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Determinants of green accounting practices in Vietnam's leather and footwear sector: A PLS SEM and ANN approach

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ABSTRACT

This study aims to investigate the key factors influencing green accounting practices in Vietnamese leather and footwear manufacturing firms, utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM) and Artificial Neural Networks (ANN). A total of 645 respondents from 105 manufacturing firms in Vietnam were surveyed. After data screening, 523 valid responses were retained for analysis. The PLS-SEM results suggest that leadership, regulation, firm size, accounting staff competence, and strategy use practice positively impact green accounting. Conversely, implementation costs have a negative influence on green accounting practices. The ANN analysis further disaggregates these effects across four green accounting measurement items. For the first variable, leadership is the most influential factor, followed by regulation, accounting staff competence, strategy use practice, implementation costs, and firm size. For the second variable, all factors exert a moderate influence, ranging from 27.3% to 52.75%, with leadership being the strongest. The third variable shows modest impact differences, with implementation costs being the most dominant. For the fourth variable, implementation costs (62.80%) and strategy use practice (54.78%) are the most influential. This study plays an important role in designing a research model related to factors affecting green accounting in manufacturing firms, thereby enhancing green accounting practices. It also employs two advanced methods (i.e., PLS-SEM, ANN) to improve the accuracy of expected results. Consequently, this research contributes to green accounting literature in manufacturing firms by highlighting the significant role of advanced empirical research methods.

Contribution/Originality: This study contributes to the existing literature by integrating four key theoretical frameworks into a model and using two advanced emerging methods that explain the determinants of green accounting adoption. Furthermore, the regression results of the study also contribute to practical implications to enhance green accounting practices.

1. INTRODUCTION

Over the past few years, sustainable development, which involves a balance between social progress, economic growth, and environmental protection, has become a global priority (Mezentseva, Baysaeva, & Fayzullaev, 2024; Wang & Zheng, 2024). Governments in many countries are increasingly enforcing stringent environmental protection regulations, compelling firms to reassess their environmental responsibilities in investment and operations (Jindal, 2025; Sun, Luo, Zhou, & Yan, 2025). Consequently, accounting practices must develop beyond financial reporting to incorporate environmental impact, including cost management related to the use of limited resources,

waste treatment, and sustainable technology investments (Rasyid, Azis, & Rahmat, 2025). Green accounting (GA) thus drives firms to adopt business models that focus on both financial and environmental aspects, thereby facilitating firms' environmental responsibility.

Therefore, given the importance of green accounting practices, there is an increase in policies requiring firms and their investors to apply green accounting practices before implementing projects in Vietnam. In 2014, Vietnam made efforts to encourage green practices by initiating many related policies, including the Environmental Protection Law No. 55/2014/QH13, amended and supplemented in 2020, National Technical Regulations, and other policies related to regulations on products generating wastewater, dust, hazardous waste, and emissions, which require an environmental license by January 1, 2025. Environmental regulations enhance green accounting practices because they help to increase enforcement power, thereby improving transparency in voluntary and mandatory accounting disclosures of firms. However, the increase in environmental regulations on green accounting practices may raise compliance costs, such as initial investments in facilities, administrative and consulting costs, and technology investments. Additionally, higher regulations and standards make periodic reports more complex and time-consuming, leading firms to allocate more resources to implement, manage, and store a large number of documents, especially in small and medium-sized firms. Therefore, research to promote green accounting implementation in firms plays a pivotal role.

Green accounting (GA) can be recognized as an emerging and integrated accounting system that accurately reflects information related to assets, liabilities, investments, revenues, and environmental expenditures aligned with a nation's environmental sustainability efforts (Khan & Gupta, 2025; Pramastha & Sulistiyowati, 2025). GA is commonly categorized into various dimensions, including environmental management accounting, environmental financial accounting, environmental finance, environmental law, and ethics and corporate social responsibility (Sudarminto & Harto, 2023). It enables firms to anticipate environmental impacts and potential risks associated with the environment, thereby equipping policymakers and managers with tools to prevent and mitigate such effects proactively. In a similar way, GA supports firms in demonstrating their corporate social responsibility and ethical conduct (Haryati, Kirana, Wilasittha, & Putri, 2023; Lusiana et al., 2021). Consequently, it helps firms reduce environmental and public health risks while facilitating the quality of both management and financial accounting practices regarding environmental concerns simultaneously.

The leather and footwear manufacturing industry is characterized by a highly complex production process, involving multiple stages from raw material purchase, processing, and assembly to final product completion (Rossi, Papetti, Marconi, & Germani, 2021; Tsega, Thoben, Rao, & Haile, 2023). Each phase generates different levels of waste and environmental pollution. For instance, during the tanning stage of the production process, hazardous chemicals are used and discharged into the environment nearby, contributing to water and air pollution (Sivakumar, 2022). Prior studies show that the main raw materials may include animal skins and tanning chemicals (Hassan, Harris, Busfield, & Bilotti, 2023; Kılıç, McLaren, Holmes, Fullana-i-Palmer, & Puig, 2023). Therefore, the purchase and treatment of these materials may significantly have a negative impact on the environment. As a result, firms are more likely to allocate resources to waste treatment, recycling, and the improvement of production processes (İncekara, 2022). Firms must invest in improving manufacturing technologies and enhancing quality control systems to meet higher and international standards. As a result, these investments could significantly increase costs and put pressure on firms to manage and report environmental costs associated with technological investments and compliance requirements. Environmental costs may include depreciation of waste treatment facilities, landfill fees, labor costs for waste sorting and maintenance of wastewater treatment plants, environmental services, and environmental-related taxes. These costs are also part of general production overhead costs and are allocated using distribution methods. The inclusion of environmental costs can affect the final product cost (Al-Mawali, 2021). Therefore, to maintain an accurate and comprehensive allocation of these related costs, firms require a high level of accounting practices, which cause challenges, particularly for small and medium-sized enterprises (SMEs).

Additionally, the lack of comprehensive regulations and clear guidelines for environmental cost accounting in Vietnam could generate difficulties in the accounting and reporting process.

Considering the above, this study aims to investigate the antecedents of green accounting practices in Vietnamese leather and footwear manufacturing firms using Partial Least Squares Structural Equation Modeling (PLS-SEM) and Artificial Neural Networks (ANN). This study advances the application of cutting-edge machine learning tools to suggest different relationships of green accounting in this industry, and, as a result, it contributes to empirical analysis and provides practical insights for firms and policymakers to initiate appropriate green accounting practices. The structure of the paper includes five main sections: Section 1 introduces the study; Section 2 reviews the literature; Section 3 presents the research methodology and data collection process; Section 4 outlines the empirical findings; and Section 5 discusses the conclusions and implications of the study.

2. LITERATURE REVIEW

2.1. Leadership Awareness and Perception

At the strategic level, leaders' understanding of green accounting is aligned with long-term business goals, which drive their attention and concerns regarding GA implementation (Da Silva, Fernandez-Feijoo, & Gago-Rodriguez, 2023; Tran, Nguyen, & Hoang, 2021). At the technical level, leadership perception reflects their capability to disclose integrated accounting information that includes financial, environmental, and social aspects of the firms, which in turn enables the generation of comprehensive reports that focus on both economic and non-economic decision-making (Lutfi, Al-Hiyari, Elshaer, Alrawad, & Almaiah, 2024; Unerman, 2021; Widiyati, Gunawan, & Guan, 2024). Common indicators used to measure managerial concerns of GA include understanding different components of green accounting and environmental practices, and skills of corporate social activities (Ashari, Muawanah, & Lisa, 2022; Haliding, Haerunnisa, Arsyad, Sakti, & Nanda, 2024).

Green accounting practices can indeed be classified into two categories, including passive implementation, where firms comply with environmental regulations in a reluctant way (Rahman, Rana, Zhu, & Zeyu, 2025) and proactive implementation, where firms proactively innovate technologies, develop eco-environmental products, and revise accounting practices to address environmental concerns (Ali, Kausar, & Amir, 2023; Faieq & Cek, 2024). Additionally, leadership styles and motivation will determine whether a firm adopts a passive or proactive approach (Pham, Vu, Van Ha, & Nguyen, 2025). Managerial perception significantly impacts the adoption of environmental regulations and strategies, either facilitating or preventing GA implementation (Van Der Poll, 2022). When managers acknowledge the benefits of GA, they are more likely to adopt proactive environmental strategies that enhance environmental disclosures, reduce operating costs, enter new markets, and attract environmentally oriented consumers (Liem & Hien, 2024). Therefore, the study proposes the following hypothesis:

H_1: Leadership perception positively influences green accounting practices in Vietnamese leather and footwear manufacturing firms.

2.2. Implementation Cost

Expense is a critical factor in the adoption of any new system or initiative (Al-Dhubaibi, 2021; Saribu, Erlina, Muda, & Putra, 2023). This factor is also an important concern for firms, especially in balancing the trade-offs between benefits and implementation costs (Chung, Kuo, & Xie, 2025) and in small and medium-sized enterprises (SMEs) (Ayboğa & Ganji, 2020). While green accounting (GA) has numerous benefits, establishing a GA system is non-trivial. This is also a major concern for firms with limited resources in terms of long-term sustainability (Riyadh, Al-Shmam, Huang, Gunawan, & Alfaiza, 2020).

The effort in maintaining the tradeoff between the benefits and implementation and maintenance costs of GA has been shown to affect its adoption in the mining industry in Binh Dinh province. While GA offers significant benefits to firms, its implementation and maintenance often require major financial investment to make changes to the current

accounting system and train employees in terms of environmental practices. Additionally, the lack of clear guidance on GA serves as another concern in addressing environmental issues in the current accounting systems (Mukwarami & van der Poll, 2024; Setthasakko, 2010). Based on this argument, the study proposes Hypothesis H2:

H_2: Implementation costs negatively influence green accounting practices in Vietnamese leather and footwear firms.

2.3. Firm Size

Firm size often refers to the scale or magnitude of a company (De Fabritiis, Pammolli, & Riccaboni, 2003), which directly affects the business structure and management systems. Researchers mostly use common indicators to measure firm size, including the number of employees (Ayyagari, Demirguc-Kunt, & Maksimovic, 2021), market share, and the value of corporate assets (Alarussi & Gao, 2023; Margono & Gantino, 2021). Green accounting (GA) practices indeed vary depending on firm size. The reason is that GA is typically more prevalent in large firms where production processes are well-structured and detailed management systems. Larger firms are generally subject to higher stakeholder pressure and tend to have a stronger commitment to their prospects, making them more willing to incur additional costs to voluntarily disclose environmental concerns as a way to differentiate themselves from competitors and facilitate firm value (Xuyen Dinh, Nguyen, & Nguyen, 2022).

Additionally, large firms are more likely to maintain and enhance their business reputation and credibility among investors and regulatory authorities, which indeed necessitates comprehensive environmental disclosures to meet stakeholder expectations (Ji, Ji, & Dong, 2022; Wachira, 2014). In terms of efficiency, large firms are typically better equipped with accounting information practices that fulfill both qualitative and quantitative data demands, thus mitigating the relative cost of extensive GA disclosures. Based on these considerations, the study proposes the following hypothesis:

H_3: Firm size positively influences green accounting practices in Vietnamese leather and footwear firms.

2.4. Accounting Staff Competence

The competence of accounting staff is defined by their level of proficiency, knowledge, and skill set in performing professional accounting practices. It can be reflected based on years of experience, depth of knowledge, and specific skills (Ashari et al., 2022). Competence in green accounting (GA) directly influences the extent to which GA is integrated within firms (Xuyen Dinh et al., 2022). GA serves as a source of disclosing both financial and non-financial environmental information to firms' stakeholders. Therefore, accountants must possess the knowledge and skill set necessary to accurately and effectively record, measure, present, and disclose environmental data.

In addition to possessing a strong knowledge of relevant regulations and laws, accountants must be capable of measuring and allocating environmental costs accurately, thereby addressing the limitations of traditional accounting practices. This complex task requires a certain level of professional expertise. Setthasakko (2010) found that insufficient knowledge and skills in environmental concerns hinder the integration of environmental practices into corporate accounting systems, as observed in Thai enterprises.

At present, there is no formal university-level curriculum in Vietnam dedicated to green accounting. Consequently, accountants rely on training programs offered by certified professional associations, including the Vietnam Association of Accountants and Auditors (VAA), the Association of Chartered Certified Accountants (ACCA), and other institutions. These training programs play an important role in facilitating the adoption of GA. Based on this analysis, the study proposes the following hypothesis:

H_4: Accounting staff competence positively influences green accounting practices in Vietnamese leather and footwear firms.

2.5. Strategy Use Practice

Strategy use practice often refers to the set of implementations and decisions that a firm plans to adopt to achieve its objectives (Sooampon, 2025). It includes the methods and approaches a firm uses in conducting its operations to

enhance business performance. Therefore, the successful implementation of green accounting (GA) requires attention to people, processes, and technology, and international collaboration, all of which are shaped by the firm's business strategy (De Silva, Gunarathne, & Kumar, 2025; Thanh, 2025).

Firms may employ different tools to analyze how environmental concerns affect their business decisions (Thuy, 2024). In the leather and footwear manufacturing industry, major business decisions may include reducing production costs, enhancing productivity, investing in machinery and equipment to produce environmentally friendly products, and shaping an eco-friendlier corporate image. These decisions require accurate identification and allocation of environmental costs (ECs). This is important to ensure appropriate product costing and to assess operational efficiency. Based on this argument, the study proposes the following hypothesis:

H_5: Business strategy positively influences green accounting practices in Vietnamese leather and footwear firms.

2.6. Legal and Regulatory Pressure

Government policies and regulations play important roles in encouraging the adoption of green accounting (GA) practices (Xuyen Dinh et al., 2022). Policymakers have initiated laws and regulations that require firms to disclose their environmental information, report on sustainability activities, and integrate GA practices into their financial reporting systems (Zhao, Mou, & Yu, 2025). For example, governments may regulate the use of standardized environmental reporting regulations such as the Global Reporting Initiative (GRI) to ensure the implementation, consistency, and comparability across firms. By establishing different legal frameworks, governments create a level playing field and compel firms to implement GA practices (Fahmie, Pamungkas, & Munawar, 2025).

In Vietnam, environmental protection is increasingly supported through a legal framework such as the Environmental Protection Tax Law; however, environmental accounting still lacks well-structured concepts and standards (Hong, Burny, Lebailly, & Son, 2025). Since the manufacturing sector becomes increasingly important to social and economic development, and the environmental impacts of production activities become more crucial, particularly in environmentally sensitive industries such as leather and footwear manufacturing, regulations have become increasingly stringent (Ding & Xu, 2025; Fan, Graff Zivin, Kou, Liu, & Wang, 2025). Given the fact that GA is an internal business activity, its development as a formal accounting field requires significant awareness in the form of regulatory guidance, enforcement methods, or incentives provided by authorities (Fahmie et al., 2025; Maryanti, 2025). Based on this analysis, the following hypothesis is proposed:

H_6: Legal and regulatory pressure positively influences green accounting practices in Vietnamese leather and footwear firms.

3. METHODOLOGY

3.1. Research Model

According to institutional theory, firms are expected to comply with social standards and legal regulations to maintain their credibility and legitimacy (DiMaggio & Powell, 1983). Environmental taxes, emission reporting, and waste management responsibilities force firms to implement environmental accounting (EA) practices to meet regulatory requirements. Additionally, internal determinants such as human resources and leadership attitudes significantly influence the practice of green accounting (GA), as suggested by stakeholder theory (Freeman, 1984) and accountability theory (Tetlock, 1983). A workforce that is highly responsible for social and environmental activities tends to promote the clear collection, processing, and disclosure of environmental concerns. Accountability theory suggests that firms are more likely to adjust their behavior to demonstrate transparency and responsibility in EA practices when they are subject to scrutiny by society and other related environmental organizations.

Strategy use and practice also shape the extent of GA adoption and implementation, which aligns with voluntary disclosure theory (Jensen & Meckling, 1976). Firms oriented toward sustainable development tend to disclose environmental information not only for compliance objectives but also to enhance their reputation with their stakeholders. Additionally, according to resource-based theory, larger firms typically possess higher resources to

invest in GA and face more intense scrutiny from regulatory bodies and society (Barney, 1991). In contrast, smaller firms may encounter difficulties in adopting GA due to constraints in human resources and financial capacity. Based on these theoretical foundations, we propose the following research model:

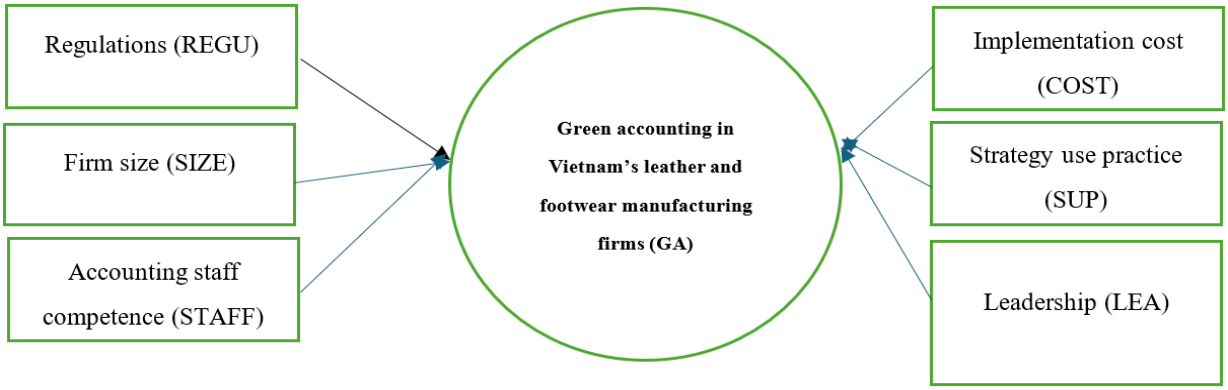

Figure 1. Proposed research model.

Figure 1 illustrates the research model of the determinants of green accounting practices in Vietnam's leather and footwear manufacturing firms. The research model includes the following independent variables: LEA, COST, SIZE, STAFF, SUP, and REGU, with GA as the dependent variable.

3.2. Data Collection

This study utilizes a non-probability, convenience sampling method due to practical obstacles in accessing research participants and its suitability for our purpose and conditions. Data were collected through an online survey using Google Forms from June to September 2024.

A total of 645 questionnaires were distributed to two surveyed groups: (1) managers and other individuals responsible for environmental accounting decisions, including CEOs, CFOs, heads of finance and accounting departments, and chief accountants; and (2) accounting employees directly engaged in daily environmental accounting activities at 105 Vietnamese leather and footwear manufacturing firms.

After screening and mitigating incomplete or invalid responses, 523 valid questionnaires were retained for our main analysis.

Table 1. Sample description.

Demographic variables		Frequency	Valid percent	Cumulative percent
Age	Below 30	215	41.11	41.11
	31-40	167	31.93	73.04
	41 or more	141	26.96	100
	Total	523	100.00	
Gender	Female	344	65.77	65.77
	Male	179	34.23	100
	Total	523	100.00	
Degree	Bachelors	189	36.14	36.14
	Masters	206	39.39	75.53
	Doctorate	128	24.47	100
	Total	523	100.00	

Table 2. Firm description.

Firm characteristics		Frequency	Valid percent	Cumulative percent
Size	Small and medium	45	42.86	42.86
	Large	60	57.14	100.00
	Total	105	100.00	
Business type	Limited liability	32	30.48	30.48
	Joint stock	45	42.86	73.33
	Private	28	26.67	100.00
	Total	105	100.00	
Geography	North	20	19.05	19.05
	Middle	34	32.38	51.43
	South	51	48.57	100.00
	Total	105	100.00	

Regarding our sample size determination, the appropriate sample size highly depends on the estimation methods used in the paper, with different guidelines available. Prior studies show that the minimum sample size for exploratory factor analysis should be at least four to five times the number of observations (Trong & Ngoc, 2008). Additionally, Green (1991) suggests that the minimum sample size for multiple regression analysis can follow the formula: 50 + 8m (where m is the number of independent variables). In this paper, our proposed research model includes seven independent variables, indicating that the minimum required sample size is 116 observations. Moreover, for structural equation modeling (SEM) involving 28 indicators, we recommend a minimum of 500 observations. Therefore, the final sample includes 523 observations that meet the requirements of regression and SEM analysis and is sufficient to allow for subgroup comparisons across industries.

Table 1 presents demographic variables in our sample. Most of our participants belong to the age group below 30, are female, and hold a master's degree. In terms of firm description, Table 2 exhibits the frequency of different firm characteristics in our sample. We primarily use large firms, joint-stock firms, and also firms located in the South of Vietnam to test our research questions.

3.3. Measurement and Analytical Techniques

Based on the literature review session, the study developed a set of 28 observation variables to measure the determinants of green accounting (GA) practices in Vietnamese leather and footwear manufacturing firms. The study also used a five-point Likert scale, ranging from 1 ("Strongly disagree") to 5 ("Strongly agree").

We utilized Partial Least Squares Structural Equation Modeling (PLS-SEM) and sensitivity analysis using Artificial Neural Networks (ANN). PLS-SEM indeed offers many advantages in behavioral research (Giao, Vuong, & Tushar, 2020). In the quality assessment of observed variables in our measurement model, we evaluated criteria including outer loadings (values > 0.7), scale reliability (Cronbach's Alpha > 0.6; Composite Reliability > 0.7), convergent validity (Average Variance Extracted [AVE] > 0.5), and discriminant validity based on the Fornell-Larcker criterion (the square root of AVE should be higher than inter-construct correlations). We also assessed multicollinearity through the Variance Inflation Factor (VIF < 2). Additionally, we utilized structural model evaluation, including the analysis of path coefficients, significance levels (p-values), and the coefficient of determination (R^2) to estimate the explanatory power of the model.

Additionally, the study employed Artificial Neural Networks (ANN) to examine a sensitivity analysis of the component variables on the dependent variable. Prior studies primarily use ANN for pattern recognition and prediction in highly complex datasets and for analyzing corporate governance factors (LeCun, Bengio, & Hinton, 2015). The ANN architecture consisted of three main layers, including the input layer, the hidden layer, and the output layer. The input layer obtains raw data from predictors, such as technological implementation and staff competence (Goodfellow, Bengio, & Courville, 2016). Next, the hidden layer includes different interconnected neurons, performs nonlinear transformations to isolate complex features, and identify nonlinear relationships between

the predictors (LeCun et al., 2015). Finally, the output layer generates predictive results regarding the influence of these factors on GA implementation by using the backpropagation algorithm (Rumelhart, Hinton, & Williams, 1986). In this study, we selected a feedforward neural network (FNN) architecture, as it is suitable for firm-level panel data and effectively captures nonlinear relationships without requiring subsequent structures.

PLS-SEM shows many advantages compared to traditional methods. PLS-SEM can combine all multivariate regression methods, factor analysis, and analysis of mutual relationships between variables in the model, simultaneously estimating variables in the overall model, estimating causal relationships between latent constructs through indicators that combine both measurement and structure of the theoretical model; determining direct and indirect effects, including measurement error and residual correlation (Hair, Black, Babin, & Anderson, 2019). However, this method is insufficient to assess the influence of each component of the key independent variable on the component variable of the dependent variable. To overcome this limitation, studies have combined the ANN method as a sensitivity analysis (Al-Emran, Abbasi, & Mezhuyev, 2021). These detailed predictions enable more comprehensive evaluation through sensitivity analysis and are suitable for complex decision-making processes. Initially, PLS-SEM was used to identify important factors affecting green accounting practices in Vietnamese footwear manufacturing enterprises. Subsequently, ANN was applied to rank the relative importance of variables for each component of the independent variable identified through PLS-SEM (Sohaib, Hussain, Asif, Ahmad, & Mazzara, 2020).

Table 3. Outer loading coefficients in quality evaluation of observed variables.

Variables	COST_	GA	LEA	REGU	SIZE	STAFF_	SUP
COST1	0.791						
COST2	0.786						
COST3	0.795						
COST4	0.816						
GA1		0.882					
GA2		0.817					
GA3		0.863					
GA4		0.773					
LEA1			0.912				
LEA2			0.806				
LEA3			0.875				
LEA4			0.927				
REGU1				0.818			
REGU2				0.835			
REGU3				0.791			
REGU4				0.769			
SIZE1					0.789		
SIZE2					0.814		
SIZE3					0.854		
SIZE4					0.842		
STAFF1						0.847	
STAFF2						0.859	
STAFF3						0.835	
STAFF4						0.835	
SUP1							0.869
SUP2							0.808
SUP3							0.748
SUP4							0.829

4. RESULTS

4.1. Partial Least Squares Structural Equation Modelling Results

Table 3 presents the outer loading coefficient in the quality evaluation of variables in our models indicates that, under normal conditions, the closer the loading coefficient is to 1, the higher the reliability of the observed variable.

In this result, all loading values are greater than or equal to 0.70; hence, the model's appropriateness is accepted (Henseler, Ringle, & Sarstedt, 2012).

Table 4. Cronbach's Alpha and Composite Reliability.

Variables	Cronbach's alpha	rho_A	Composite reliability	Average variance extracted (AVE)
COST_	0.809	0.810	0.875	0.636
GA	0.854	0.856	0.902	0.697
LEA	0.903	0.903	0.933	0.777
REGU	0.819	0.836	0.879	0.646
SIZE	0.844	0.852	0.895	0.681
STAFF_	0.866	0.872	0.908	0.712
SUP	0.834	0.882	0.887	0.664

Table 4 exhibits the Cronbach's Alpha and Composite Reliability of our research model. Composite Reliability measures the internal consistency of the measurement scale when we use the PLS-SEM method. In theory, this coefficient ranges from 0 to 1, with values closer to 1 reflecting greater reliability in the PLS-SEM model. A Composite Reliability value in these results is higher than or equal to 0.70; hence, we generally accept the measurement scales (Henseler et al., 2012). Average Variance Extracted (AVE) is used to assess the convergent and discriminant validity of the model. AVE values in this case are greater than or equal to 0.50; therefore, the constructs in the research model are considered satisfactory (Avkiran, 2018).

Table 5. Discriminant validity assessment using the Fornell-Larcker criterion table.

Variables	COST_	GA	LEA	REGU	SIZE	STAFF_	SUP
COST_	0.797						
GA	-0.487	0.835					
LEA	-0.453	0.660	0.881				
REGU	-0.353	0.460	0.393	0.804			
SIZE	-0.242	0.560	0.462	0.192	0.825		
STAFF_	-0.366	0.460	0.511	0.317	0.214	0.844	
SUP	-0.192	0.379	0.278	0.185	0.254	0.135	0.815

Table 5 shows the discriminant validity assessment result using the Fornell-Larcker criterion table. The Fornell and Larcker (1981) criterion estimates discriminant validity by matching the square root of the Average Variance Extracted (AVE) for each construct with the Pearson correlations between that construct and all other observed variables. Discriminant validity is established when the square root of the AVE for a given construct is higher than its correlations with other concepts. According to Table 5, the diagonal values, which represent the square roots of AVEs, are higher than the corresponding off-diagonal values in the same rows and columns. This suggests that the measurement model satisfies the criteria for discriminant validity.

Table 6. Discriminant validity assessment using the Heterotrait-Monotrait ratio criterion.

Variables	COST_	GA	LEA	REGU	SIZE	STAFF_	SUP
COST_							
GA	0.585						
LEA	0.528	0.750					
REGU	0.429	0.534	0.454				
SIZE	0.299	0.654	0.527	0.223			
STAFF_	0.437	0.530	0.578	0.381	0.246		
SUP	0.230	0.432	0.312	0.224	0.275	0.150	

Table 6 also presents the discriminant validity assessment result using the Heterotrait-Monotrait ratio criterion. Researchers have proposed the Heterotrait-Monotrait Ratio (HTMT) as a more robust criterion to assess discriminant validity. HTMT is defined as the average of all correlations between indicators across different constructs relative to the average of correlations within the same construct. While an HTMT value higher than 0.90 suggests a lack of discriminant validity between two constructs, values below 0.85 are considered acceptable. Table 6 shows that all HTMT values fall within the acceptable range, thereby indicating that the constructs demonstrate adequate discriminant validity.

Table 7. Assessment of multicollinearity (Inner VIF values).

Variables	VIF
COST_	1.575
LEA	1.652
REGU	1.631
SIZE	1.789
STAFF	1.491
SUP	1.877

Table 7 presents the assessment of multicollinearity and indicates that all variables in the model have VIF values below 2, suggesting that there is no significant multicollinearity among the variables.

Table 8. Structural model assessment (Path coefficients).

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P Values
COST_ -> GA	-0.154	-0.154	0.032	4.809	0.000
LEA -> GA	0.283	0.278	0.036	7.834	0.000
REGU -> GA	0.172	0.174	0.028	6.111	0.000
SIZE -> GA	0.296	0.296	0.030	9.884	0.000
STAFF_ -> GA	0.122	0.124	0.028	4.286	0.000
SUP -> GA	0.147	0.150	0.027	5.384	0.000

Table 8 exhibits the structural model assessment and indicates that the factors, including LEA, REGU, SIZE, STAFF, and SUP, have a positive impact on GA. In contrast, COST has a negative impact on GA, with a p-value of 0.000, demonstrating that these relationships are statistically significant at the 1% level.

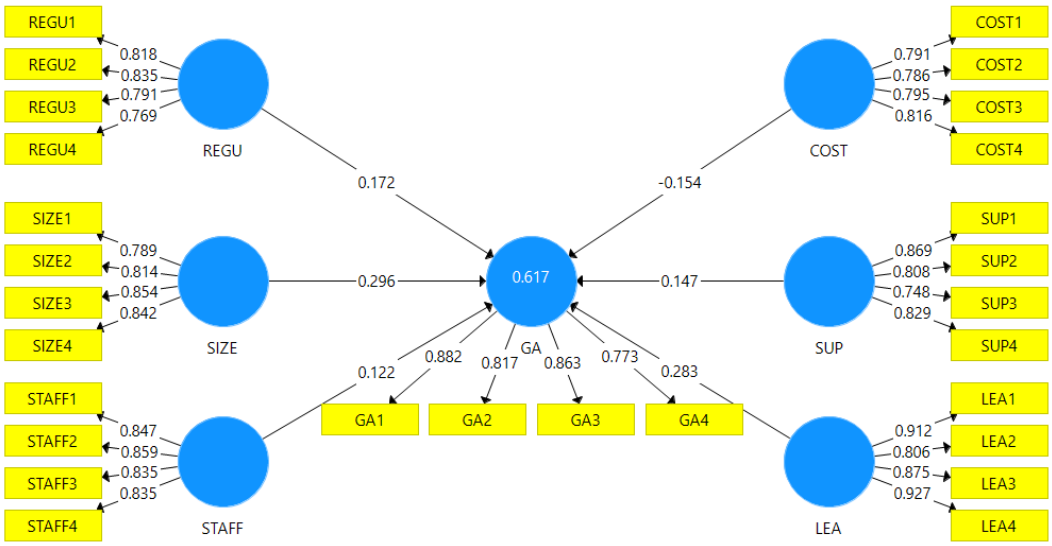

Figure 2. Partial least squares SEM model result.

Figure 2 illustrates the partial least squares SEM model results indicate that the competency of accounting staff has a path coefficient of 0.122, with a p-value of less than 0.001, demonstrating a positive impact on the implementation of Green Accounting (GA) practices in Vietnamese leather and footwear manufacturing firms. This finding supports hypothesis H4 and aligns with prior studies by Ashari et al. (2022). Vietnamese leather and footwear firms should prioritize ongoing training and skill updates for accounting and auditing staff. Regular professional development, combined with evaluation and feedback mechanisms, is essential for enhancing individual capabilities and responsibilities in practice.

Firm size, with a path coefficient of 0.296 and a p-value below 0.001, identifies the strongest positive effect on green accounting. This finding supports Hypothesis H3 and is consistent with previous research from Ashari et al. (2022). Larger firms generally have stronger financial and human resources, facilitating investment in environmental accounting systems, the development of green technology, and better compliance with environmental reporting frameworks. Given that most Vietnamese leather and footwear manufacturers are considered small and medium-sized firms, macroeconomic policymakers should build a transparent financial market that enhances easier access to capital and funding. Improved capital availability will expand investment opportunities, thereby enhancing the capacity for GA implementation.

The cost of implementation exhibits a negative path coefficient of -0.154 with statistical significance at the 1% level, indicating that greater costs are associated with lower levels of GA practice. This result supports hypothesis H5 and aligns with prior studies by Setthasakko (2010). Financial barriers remain a significant hindrance to the adoption and implementation of environmental accounting in the industry. To mitigate these adverse effects, firms may adopt advanced digital technologies to automate environmental accounting processes, seek suitable loans or sustainable investment funds, and enhance industry collaborations to share implementation costs.

Legal regulations show a positive effect on GA implementation, with a path coefficient of 0.172 and significance at the 1% level. This finding is consistent with hypothesis H4 and previous findings by Sayyadi and Askari (2020). Currently, Vietnam's green accounting regulations, regimes, and guidelines do not adequately guide firms in recognizing and tracking environmental costs within production and operational expenses, nor do they provide essential accounts for environmental cost accounting. Policy makers and firms should study international best practices, especially from developed countries, to develop similar frameworks applicable to Vietnam. This process would support the development of comprehensive legal regulations that meet international market economy requirements, align with accepted international standards, and ensure legal coherence and comprehensiveness across industries.

Strategy use practice exhibits a positive path coefficient of 0.147, significant at the 1% level, supporting hypothesis H5 and corroborating prior research by Sayyadi and Askari (2020); Thuy (2024); Ashari et al. (2022). This indicates that firms with sustainable development-oriented business strategies are more likely to invest in green technologies, optimize production processes to minimize environmental effects, and adopt environmental accounting systems to transparently monitor and report environmental activities.

The leadership variable has a path coefficient of 0.283, indicating the second strongest positive impact on GA practices in Vietnamese leather and footwear manufacturing firms. This result supports hypothesis H1 and aligns with the findings of Ashari et al. (2022). Corporate leaders should proactively support and enhance the effectiveness and implementation of green accounting practices. Additionally, leaders must strengthen their advisory capabilities to guide practitioners in resolving difficulties and implement direct management procedures to identify, prevent, and address violations related to the environment.

Table 9. Results of the R-square test.

Variables	R square	R square adjusted
GA	0.617	0.613

Table 9 shows the results of the R-square test of our model. According to Hair, Ringle, and Sarstedt (2011), R^2 values of 0.75, 0.50, or 0.25 can be considered significant, moderate, or weak, respectively.

The adjusted R^2 value in the above model is 0.613, indicating that the research model meets the acceptable threshold. The independent variables in the model explain approximately 61.3% of the variance in the dependent variable.

Table 10. Evaluation of Accuracy and Loss Metrics for GA.

Criteria	GA1	GA2	GA3	GA4
Loss	1.23	2.84	1.37	1.81
Accuracy	89.72%	76.64%	87.85%	85.98%

4.2. ANN Sensitivity Analysis

Table 10 presents the evaluation of accuracy and loss metrics for green accounting practices. The loss values in our four ANN models trained for each GA variable are as follows: GA1 (1.23), GA2 (2.84), GA3 (1.37), and GA4 (1.81).

Compared to the ideal threshold near zero and the random baseline of 1.386 for four layers, these loss values are relatively acceptable, indicating that the models exhibit only minor errors (Zhang & Sabuncu, 2018).

Table 11. Sensitivity analysis results for the variable GA1.

Variables	RI	NI	AVG RI	AVG NI	Ranking
REGU1	0.0153	51.4711	0.020675	69.71%	2
REGU2	0.0246	83.0629			
REGU3	0.0297	100.0000			
REGU4	0.0131	44.3066			
SIZE1	0.0091	30.6549	0.0121	40.72%	6
SIZE2	0.0152	51.1890			
SIZE3	0.0135	45.4199			
SIZE4	0.0106	35.6434			
STAFF1	0.0102	34.5165	0.0194	65.82%	3
STAFF2	0.0138	46.4114			
STAFF3	0.0247	83.1399			
STAFF4	0.0289	97.2273			
COST1	0.0079	26.7352	0.012525	42.73%	5
COST2	0.0167	56.3300			
COST3	0.0134	45.2236			
COST4	0.0121	40.6651			
SUP1	0.0161	54.2936	0.018225	61.35%	4
SUP2	0.0052	17.4386			
SUP3	0.0246	82.8837			
SUP4	0.0270	90.8224			
LEA1	0.0248	83.5149	0.020625	69.96%	1
LEA2	0.0095	32.1476			
LEA3	0.0288	96.9721			
LEA4	0.0194	65.2142			

Table 11 illustrates the sensitivity analysis results for the variable GA1. The findings indicate that the impact of variables on GA1, ranked from highest to lowest, are as follows: LEA (69.96%), REGU (69.71%), STAFF (65.82%), SUP (61.35%), COST (42.73%), and SIZE (40.72%).

Notably, the items with the most significant influence on GA1 are REGU3 (100%), STAFF4 (97.22%), LEA3 (96.97%), and SUP4 (90.82%).

Table 12. Sensitivity analysis results for the variable GA2.

Variables	RI	NI	AVG RI	AVG NI	Ranking
REGU1	0.0092	51.5855	0.007725	43.83%	2
REGU2	0.0051	28.5792			
REGU3	0.0030	16.7833			
REGU4	0.0136	76.3829			
SIZE1	0.0075	42.0676	0.00605	33.90%	4
SIZE2	0.0067	37.7131			
SIZE3	0.0065	36.3505			
SIZE4	0.0035	19.4801			
STAFF1	0.0121	67.6106	0.006475	36.79%	3
STAFF2	0.0053	29.8602			
STAFF3	0.0051	28.4276			
STAFF4	0.0034	19.2951			
COST1	0.0024	13.5764	0.0054	30.79%	5
COST2	0.0045	25.3533			
COST3	0.0042	23.3034			
COST4	0.0105	58.9413			
SUP1	0.0014	7.8050	0.004875	27.30%	6
SUP2	0.0064	35.8505			
SUP3	0.0021	11.9038			
SUP4	0.0096	53.6614			
LEA1	0.0035	19.5165	0.009425	52.75%	1
LEA2	0.0178	100.0000			
LEA3	0.0070	39.0612			
LEA4	0.0094	52.4569			

Table 12 shows the sensitivity analysis findings for item GA2 and indicates that the variables do not exhibit strong effects on GA2 (mostly below 50% but above 20%). The impact strength, ranked from highest to lowest, is as follows: LEA (52.75%), REGU (43.83%), STAFF (36.79%), SIZE (33.90%), COST (30.79%), and SUP (27.30%). Among these, items with particularly high influence on GA2 include LEA2 (100%) and STAFF1 (67.61%), while SUP1 (7.8%) shows a negligible effect on GA2 (less than 10%).

Table 13. Sensitivity analysis results for the variable GA3.

Variables	RI	NI	AVG RI	AVG NI	Ranking
REGU1	0.0195	56.3292	0.015275	44.53%	2
REGU2	0.0120	34.5218			
REGU3	0.0186	53.5550			
REGU4	0.0110	31.7234			
SIZE1	0.0105	30.2603	0.014025	40.47%	5
SIZE2	0.0165	47.7333			
SIZE3	0.0233	67.1601			
SIZE4	0.0058	16.7623			
STAFF1	0.0236	68.2058	0.01495	43.13%	3
STAFF2	0.0212	61.1759			
STAFF3	0.0113	32.6300			
STAFF4	0.0037	10.5319			
COST1	0.0062	17.9082	0.01665	48.54%	1
COST2	0.0066	19.0620			
COST3	0.0191	55.2105			
COST4	0.0347	100.0000			
SUP1	0.0134	38.7191	0.010825	31.73%	6
SUP2	0.0087	25.0698			
SUP3	0.0063	18.1724			
SUP4	0.0149	42.9788			
LEA1	0.0139	40.1096	0.009425	42.90%	4
LEA2	0.0201	57.9831			
LEA3	0.0097	27.8727			
LEA4	0.0151	43.6607			

Table 13 presents the sensitivity analysis of the variables affecting GA3 and indicates relatively small differences in impact levels, primarily around 40%. Specifically, the effects are as follows: COST (48.54%), REGU (44.53%), STAFF (43.13%), LEA (42.90%), SIZE (40.47%), and SUP (31.73%). Among these, the items with particularly high influence on GA3 are COST4 (100%), STAFF1 (68.20%), and SIZE3 (67.16%).

Table 14. Sensitivity Analysis Results for the Variable GA4.

Variables	RI	NI	AVG RI	AVG NI	Ranking
REGU1	0.0234	50.5056	0.0192	41.97%	3
REGU2	0.0227	49.1152			
REGU3	0.0175	37.7697			
REGU4	0.0132	28.5105			
SIZE1	0.0043	9.1896	0.01545	33.35%	4
SIZE2	0.0140	30.2251			
SIZE3	0.0087	18.8630			
SIZE4	0.0348	75.1598			
STAFF1	0.0141	30.3957	0.0118	25.98%	5
STAFF2	0.0098	21.1880			
STAFF3	0.0081	17.4147			
STAFF4	0.0152	32.9548			
COST1	0.0062	13.4964	0.028825	62.80%	1
COST2	0.0202	43.7025			
COST3	0.0426	92.0088			
COST4	0.0463	100.0000			
SUP1	0.0317	68.4315	0.02535	54.78%	2
SUP2	0.0137	29.6477			
SUP3	0.0409	88.4697			
SUP4	0.0151	32.5942			
LEA1	0.0042	9.1677	0.011525	24.93%	6
LEA2	0.0137	29.6942			
LEA3	0.0165	35.6464			
LEA4	0.0117	25.2240			

Table 14 presents the sensitivity analysis results for item GA4 and indicates that the variables impact GA4 in the following order from highest to lowest: COST (62.80%), SUP (54.78%), REGU (41.97%), SIZE (33.35%), STAFF (25.98%), and LEA (24.93%). Firms should focus on developing the items with particularly high influence on GA4, including COST4 (100%), COST3 (92.00%), SUP3 (88.46%), and SUP1 (68.43%).

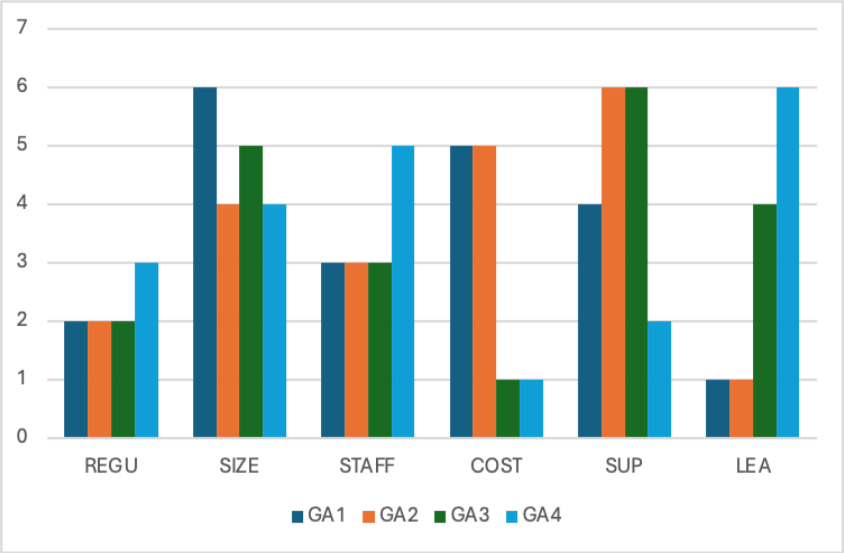

Figure 3. Rank the impact of factors on GA.

Figure 3 illustrates the average ranking of the influence levels of the independent variables on each component of the GA variable, in order. The results show that most of the component variables of GA are affected by the cost of implementing green accounting (COST), leadership awareness and perception (LEA), and the legal and regulatory pressure from the government on supporting and implementing green accounting in enterprises (REGU).

5. CONCLUSION

This study aims to assess the factors influencing green accounting (GA) practices in Vietnamese leather and footwear manufacturing firms by employing Partial Least Squares Structural Equation Modeling (PLS-SEM) and Artificial Neural Network (ANN) methodologies. The survey collected responses from 645 participants across 105 Vietnamese leather and footwear firms. After screening and removing invalid responses, a total of 523 valid questionnaires were used for the main analysis. The PLS-SEM estimation results indicate that factors such as leadership awareness, regulations, firm size, accounting staff competency, and strategic use practices have significant positive effects on GA at the 1% significance level, with path coefficients of 0.296 (SIZE), 0.283 (LEA), 0.172 (REGU), 0.147 (SUP), and 0.122 (STAFF), respectively. Conversely, implementation cost exhibits a significant negative impact, with a regression coefficient of -0.154.

More specifically, the ANN-based sensitivity analysis of each variable's influence on GA items shows different outcomes. For GA1, variables affect the outcome in descending order: LEA (69.96%), REGU (69.71%), STAFF (65.82%), SUP (61.35%), COST (42.73%), and SIZE (40.72%). For GA2, the variables demonstrate relatively moderate effects (mostly below 50% but above 20%), ordered as LEA (52.75%), REGU (43.83%), STAFF (36.79%), SIZE (33.90%), COST (30.79%), and SUP (27.30%). For GA3, the impact levels among variables are relatively close, primarily around 40%, with COST (48.54%), REGU (44.53%), STAFF (43.13%), LEA (42.90%), SIZE (40.47%), and SUP (31.73%). For GA4, the descending order of influence is COST (62.80%), SUP (54.78%), REGU (41.97%), SIZE (33.35%), STAFF (25.98%), and LEA (24.93%).

For its contribution to the literature, this research integrates four key theoretical frameworks into a model that explains the determinants of green accounting adoption. These theories include institutional theory, which explains compliance pressures from legal regulations such as environmental taxes and waste management; stakeholder theory (Freeman, 1984) clarifying the role of employees and leadership in enhancing transparency; accountability theory (Tetlock, 1983) indicating policy mechanisms that shape corporate behavior under pressure; and voluntary disclosure theory (Jensen & Meckling, 1976) linking sustainability strategies with motivations for voluntary information disclosure. This integrated approach overcomes limitations of prior studies and provides a comprehensive perspective on the interaction between external (legal) and internal (cost, size, leadership, strategy, resources) antecedents.

In practice, based on the research results, Vietnamese footwear manufacturing firms need to focus on proactively implementing and creating conditions for better and more effective green accounting practices. First, managers at footwear manufacturing firms need to have more information about the environmental cost aspect arising in the firms' contracts to make appropriate production investment decisions. As a result, they can both obtain profits from projects and avoid environmental-related penalties. Managers also need to improve their professional consulting skills to help practitioners handle problems; have a direct management process to detect, prevent, and promptly handle environmental-related violations. Second, improving the quality of accounting human resources to meet job requirements in the new emerging economy is essential. Because green accounting is currently not popular within firms, the accounting department has very few accountants with knowledge of environmental accounting or specialized environmental accounting staff. Therefore, in the future, firms should focus on training processes to improve the quality of the accounting staff and build an accounting department with capacity and experience in green accounting. Third, it is crucial to change awareness in applying green accounting in production and business activities. Currently, firms do not realize the meaning and benefits of environmental protection activities in general and the application of green accounting. Most footwear firms in Vietnam have not yet implemented methods of

environmental cost calculation. Additionally, many firms do not realize that the cost of determining environmental costs is much smaller than the total costs, such as taxes, fees, or fines associated with environmental violations. Fourth, continuing to supplement and enhance regulations on green accounting is necessary in the upcoming time. The current accounting system is not qualified enough for firms to perform environmental accounting. Strengthening sanctions, implementing tax and environmental fee policies for firms, thereby helping firms raise awareness and fulfill their responsibilities towards environmental protection. Policies to reward, encourage, and commend firms that fulfill their social responsibilities, including good implementation of green accounting, will contribute to widely promoting the application of green accounting in practice. For example, firms that implement green accounting effectively over a period, such as five years, will receive preferential credit loans for feasible projects. Additionally, because most Vietnamese footwear manufacturing firms are small and medium-sized enterprises, macro policymakers should build an open and efficient financial market, facilitate access to capital and finance, and as a result, expand investment plans and enhance the ability to implement green accounting.

Given that the findings contribute significantly to the application of advanced machine learning tools in enhancing green accounting within Vietnamese leather and footwear firms, this study has limitations. First, it focuses primarily on external (legal) and internal (cost, size, leadership, strategy, resources) factors of GA practice, while other external factors, such as social influence, investor pressure, and internal factors like technology adoption capacity, could be further explored. Second, as the study focuses on the leather and footwear industry, which is characterized by mostly small-sized firms with unique, outsourcing-dependent business models and limited environmental focus, its empirical results may have limited application to other industries' green accounting practices. Future research should consider factors affecting green accounting practices in service businesses, such as tourism, transportation, and technology, where business nature and processes are different from manufacturing firms.

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Institutional Review Board Statement: The study involved minimal risk and followed ethical guidelines for social science fieldwork. Formal approval from an Institutional Review Board was not required under the policies of Institute for Research Ethics Committee of the Faculty of Accounting and Auditing- Van Lang University, Vietnam. Informed verbal consent was obtained from all participants, and all data were anonymized to protect participant confidentiality.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: The corresponding author can provide the supporting data of this study upon a reasonable request.
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