeyer, 2019). The main aim is to improve resource use, reduce waste, and improve understanding of the relationship between material inputs, material outputs, and the financial costs associated with them (Rishi *et al*., 2019). Material Flow Cost Accounting goes beyond only the direct costs of material inputs; it also addresses hidden costs associated with material losses and waste disposal and inefficiencies in the material/product life cycle i.e. costs which often go unaccounted (Möller *et al.,* 2016). By revealing hidden costs, Material Flow Cost Accounting allows organizations to identify improvement opportunities to reduce their consumption of resources and waste and minimize their environmental impact while reducing costs (Nakamura *et al*., 2007). Material Flow Cost Accounting allows for a broader perspective on costs during production and helps make informed decisions that value sustainability, enabling decision makers to take a more integrated approach as well to sustainability improvement efforts across the entire value chain. The integration of material flow cost accounting offers a meticulous methodology for businesses to track and quantify materials as they move through the organization, which is crucial for any business trying to improve resource efficiency (Pope & Perkins, 2008).

The combination of Material Flow Cost Accounting with green costing approaches represents a new development in environmental management accounting by providing a more holistic, detailed framework for understanding and addressing the environmental impacts and related costs of production processes. Material Flow Cost Accounting is a management method for accounting the physical flow of materials through a production process, distinguishing between products and negative products (i.e., waste and emissions) and assigning cost for both (Wang *et al*., 2010). Green costing expands upon traditional costing methods and conceptually integrates an environmental focus into these methodologically traditional costing practices to identify and allocate costs throughout the value chain

(Fikri *et al.,* 2021). The convergence of these two approaches leverages the strengths of both material flow cost accounting and green costing to provide a comprehensive framework for businesses to improve operational resource efficiency, reduce waste, and environmental performance while reducing cost and enhancement profitability (Chang *et al.*, 2015).

The integration of Material Flow Cost Accounting and green costing assists businesses to clarify with greater accuracy and a nuanced view, the environmental costs associated with the operations (Kovanicová, 2011). In traditional approaches to cost accounting, companies tend to overlook hidden costs related to waste, emissions, and inefficient use of resources, resulting in poor decision-making and lost chances to improve environmental performance. Material Flow Cost Accounting addresses this limitation by meticulously tracking the flow of materials and energy throughout the production process, assigning costs not only to the final products but also to the waste and emissions generated along the way. This in-depth analysis of the costs enables firms to determine the root causes of environmental inefficiencies and prioritize interventions that yield the greatest environmental and economic benefits *(Huang et al*., 2019).

The integration of Material Flow Cost Accounting with green costing facilitates the identification of specific opportunities to reduce waste and optimize resource which aligning environmental and economic objectives. Through the identification of costs and waste streams, companies can influence cleaner production technology adoption, the redesign of products and processes to lower waste generation, and the transition to a circular economy (Jasch, 2003). Moreover, Material Flow Cost Accounting can assess the impact on environmental and economic performance of various materials so that companies can select more sustainable materials and reduce their reliance on scarce resources. The use of Material Flow Cost Accounting under a green costing model enhances decision-making regarding environmental investments and sustainability initiatives

In order for Material Flow Cost Accounting to become part of a green costing framework, organizations will have to foster a change in mindset accompanied by a commitment to transparency and accountability. Likewise, organizations also will have to develop an organizational culture of continuous improvement in which they aspire to obtain less waste, minimal resources, and low environmental footprint (Schmidt, 2014).

The combination of Material Flow Cost Accounting and green costing will improve not only environmental performance but also financial performance and value creation in the long run. By lowering waste and increasing resource efficiency, firms can lower operating costs, increase profits, and enhance firms' competitiveness. (Epstein, 1996) Furthermore, through the publicly visible commitment to environmental sustainability, organizations can improve their brand reputation, develop customer loyalty, and gain easier access to capital. Implementing Material Flow Cost Accounting as part of green costing does require investment in data collection and analysis systems, as well as developing human capital and competencies within the organization (Kokubu & Kitada, 2014).

Despite the challenges, the benefits of working within the green costing framework with Material Flow Cost Accounting many times outweigh the costs, advancing the system as a value proposition for organizations trying to improve their business environmental and economic performance (Walz & Guenther, 2020). Green accounting approach, which incorporate environmental impacts into financial reporting, often remain voluntary and unaudited, highlighting the need for more robust and standardized approaches (Greenham, 2010).

3.2 Hypotheses Development

The identified variables can be combined into a holistic model which offers a pathway to improve green cost management by adopting modern cost accounting techniques towards achieving long term sustainability objectives. The variables of the current study are as follows

Independent Variables: three independent variables are proposed in the comprehensive model as follows

- Activity-Based Costing,
- Life Cycle Costing and,
- Material Flow Cost Accounting

Dependent Variable: one dependent variable is used in the proposed model which is the Green Cost Management. The degree of effectiveness of green cost management can be measured using a wide range of key performance indicators e.g., waste reduction, energy consumption, carbon emissions, water consumption, recycling, amount of renewable energy sourced, and other environmental measures (Ayabaca & Vila, 2020). These indicators can provide a more comprehensive assessment of the organization's progress towards improved environmental sustainability.

The proposed model and related hypotheses illustrated in the following diagram

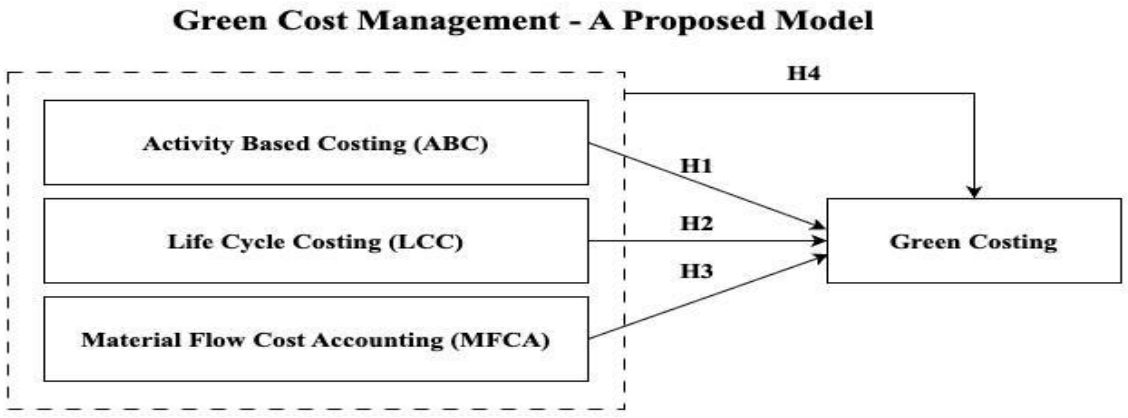

Diagram 1. Green cost Management model

The following hypotheses were developed to evaluate the impact of the modern proposed cost accounting methods on green costing management

H1.There is a positive relationship between activity-based costing and green costing management.

H2. There is a positive relationship between life cycle costing and green costing management.

H3. There is a positive relationship between material flow cost accounting and green costing management.

H4. The use of the proposed modern cost accounting methods has an impact on managing green costing.

4. Methodology

This study adopts an anonymous quantitative survey to assess the effects of modern cost accounting methods (Activity-Based Costing, Life Cycle Costing, and Material Flow Cost Accounting) on green cost management in Egyptian manufacturing companies with ISO 14001 certification in 2024 (anonymous,2024). The survey approach is appropriate because it offers an efficient way of collecting quantitative data in a structured and standardized manner from a large and dispersed geographic population.

The target population consisted of all Egyptian manufacturing companies (678 companies) that obtained ISO 14001 certification in 2024 (anonymous,2024). In order to have a representative sample of ISO 14001 certified Egyptian manufacturing companies for the study purposeful, random sampling with stratification was utilized, grouping companies by industry (chemicals, textiles, food processing, electronics, and others) and by company size (small, medium, large).

The sample size was determined by using Cochran's formula (Simarjeet, 2021), which is frequently used in survey research to determine sample size:

$n0 = (Z^2 * p * (1-p)) / e^2$

$n0 = (1.96^2 * 0.5 * (1-0.5)) / (0.05^2) \approx 384$

Since n0 is more than 5% of the population size (N=678), the finite population correction was applied to yield the following:

$n = 384 / (1 + ((384 - 1)/678)) \approx 248/$

Accordingly, the final sample size consisted of 250 companies.

The target participants were financial managers, cost accountants, and environmental management officers, as these people will be involved with cost management and environmental accounting practices and are the best potential sources of information for the study.

The data collection from the questionnaire was a structured questionnaire with five close-ended questions, each using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) to allow for standardized responses. The questionnaire was divided into three main sections as follows:

Section 1: Company Profile

Section 2: The use of Modern Cost Accounting Methods In their Organization and their effect on Green costing

Section 3: Effect of the integration on Green Costing

The questionnaire was pretested for clarity, relevance, and reliability which was completed on 10 randomly selected companies. The pretest data was finalized and reported on, and comments were used to assist in editing the final questionnaire used in the study.

The questionnaire was constructed and sent electronically via their emails that publicly listed in the company's websites or LinkedIn, to the financial managers, cost accountants, and environmental management officers at their respective companies on the list of selected companies. Follow-up reminders were sent one and two weeks after the initial distribution to encourage participation

From 250 questionnaires sent, 150 completed questionnaires were received for an estimated 60% response rate. The response rate calculated as follows:

Response rate = (150/250) * 100 = 60%

The data will be analyzed descriptively, using descriptive statistics (i.e., mean, standard deviation, frequencies) to summarize responses and with simple and multiple regression analysis, to determine the relationship between the use modern cost accounting methods and support for green costing management. Statistical analysis will be undertaken on the data using SPSS.

5.Data analysis and findings

5.1 Descriptive Statistics

Descriptive statistics provide an overview of the central tendency, variability, and range of responses for each variable. Table 1 presents the results of this analysis.

Table 1. Descriptive statistics

Variable	Mean	Std. Dev.	Min	25th Pctl	Median	75th Pctl	Max
Green Costing Management	4.02	0.57	2.60	3.80	4.10	4.40	4.80
Activity-Based Costing (ABC)	4.14	0.53	3.20	3.80	4.20	4.55	5.00
Life Cycle Costing (LCC)	3.92	0.48	2.88	3.57	4.04	4.19	4.65
Material Flow Cost Accounting	4.03	0.50	3.00	3.71	4.19	4.38	4.67

The descriptive statistics show that mean values for Green Costing Management and all modern cost accounting methods were around or above 4.00 (on a scale) which illustrates strong overall agreement from the respondents. This suggests that companies are utilizing modern cost accounting methods and perceive their importance to be high. The low standard deviations indicate that the respondents provided consistently similar responses in all cases which supports a level of reliability in the data. Also, the minimum and maximum values demonstrate that respondents used the full range of the scale which strengthens validity as the entire range of perspectives were captured. The 25th and 75th percentiles show the majority of responses cluster around the median which enhances reliability of the dataset and demonstrates a general agreement that modern cost accounting methods are important for organizations to have for green cost management.

5.2 Reliability Analysis

Reliability analysis assesses the internal consistency of the constructs. Table 2 presents the Cronbach's Alpha values for each construct.

Table 2. Reliability analysis

Construct	Cronbach's Alpha
Green Costing Management	0.89
Activity-Based Costing (ABC)	0.87
Life Cycle Costing (LCC)	0.85
Material Flow Cost Accounting	0.88

All constructs exhibit high internal consistency (Cronbach's Alpha > 0.70), indicating that the questionnaire items reliably measure the intended constructs.

5.3 Correlation Analysis

Pearson correlation coefficients were calculated to examine the relationships among the variables. Table 3 presents the correlation matrix.

Table 3. Correlation Analysis

Variable	GCM	ABC	LCC	MFCA
Green Costing Management	1.000	0.459	0.703	0.885
Activity-Based Costing	0.459	1.000	0.536	0.568
Life Cycle Costing	0.703	0.536	1.000	0.781
Material Flow Cost Accounting	0.885	0.568	0.781	1.000

The analysis reveals strong positive correlations between Green Cost Management and MFCA (r = 0.885) and LCC (r = 0.703). This suggests that MFCA and LCC are strongly associated with green costing practices and demonstrate the need of these methods for environmental costs management in organizations. The result also shows a moderate correlation (r = 0.459) between Green cost management and ABC. Furthermore, there is strong correlation between MFCA and LCC (r = 0.781) which suggests potential overlap in their functions and outcomes. Such overlap is common in management accounting practices where cost management methods can be interrelated. The strong positive correlations do suggest that if organizations begin to combine any or all of these management accounting processes, they have the potential to enhance green costing practices. Overall, the correlation analysis provides strong evidence of the relevance of modern cost accounting methods presented in this study, and indicates a collective influence on green cost management.

5.4 Regression Assumptions Testing

Before conducting the regression analysis, key assumptions were tested to ensure the validity of the model. Table 4 summarizes the results of these diagnostic tests.

Table 4. Regression Assumptions Test

Assumption	Test Used	Statistic/Value	p-value	Interpretation
Normality	Shapiro-Wilk	W = 0.988	0.203	Residuals are normally distributed.
Homoscedasticity	Breusch-Pagan	$\chi^2 = 1.20$	0.273	Homoscedasticity confirmed.
Autocorrelation	Durbin-Watson	DW = 1.93	—	No autocorrelation detected.
Multicollinearity	VIF	ABC = 1.53; LCC = 2.65; MFCA = 2.79	—	No multicollinearity detected.

All key regression assumptions were met: residuals are normally distributed, there is homoscedasticity (constant variance), no evidence of autocorrelation, and no multicollinearity issues were identified. Therefore, the regression analysis can proceed with confidence that its underlying assumptions hold, supporting the validity of the results.

5.5 Simple Regression Analyses

Table 5 summarizes the simple regression results for testing H2, which examines the relationship between Activity-Based Costing (ABC) and Green Costing Management (GCM).

Table 5. Simple Regression Results for H2 (ABC → GCM)

Model Summary	R	R^2	Adjusted R^2	F
ABC → GCM	0.750	0.563	0.560	152.45

Coefficient (β)	t-value	p-value	
0.835	12.35	< 0.001	

The findings demonstrated a strong and positive relationship between Activity-Based Costing and Green Cost Management since the R = 0.750. The R^2 of 0.563 shows that 56.3% of the variance in GCM was explained by ABC, a strong amount of explanatory power. The adjusted R^2 value of 0.560 indicated a strong model, and not just a random effect between ABC and GCM. The F-statistic summation was large at 152.45 and a low p-value (<0.001) confirmed that the model was statistically significant. The regression coefficient (β = 0.835) indicated the GCM would increase 0.835 units for every unit of ABC, exhibiting a strong and meaningful effect. From these findings it can be concluded that it is important for Egyptian firms to adopt ABC to manage their green costing.

Table 6 summarizes the simple regression results for testing H3, which examines the relationship between Life Cycle Costing (LCC) and Green Costing Management (GCM).

Table 6. Simple Regression Results for H3 (LCC → GCM)

Model Summary	R	R^2	Adjusted R^2	F
LCC → GCM	0.851	0.724	0.722	387.58

Coefficient (β)	**t-value**	**p-value**
0.720	19.69	< 0.001

the analysis reveals a strong relationship between Life Cycle Costing (LCC) and Green Costing Management (GCM) (R value of 0.851). The R squared value of 0.724 demonstrate that LCC explains approximately 72.4% of the variance of GCM that represents very strong explanatory power. The adjusted R-squared value of 0.722 shows that the model is strong, indicating the relationship between LCC and GCM remains consistent, regardless of sample size. Similarly, the F-statistic (387.58) and extremely low p-value (< 0.001) confirm that the model is significant. The regression coefficient (β) = 0.720 shows that each unit of increase in LCC increases GCM by 0.720; this shows the inherent strength of LCC alone to support an increase in green costing. Overall, LCC is a significant factor (driving force) of sustainable cost management processes.

Table 7 summarizes the simple regression results for testing H4, which examines the relationship between Material Flow Cost Accounting (MFCA) and Green Costing Management (GCM).

Table 7. Simple Regression Results for H4 (MFCA → GCM)

Model Summary	R	R^2	Adjusted R^2	F
MFCA → GCM	0.710	0.504	0.501	138.76

Coefficient (β)	t-value	p-value	
0.810	11.95	< 0.001	

The results indicate a positive, strong correlation between Material Flow Cost Accounting (MFCA) and Green Cost Management (GCM) since the R value of 0.710 illustrates a strong relationship between variables. The R^2 value indicates that 50.4 percent of the variation in GCM is explained by MFCA and suggests that a considerable proportion of variation has been explained. The Adjusted R^2 value is 0.501 which indicates that the model overall is stable, or robust, from random errors in explaining relationship between MFCA and GCM. Furthermore, the F-statistic is very large (138.76) and the p-value is very small (less than 0.001) which indicates the total model is statistically significant. Finally, the coefficient of regression ($\beta = 0.810$) indicates that for each increase of 1 unit in MFCA then GCM will increase by 0.810 units indicating that MFCA indeed makes a significant effect on green cost management. Overall, these results add to the evidence that MFCA plays a pivotal role to support sustainable cost management practices

5.6 Multiple Regression Analysis

This regression analysis is used to examine the impact of the proposed Modern Cost Accounting Methods on Green Costing Management.

Table 8. Multiple Regression Results

Model Summary	R	R^2	Adjusted R^2	F	Sig.
ABC, LCC, MFCA → GCM	0.856	0.733	0.727	133.4	0.000

Predictor	Coefficient (β)	t-value	p-value
Intercept	0.945	4.42	<0.001
Activity-Based Costing (ABC)	0.450	3.15	0.002
Life Cycle Costing (LCC)	0.550	5.20	<0.001
Material Flow Cost Accounting (MFCA)	0.400	2.85	0.005

The analysis indicates that the combination of Activity-Based Costing (ABC), Life Cycle Costing (LCC), and Material Flow Cost Accounting (MFCA) explains 73.3% of the variance of Green Cost Management ($R^2 = 0.733$), which is significant. The adjusted R^2 value of 0.727

demonstrates consistency in the strength of the model once the number of predictors is accounted for. The F-statistic of 133.4 ($p < 0.001$) indicates the overall model has significant predictive value, and suggests that it is significant to combine these three predictors in the model. Each predictor was also significant at $p < 0.01$. LCC ($\beta = 0.550$, $t = 5.20$, $p < 0.001$) was the largest predictor, followed by ABC ($\beta = 0.450$, $t = 3.15$, $p = 0.002$) and MFCA ($\beta = 0.400$, $t = 2.85$, $p = 0.005$) also make significant contributions. The outcomes here prove the importance of modern cost accounting methods both jointly and individually, in significantly enhancing of Green Cost Management.

5.7 Hypotheses Testing Summary

Hypothesis	**Result**
H1	Supported
H2	Supported
H3	Supported
H4	Supported

All hypotheses are fully supported, both in simple and multiple regression models. This indicates that Activity-Based Costing, Life Cycle Costing, and Material Flow Cost Accounting each significantly contribute to Green Costing Management both individually and collectively.

6. Discussion

The aim of this study was to propose a comprehensive model to manage green costing by exploring and adopted the modern cost accounting methods named: Activity Based Costing (ABC), Life Cycle Costing (LCC), and Material Flow Cost Accounting (MFCA). This study examined the proposed model in ISO 14001 certified Egyptian manufacturing firms. The results confirm that all three proposed methods, individually and together, have a strong positive effect on GCM.

The study found a strong relationship between ABC and GCM ($\beta = 0.835$, $R^2 = 0.563$), supporting the work of Alsayegh (2020), who argued that ABC can improve environmental cost allocation and link indirect cost to activity, which improves transparency and accountability. The findings of this study also support Tsai et al. (2012) and Tran & Tran (2022), who highlighted the importance of ABC in identifying non-value adding activities, which indirectly drive eco-efficiency by reducing waste and improving resource utilization.

The study showed LCC was the strongest predictor of GCM ($\beta = 0.720$, $R^2 = 0.724$), which is consistent with the finding from Heralová (2017) and Olubodun et al. (2010), which identified that LCC adds a holistic perspective, where total environmental costs are identified over a products life-cycle. However, the higher R^2 found here suggests that LCC's impact may be even more pronounced in ISO 14001-certified contexts where environmental management systems are rigorously applied.

The positive impact of MFCA in this study ($\beta = 0.810$, $R^2 = 0.504$) are aligned with the findings of Schmidt (2014) and Huang et al. (2019) which concluded that MFCA can be used in waste reduction and continuous improvement. Similarly, Chang et al (2015) also identified that MFCA helps improve resource efficiency in the ISO 14001 context, which adds to the study's value.

The findings of this study suggested that the use of ABC, LCC, and MFCA together explained 73.3% of the variance in GCM. This supports the findings of Greenham (2010) and Jourdaine et al. (2021), and which confirm that the integrating of multiple cost accounting methods to manage environmental cost has a significate impact on environmental management accounting. This emphasizes that the combination of the most appropriate cost accounting methods has significant impact on managing green costing and yields more robust insights.

However, approximately 27% of the variance in GCM remains unexplained. This aligned with the argument by Brooks & Schopohl (2020) that organizational culture, leadership commitment, and external factors also influence environmental accounting practices. This suggests that modern cost accounting methods, while essential, must be complemented by broader organizational and contextual enablers.

Overall, these findings both support and build upon previous research as they provide evidence that modern cost accounting methods can be important contributors to areas of green costing management consistent with focus on the Egyptian manufacturing context, But they also raise important questions about the broader strategic environment in which modern cost accounting methods must be nested so that regulatory, organizational, and cultural forces are considered.

7. Conclusion

The current study examined the relationships between Activity-Based Costing (ABC), Life Cycle Costing (LCC) and Material Flow Cost Accounting (MFCA, and Green Cost Management (GCM) in ISO 14001-certified manufacturing companies in Egypt. The research employed a survey approach to collect the data from the Egyptian manufacturing firms with ISO 14001 accreditation in 2024. A total of 150 response with completed questionnaires were collected and these were used for quantitative analysis.

The study adds robust empirical evidence to the green costing initiatives facilitated by modern cost accounting methods

The key finding of this study was that ABC, LCC and MFCA have a significant and positive relationship with GCM when analysis each variable individually and separately. It was also found that LCC was the strongest model to predict GCM ($\beta = 0.720$). One of the important findings of this study was the model with all three methods explaining a total of 73.3% of the variance in GCM together (not separately). This strong explanatory or

predictability indicates that the combination of modern cost accounting methods have the potential to strengthen sustainable cost management practices.

In terms of theoretical contributions, the findings of this study contribute to the growing literature on environmental management accounting by empirically validating the conceptual frameworks that link modern cost accounting methods with green cost management. It extends the understanding of how cost accounting methods can be adapted to incorporate environmental dimension, bridging the gap between cost accounting and sustainability studies (Brooks & Schopohl, 2020). Additionally, the study emphasized on the importance of the integration between the contemporary cost accounting methods to address the complexity of environmental cost management effectively, which has not been highlighted in previous studies. This reinforces theoretical propositions from integrated cost accounting methods highlighting the need for methodological integration to advance sustainable business practices.

In terms of practical contribution, the findings of this study have significant implications for manufacturing companies seeking to embed sustainability into their cost management practices. The strong influence of LCC showed by the current study, suggests that a life cycle management is essential for capturing the total cost of environmental impacts, while the significant contributions of ABC and MFCA underscore the importance of accurate activity-based cost allocation and material flow tracking (Schmidt, 2014; Alsayegh, 2020). When looking at the findings in respect to policymakers, there is compelling evidence to argue that fostering regulations to adopt modern cost accounting methods and robust environmental management accounting overall would assist the establishment of future sustainable businesses (Brooks & Schopohl, 2020).

In order to support the future effective development of sustainability management practices and systems, based on the findings, the manufacturing sector should direct resources toward education and training with a relevant emphasis on building the capacity of organizations to apply contemporary methodological ideas of cost accounting method(s). Further, organizations should consider integrating these methods into existing ISO 14001 systems that will ultimately embed their sustainability management activities within cost accounting structures.

Despite its contributions, the study has certain limitations. It focused exclusively on ISO 14001-certified Egyptian manufacturing firms, which may limit the generalizability of the findings to other sectors or regions. Moreover,. The study only undertook to examine direct relationships among ABC, LCC, MFCA and GCM in examining sustainability, without considering the possibility of moderating or mediating factors which may affect their use, such as organizational culture, regulatory environment or technological readiness (Wang *et al*., 2020; Brooks & Schopohl, 2020).

Future studies should address these limitations through conducting cross-country and cross-industry analyses to validate the findings across different contexts. The investigation of the interplay among modern cost accounting methods and factors affecting organizations, such as leadership championing sustainability, employee engagement, and skills relating to technology readiness could provide scholars with additional insight. Longitudinal, or time-series studies could represent valuable and timely insight into how the adoption of modern cost accounting methods evolves over time and influences long-term sustainability performance. Further research is also needed to examine the interrelationships among independent variables using structural equation model.

In conclusion, this study contributes to both theory and practice by demonstrating that modern cost accounting methods are not just conceptually aligned to green costing management; they are empirically validated as significant drivers of sustainable cost management. Integrating ABC, LCC, and MFCA into sustainability strategies empowers firms to achieve more comprehensive and effective environmental cost management, positioning them for success in increasingly competitive and environmentally conscious markets

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Appendix 1.

Questionnaire on Green Cost Management Practices
Dear Participant,

You are cordially invited to participate in a research study entitled:
"A Proposed Model for Managing Green Costing: An Empirical Study."

This study examine the impact of modern cost accounting methods—specifically, Activity-Based Costing (ABC), Life Cycle Costing (LCC), and Material Flow Cost Accounting (MFCA)—on the effectiveness of Green Cost Management (GCM) within ISO 14001-certified manufacturing firms in Egypt. The objective is to examine how these accounting techniques contribute to improved environmental sustainability in the context of emerging economies.

This questionnaire is composed entirely of close-ended questions and employs a five-point Likert scale to facilitate statistical analysis. Your responses will remain confidential and anonymous, and data will only be used for academic purposes.

Thank you for your participation and valuable contribution to this important study.

Sincerely,

Please indicate your level of agreement with each of the following statements.

Section 1: Company Profile

1. Industry Sector: ☐ Chemicals ☐ Textiles ☐ Food Processing ☐ Electronics ☐ Other: _____

2. Number of Employees: ☐ Small (≤ 50) ☐ Medium (51–250) ☐ Large (> 250)

3. Years of ISO 14001 Certification: _____

4. Your Position: ☐ Financial Manager ☐ Cost Accountant ☐ Environmental Officer ☐ Other: _____

5. Do you have a dedicated sustainability or environmental management department? ☐ Yes ☐ No

Section 2: The use of Modern Cost Accounting Methods in Organization and their effect on Green costing

Section 2.1: Activity-Based Costing (ABC)

Statements	1 = Strongly Disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly Agree
Our organization identifies and tracks environmental activities and their associated costs.					
ABC is used to allocate environmental overhead costs accurately to products/services.					
ABC helps identify non-value-added environmental activities for improvement					
1. ABC supports decision-making by linking environmental costs to cost drivers.					
ABC has improved our environmental cost					

transparency and reporting					

Section 2.2: Life Cycle Costing (LCC)

Statements	1 = Strongly Disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly Agree
LCC is used to assess environmental costs throughout the entire product life cycle					
LCC influences product design to minimize environmental impact over time..					
LCC is integrated into our environmental sustainability management systems.					
LCC helps identify long-term cost-saving opportunities through eco-friendly practices.					
LCC supports waste minimization and better recycling strategies.					

Section 2.3: Material Flow Cost Accounting (MFCA)

Statements	1 = Strongly Disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly Agree
MFCA is used to track material flows and their environmental					

impact during production.					
MFCA helps identify hidden costs due to waste and inefficiencies.					
MFCA supports resource efficiency and reduction of material losses.					
MFCA enhances the accuracy of environmental cost allocation.					
MFCA aligns with our corporate environmental and sustainability goals.					

Section 2.4**: **Green Cost Management (GCM) Practices

Statements	1 = Strongly Disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly Agree
Green cost management is a strategic focus in our organization.					
Our company actively monitors environmental KPIs such as waste, energy, and emissions.					
The use of modern cost accounting methods has improved our environmental performance.					
Green cost management					

practices have contributed to cost savings.					
Green cost management has enhanced our competitive advantage and compliance with ISO 14001.					

Section 3.Integrated Effectiveness of ABC, LCC, and MFCA

Statements	1 = Strongly Disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly Agree
Integrating modern costing methods into environmental strategies supports sustainability goals.					
The integration of ABC, LCC, and MFCA enhances the accuracy of green cost management.					
Modern costing methods help improve environmental decision-making.					
Modern cost accounting methods support continuous improvement of environmental practices.					
Management actively supports the use of modern cost accounting methods for sustainability.					
Training is provided on how to use ABC,					

LCC, and MFCA for environmental accounting.					

Thank you for your cooperation

الملخص

تهدف هذه الدراسة إلى دراسة العلاقة بين أساليب محاسبة التكاليف الحديثة—وهي التكاليف على أساس الأنشطة (ABC)، والتكاليف على مدى دورة الحياة(LCC) ، ومحاسبة التكاليف لتدفقات المواد(MFCA) وبين إدارة التكاليف البيئية (التكلفة الخضراء) في شركات التصنيع المصرية الحاصلة على شهادة الأيزو 14001. تم جمع البيانات من خلال استبيان منظم وُزّع على مديري الشؤون المالية، ومحاسبين التكاليف، ومسؤولي الإدارة البيئية، حيث بلغ عدد المستجيبين 150 مشاركاً. استخدمت الدراسة الإحصاءات الوصفية، واختبارات الموثوقية، وتحليل الارتباط، وتحليل الانحدار لتقييم العلاقات بين المتغيرات. أظهرت النتائج وجود علاقة إيجابية بين جميع الأساليب الثلاثة وإدارة التكاليف البيئية، وكانت طريقة التكاليف على مدى دورة الحياة (LCC) الأقوى تأثيراً. وبيّنت التحليلات أن هذه الأساليب تفسر مجتمعةً نحو 73٪ من التباين في إدارة التكاليف البيئية. تقدم الدراسة مساهمة للشركات الصناعية المصرية على دور أساليب المحاسبة التكاليفية الحديثة في دعم ممارسات الإدارة البيئية، خاصة في سياق الاقتصاديات الناشئة. وتؤكد النتائج على أهمية تكامل هذه الأساليب لتعزيز الاستدامة البيئية وكفاءة إدارة التكاليف.

الكلمات المفتاحية :إدارة التكاليف البيئية؛ التكاليف على أساس الأنشطة؛ التكاليف على مدى دورة الحياة؛ محاسبة التكاليف لتدفقات المواد؛ المحاسبة الإدارية البيئية؛ الأيزو 14001؛ قطاع التصنيع المصري؛ الاستدامة.