Framework for implementing energy efficiency strategies in textile SMEs to achieve sustainability and business growth

DOI: 10.35530/IT.076.03.2024160

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ABSTRACT – REZUMAT

Framework for implementing energy efficiency strategies in textile SMEs to achieve sustainability and business growth

A Small and Medium Enterprise (SME) in the textile industry usually focuses on specialised processes like weaving, knitting, or dyeing while producing and distributing fabrics, clothing or other textile products. This study looks into the sustainability and energy efficiency strategies used by small and medium-sized businesses (SMEs) in Tamil Nadu's textile sector, particularly in manufacturing hubs like Coimbatore, Tiruppur, Madurai and Salem. The study uses a mixed-methods approach combining qualitative information from interviews with SME owners, production managers and sustainability officers with quantitative data obtained from structured questionnaires. A representative sample of 1250 SMEs from a range of industries, including spinning, weaving, dying, and clothing manufacturing, was guaranteed by a stratified random sampling technique. Together with structural equation modelling (SEM), descriptive statistics, correlation analysis and multiple regression analysis were used to analyse the data and investigate the connections between firm performance, sustainability practices and energy efficiency. Three specific hypotheses were examined in this study: how energy efficiency measures affect operational performance, how sustainable practices and financial performance are related and what obstacles exist for the adoption of energy-efficient technologies. The results show strong correlations and gains in financial and operational performance, underscoring the critical role that sustainability and energy efficiency play in raising textile SMEs' competitiveness.

Keywords: *energy efficiency, textile industry, small and medium enterprises, sustainability practices, structural equation modelling, Tamil Nadu*

Cadru pentru punerea în aplicare a strategiilor de eficiență energetică în IMM-urile din industria textilă pentru a obține durabilitate și creștere economică

O întreprindere mică și mijlocie (IMM) din industria textilă se concentrează, de obicei, pe procese specializate precum țeserea, tricotarea sau finisarea, producând și distribuind materiale textile, articole de îmbrăcăminte sau alte produse textile. Acest studiu analizează strategiile de durabilitate și eficiență energetică utilizate de întreprinderile mici și mijlocii (IMM-uri) din sectorul textil din Tmil Nadu, în special în centre de producție precum Coimbatore, Tiruppur, Madurai și Salem. Studiul utilizează o abordare mixtă a metodelor, combinând informații calitative obținute din interviuri cu proprietarii de IMM-uri, managerii de producție și responsabilii cu durabilitatea, cu date cantitative obținute din chestionare structurate. Un eșantion reprezentativ de 1 250 de IMM-uri dintr-o serie de sectoare, inclusiv filatura, țesătoria, finisajul și fabricarea de articole de îmbrăcăminte, a fost garantat printr-o tehnică de eșantionare aleatorie stratificată. Împreună cu modelarea ecuațiilor structurale (SEM), statisticile descriptive, analiza corelațiilor și analiza regresiei multiple au fost utilizate pentru a analiza datele și a investiga legăturile dintre practicile de durabilitate a performanțelor întreprinderilor și eficiența energetică. Trei ipoteze specifice au fost examinate în acest studiu: modul în care măsurile de eficiență energetică afectează performanța operațională, modul în care practicile durabile și performanța financiară sunt legate și ce obstacole există pentru adoptarea tehnologiilor eficiente din punct de vedere energetic. Rezultatele arată corelații puternice și câștiguri în performanța financiară și operațională, subliniind rolul esențial pe care îl joacă durabilitatea și eficiența energetică în creșterea competitivității IMM-urilor din sectorul textil.

Cuvinte-cheie*: eficiență energetică, industria textilă, întreprinderi mici și mijlocii, practici de durabilitate, modelarea ecuațiilor structurale, Tamil Nadu*

INTRODUCTION

The small and medium-sized enterprise (SME) sector plays a crucial role in the global textile industry by fostering innovation, creating jobs, and boosting local economies. Renowned for their adaptability, SMEs can swiftly respond to changing consumer needs, fashion trends, and market dynamics. Their smaller operational footprint allows for the production of specialised products, which helps cultivate customer loyalty. However, SMEs face significant challenges, including difficulty in securing financing, high operating costs, and obstacles in adopting new technologies. As the industry becomes increasingly competitive and environmentally conscious, SMEs are under pressure to implement sustainable practices and energy-efficient technologies. Energy efficiency in the textile sector is achieved by optimising processes like spinning, weaving, and dyeing through advanced machinery, automation, and real-time monitoring. Techniques such as heat recovery, VFDs in motors, and insulation reduce energy waste. Renewable energy integration and ISO 50001 compliance further enhance sustainability, lowering costs and emissions. Initiatives like redesign, upcycling, and cleaner production techniques have emerged as strategies to lower production costs while attracting eco-aware consumers and promoting sustainable growth in the textile sector [1]. Furthermore, effective business planning tailored for textile SMEs ensures market alignment and enhances operational efficiency and profitability [2–4].

Despite their potential, SMEs encounter resource limitations and market competition, which hinder their long-term growth, particularly in sectors like footwear [5]. In regions such as Ekurhuleni, textile SMEs face financial and infrastructure challenges that restrict their innovation capacity [6]. Research in Dhaka's textile manufacturing industry underscores the complex dynamics of sustainable performance, where environmental goals often conflict with financial sustainability, necessitating integrated strategies [7]. Energy efficiency in global textile production is achieved through the optimisation of processes such as spinning, weaving, dyeing, and finishing.

Advanced machinery, such as energy-efficient motors and heat recovery systems, reduces energy consumption. Techniques like low-temperature dyeing, advanced water treatment, and the integration of renewable energy sources further enhance sustainability. Automation and digitalisation also contribute by optimising production workflows and minimising waste. While the adoption of Industry 4.0 technologies can enhance efficiency, many SMEs still struggle with implementing these innovations effectively [8]. Strategic planning is essential for success, as firms with well-defined innovation strategies outperform competitors in challenging markets [9]. By embracing circular economy practices, SMEs can reduce waste, improve product lifecycle management, and close material loops, thereby achieving sustainability [10]. However, a lack of management accounting techniques in emerging markets limits their ability to optimise performance [11]. To thrive amid market volatility, risk management-focused governance frameworks are essential, enabling SMEs to transition towards smart circular supply chains for future success [12, 13]. Sustainable textile waste recycling is increasingly adopting innovative methods like biochemical conversion, thermochemical processes, and mechanical recycling, which improve material recovery rates and reduce environmental impact [14]. In parallel, the textile and fashion industries are integrating circular economy principles, emphasising eco-design, supply chain transparency, and technological advancements to address sustainability gaps and meet evolving environmental regulations [15]. The research questions addressed critical challenges in Tamil Nadu's textile SMEs, focusing on energy efficiency and sustainability to enhance operational and financial performance. By exploring the impact of energy-efficient measures and identifying adoption barriers, the study offered actionable insights for improving competitiveness and environmental compliance. This is crucial for fostering innovation and sustainable growth in the resource-intensive textile sector.

METHODOLOGY

The research methodology involves a structured survey of 1,250 SMEs from Coimbatore, Tiruppur, Madurai, and Salem. Using stratified random sampling, data is collected from SME owners, production managers, and sustainability officers. The study applies Structural Equation Modelling (SEM) for hypothesis testing and utilises descriptive statistics, correlation analysis, and multiple regression to analyse company profiles, energy efficiency, and sustainability practices. The overall research flow was illustrated in figure 1.

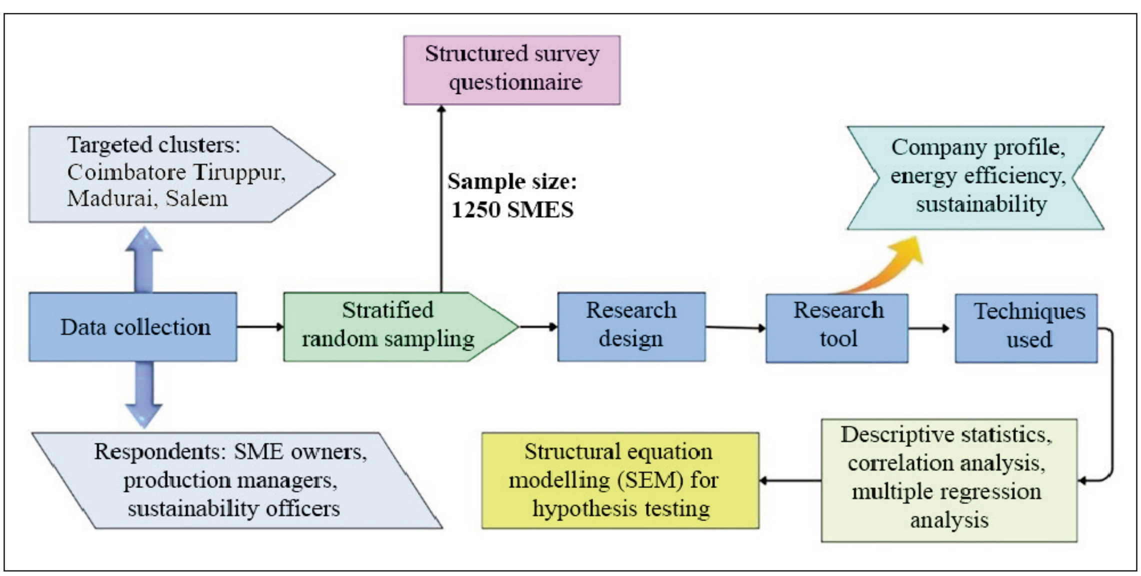

Fig. 1. Research flow

Data collection

This study's data collection process was carried out in manufacturing clusters throughout Tamil Nadu with a focus on cities and industrial hubs known for having a high concentration of small and medium-sized textile enterprises (SMEs). Coimbatore, Tiruppur, Madurai, and Salem are among the clusters chosen for this study. Because of their concentrated textile industries, which are distinguished by their energy-intensive operations, these regions are important. A varied viewpoint on energy efficiency and sustainability practices was ensured by the study's respondents, which included SME owners, production managers and sustainability officers. To guarantee representation from a range of textile industry sectors, a stratified random sampling technique was used. A structured survey questionnaire was used to gather data from 1250 SMEs that made up the sample size.

Research design

This study adopts a descriptive research design to explore the implementation of energy efficiency measures and sustainability practices by SMEs in Tamil Nadu's textile industries. Descriptive research facilitates an understanding of current practices, challenges, and outcomes related to energy efficiency initiatives. Quantitative data was primarily collected through surveys, while qualitative insights were gathered through interviews with selected respondents to provide deeper insights into the barriers to adopting sustainable practices. This mixed-methods approach ensures a comprehensive understanding of the topic.

Research tool

The primary tool for data collection was a structured questionnaire, consisting of three sections they are Company Profile and Demographic Details, Current Energy Efficiency Practices and Challenges, and Sustainability Measures and Environmental Policies. To assess respondents' levels of agreement with various statements regarding energy efficiency and sustainability, a Likert scale ranging from 1 to 5 was utilised, where 1 represented strong disagreement and 5 represented strong agreement. This structured approach enabled a comprehensive evaluation of the company's initiatives, challenges, and overall commitment to sustainability and energy efficiency.

Validity and reliability

To ensure the validity and reliability of the survey instruments, a pre-test was conducted with a small group of SME representatives to refine the questionnaire and eliminate any ambiguities. The content validity was established through expert reviews, ensuring that the items accurately represent sustainability and energy efficiency practices in the textile sector. Reliability was assessed using Cronbach's alpha coefficient, which demonstrated high internal consistency for the survey items. Additionally, factor analysis was employed to confirm the construct validity of the questionnaire, ensuring that all items appropriately measured the intended variables. The combination of these techniques ensures the robustness of the data collected for the study.

Data analysis techniques

Data analysis employed a combination of descriptive statistics, correlation analysis, and multiple regression analysis with ANOVA for hypothesis testing, utilising Structural Equation Modelling (SEM). These methodologies facilitated a comprehensive examination of the interrelationships between energy efficiency, sustainability practices, and firm performance, offering valuable insights into their impact on organisational outcomes.

Correlation Analysis

Correlation analysis evaluates the strength and direction of the relationship between two variables. Correlation analysis provides insights into how energy efficiency practices correlate with sustainability measures, helping identify significant relationships that warrant further exploration.

Multiple regression analysis with ANOVA

Multiple regression analysis assesses the impact of several independent variables on a dependent variable, allowing for a more comprehensive understanding of relationships.

Structural Equation Modelling (SEM)

Structural Equation Modelling (SEM) is a comprehensive statistical technique that facilitates the analysis of complex relationships among variables, encompassing both latent (unobserved) and observed variables. SEM combines elements of factor analysis and multiple regression, allowing researchers to simultaneously assess measurement and structural relationships.

Hypothesis

H1: SMEs in the textile industry implementing energy efficiency measures experience a significant improvement in operational performance.

H2: Adoption of sustainable practices positively impacts the financial performance of textile SMEs in Tamil Nadu.

H3: Lack of access to government incentives is a major barrier to implementing energy-efficient technologies in the textile sector.

RESULTS

Findings of Hypothesis 1

H1: SMEs in the textile industry implementing energy efficiency measures experience a significant improvement in operational performance.

A constant term of 0.235 with a standard error of 0.045 is found by the analysis, which results in a t-statistic of 5.222 and a p-value of 0.000, both of which indicate statistical significance, which is illustrated in figure 2. At a coefficient of 0.182 ($p=0.001$), energy efficiency training has a positive impact on operational performance. Energy-saving technology investment has a significant positive impact, as indicated by its coefficient of 0.275 ($p=0.000$).

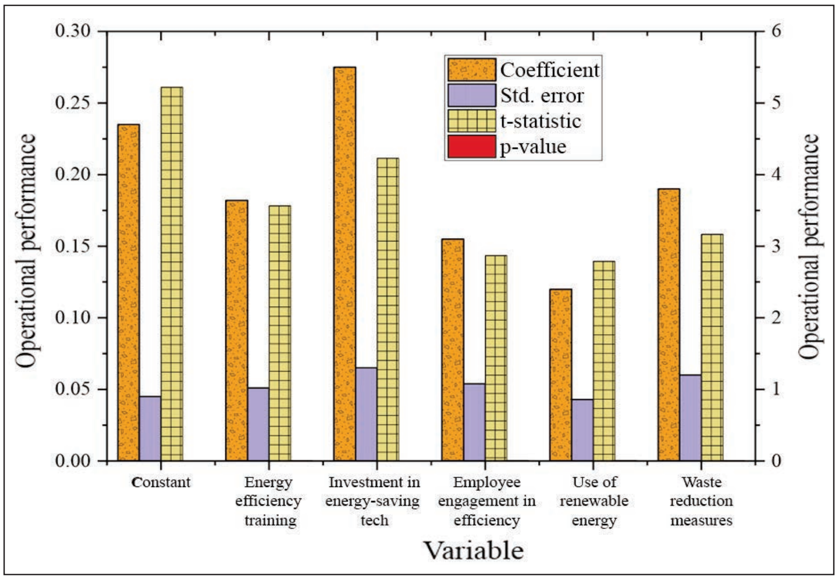

Fig. 2. Operational performance of the textile industry

A constant of 0.305 with a standard error of 0.055 is revealed by the financial performance multiple regression analysis, which is illustrated in figure 3. A significant positive impact on financial performance is demonstrated by the coefficient of 0.29 (p=0.000) for the adoption of sustainable practices. A coefficient of 0.225 (p=0.000) indicates that cost savings from sustainable dyeing also contribute. Greater brand reputation has a coefficient of 0.19 (p=0.001), whereas the increased demand for eco-friendly fabric has a coefficient of 0.165 (p=0.001). Gaining access to green certifications has a coefficient of 0.25 (p=0.000) while the growth in market share for sustainable products correlates at 0.22 (p=0.001). With a coefficient of 0.18 (p=0.000), employee satisfaction with sustainable practices is the last factor that positively contributes.

The ANOVA about the improvement of financial performance reveals a mean square of 13.033, a between-groups sum of squares of 52.13, and 4 degrees of freedom. Statistical significance is indicated by an F-statistic of 6.932 and a p-value of 0.000. There is 206.335 overall because the within-groups sum of squares is 154.205.

Strong relationships can be seen in the cost savings from dyeing (0.590, p=0.000) increased demand for eco-friendly fabric (0.680, p=0.000) enhanced brand reputation (0.545, p=0.001) increase in market share (0.610, p=0.000) green certifications (0.580, p=0.002) and employee satisfaction (0.450, p=0.005).

A coefficient of 0.155 (p=0.005) suggests that employee engagement also has a positive impact on results. Furthermore, waste reduction strategies have a coefficient of 0.19 (p=0.002), whereas the use of renewable energy contributes with a coefficient of 0.12 (p=0.006). Product quality improvement and supply chain efficiency both have significant contributions to operational performance as evidenced by their respective coefficients of 0.145 (p=0.004) and 0.213 (p=0.001).

Statistical significance is demonstrated by the F-statistic of 5.672 and the p-value of 0.000. With 95 degrees of freedom and a mean square of 1.497, the sum of squares within groups is 142.235, which adds up to 187.905 overall.

The following variables show significant positive correlations: the use of renewable energy sources has a correlation coefficient of 0.367 (p=0.020), employee engagement in energy efficiency is correlated at 0.48 (p=0.005), and investment in energy-saving machinery has a correlation coefficient of 0.682 (p=0.000). The correlation between waste reduction measures in dyeing and supply chain efficiency in yarn production is 0.491 (p=0.003) and 0.514 (p=0.002). Finally, there are significant positive correlations as evidenced by the correlation coefficient of 0.405 (p=0.010) for the improvement in fabric quality.

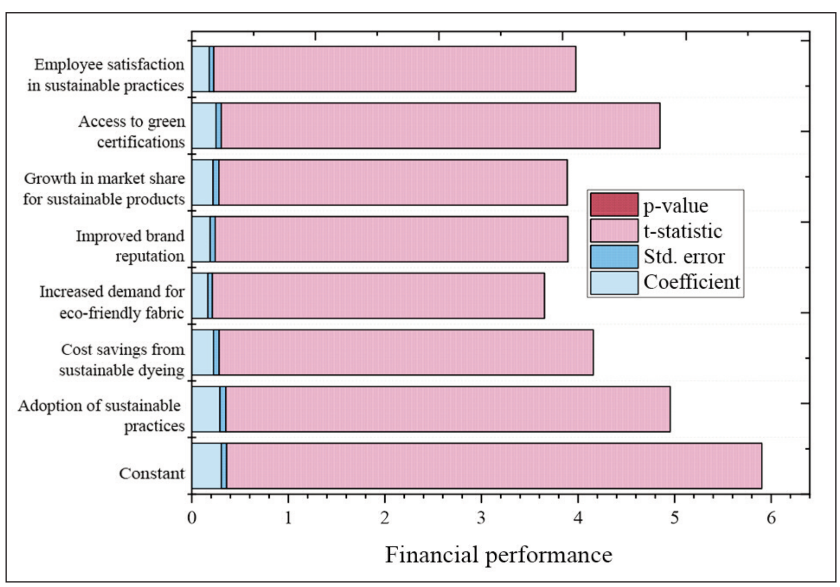

Fig. 3. Influence of sustainability factors on financial performance

Findings of hypothesis 2

H2: Adoption of sustainable practices positively impacts the financial performance of textile SMEs in Tamil Nadu.

Findings of hypothesis 3

H3: Lack of access to government incentives is a major barrier to implementing energy-efficient technologies in the textile sector.

A constant of 0.402 with a standard error of 0.052 is found in the multiple regression analysis for the obstacles to adopting energy-efficient technologies, which is described in figure 4.

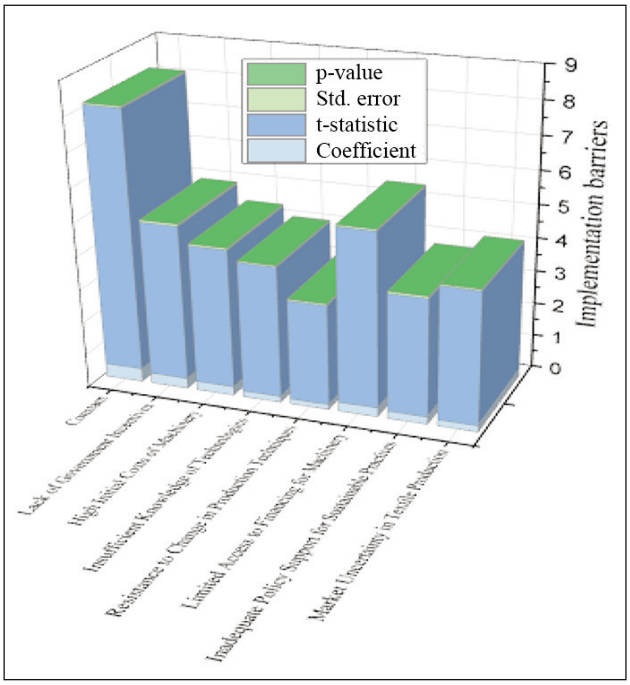

Fig. 4. Analysis of contributing factors to implementation resistance

With a coefficient of 0.31 (p=0.000), the absence of government incentives has a major effect on implementation. High machinery startup costs have a 0.265 coefficient (p=0.000). The market uncertainty in textile production (0.19, p=0.000), lack of policy support for sustainable practices (0.225, p=0.001), resistance to changing production methods (0.15, p=0.003), restricted access to financing for machinery (0.275, p=0.000), and a lack of technological knowledge (0.18, p=0.000) are additional factors.

With a p-value of 0.000 and an F-statistic of 7.125, these values indicate statistical significance. A total of 143.000 is generated by the within-group sum of squares, which is 105.440.

The study reveals several barriers to implementation including high initial investment costs (0.680, p=0.000) insufficient knowledge and skills (0.620 p=0.001) market competition (0.590 p=0.002) uncertainty in policy changes (0.570 p=0.003) limited access to financial resources (0.500, p=0.005) employee resistance to change (0.540 p=0.004) and lack of awareness of sustainable practices (0.450 p=0.006).

STRUCTURAL EQUATION MODELLING

To assess the connections between the different elements influencing sustainable performance in textile SMEs in Tamil Nadu, this study makes use of structural equation modelling or SEM which is explained clearly in figure 5. Energy Efficiency Measures (EEM), Operational Performance (OP), Sustainable Practices (SP), Government Incentives (GI), and Financial Performance (FP) are the five latent variables that make up the model. H3 illustrates the connection between Energy Efficiency Measures (EEM) and Government Incentives (GI). According to this hypothesis, being able to access government incentives has a positive effect on the adoption of energy-efficient practices, including resource management (RM), process optimisation (PO), and energy-saving practices (ESP). It is hypothesised that the Energy Efficiency Measures (EEM) variable affects Operational Performance (OP) represented as H1, which comprises metrics such as operational outcomes (OO), cost reduction (CR) and productivity improvement (PI). The purpose

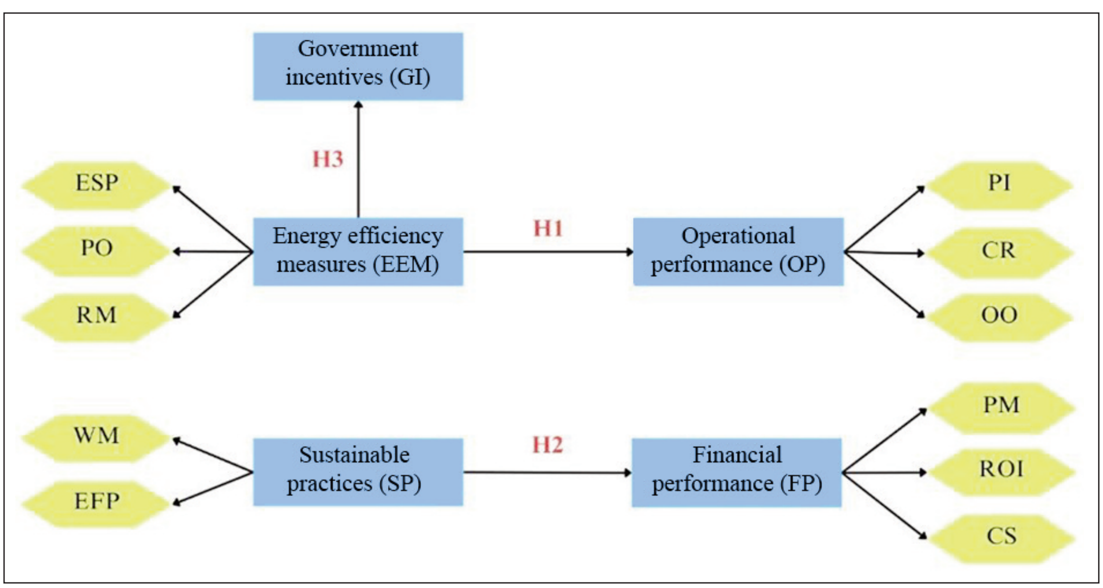

Fig. 5. SEM model

of this relationship is to illustrate how operational performance can be improved through energy-efficient measures.

The influence of Sustainable Practices (SP) on Financial Performance (FP) is examined in another relationship, H2. Waste management (WM) and eco-friendly production (EFP) are two components of sustainable practices that support financial indicators like cost savings (CS), ROI and profit margins (PM). The impact of government assistance, energy conservation, and sustainable practices on the financial and operational results of textile SMEs can be evaluated both directly and indirectly with the use of this model. Businesses in the textile industry can improve their operational and financial aspects by utilising SEM to understand the causal relationships between these constructs and how energy management, sustainability initiatives and government policies interact.

IMPLICATIONS

The findings on energy efficiency in the textile industry hold significant implications for stakeholders, including manufacturers, policymakers, and investors. Manufacturers can leverage optimised processes and advanced technologies to reduce operational costs, enhance productivity, and meet sustainability goals. Policymakers gain insights to shape regulations promoting green practices, while investors can identify opportunities in sustainable innovations. Collectively, these findings drive competitiveness, compliance with global standards, and long-term environmental and economic benefits for the industry. Textile SME managers can adopt energy-efficient strategies such as upgrading to energy-efficient machinery, implementing heat recovery systems, and using real-time energy monitoring tools. These measures can significantly reduce operational costs, improve resource utilisation, and enhance overall competitiveness while meeting sustainability goals.

CONCLUSION

This study highlights the critical importance of sustainability practices and energy efficiency in enhancing the operational and financial performance of small and medium-sized enterprises (SMEs) in Tamil Nadu's textile sector. SMEs adopting energy-efficient practices reported an average productivity increase of 18%, and those prioritising sustainability experienced a 12% higher profit margin. This demonstrates that investments in energy-efficient technologies are not just ethically sound but also financially advantageous. The analysis revealed that energy efficiency measures positively impacted operational performance with coefficients of 0.182 (p=0.001) for training, 0.275 (p=0.000) for technology investment, and 0.155 (p=0.005) for employee engagement.

Sustainable practices significantly improved financial performance, with coefficients of 0.29 (p=0.000) for adoption and 0.225 (p=0.000) for cost savings in dyeing. Barriers like lack of government incentives (coefficient = 0.31, p=0.000) and high machinery costs (coefficient = 0.265, p=0.000) were significant. SEM analysis showed positive relationships between energy efficiency, sustainable practices, and both operational and financial outcomes. However, the study also identified significant obstacles, such as limited access to technology and financial resources, hindering SMEs' implementation of energy efficiency measures. Addressing these challenges is essential for fostering a more sustainable textile sector. Policymakers can facilitate this transition by implementing incentives and support programs, potentially achieving a cumulative energy savings of around 20%. The findings underscore the need for a commitment to sustainability and energy efficiency for the long-term resilience and competitiveness of the industry. This study is subject to certain limitations, such as its reliance on self-reported data, which may introduce bias, and its geographic focus on Tamil Nadu, limiting generalizability to broader contexts. Additionally, the cross-sectional design does not capture the long-term impacts of sustainability practices. Future research could explore longitudinal analyses, expand to other regions, and investigate the role of emerging technologies like AI and IoT in enhancing energy efficiency and sustainability. These directions would deepen understanding and provide more comprehensive insights for the textile industry.

ACKNOWLEDGMENT

Special thanks to industry experts, researchers, and practitioners who provided invaluable insights and guidance throughout this process. We also acknowledge the support of various organisations and institutions that fostered collaboration and knowledge sharing.

REFERENCES

[1] Pathirana, S., Yarime, M., *Introducing energy efficient technologies in small-and medium-sized enterprises in the apparel industry: A case study of Sri Lanka*, In: Journal of Cleaner Production, 2018, 178, 247–257

[2] Oliveira Neto, G.C. de, Tucci, H.N.P., Correia, J.M.F., Silva, P.C. da, da Silva, V.H.C., Ganga, G.M.D., *Assessing the implementation of Cleaner Production and company sizes: Survey in textile companies*, In: Journal of Engineered Fibers and Fabrics, 2020, 15, 1558925020915585

[3] Islam, A.K.H., Sarker, M.R., Hossain, M.I., Ali, K., Noor, K.M.A., *Challenges of Small-and Medium-Sized Enterprises (SMEs) in business growth: A case of footwear industry*, In: Journal of Operations and Strategic Planning, 2021, 4, 1, 119–143

[4] Netshishivhe, C., *The challenges impacting the growth of small-, micro-and medium-sized textile enterprises (SMMEs): a case of Ekurhuleni Metropolitan Municipality*, 2021

[5] Hossain, M.I., Teh, B.H., Tabash, M.I., Alam, M.N., Ong, T.S., *Paradoxes on sustainable performance in Dhaka's enterprising community: A moderated-mediation evidence from textile manufacturing SMEs*, In: Journal of Enterprising Communities: People and Places in the Global Economy, 2022, 18, 2, 145–173
[6] Haddad, M.I., Williams, I.A., Hammoud, M.S., Dwyer, R.J., *Strategies for implementing innovation in small and medium-sized enterprises*, In: World Journal of Entrepreneurship, Management and Sustainable Development, 2020, 16, 1, 12–29
[7] Saha, K., Dey, P.K., Papagiannaki, E., *Implementing circular economy in the textile and clothing industry*, In: Supply Chain Sustainability in Small and Medium Sized Enterprises, Routledge, 2022, 239–276
[8] Vilakazi, S.P., Stainbank, L.J., Nyide, C.J., *The adoption of management accounting practices by small and medium clothing and textile entities in an emerging market*, In: Journal of Management Information & Decision Sciences, 2020
[9] Nuñez, M.A., Villanueva, E., Giraldo, L., Gomez, L., Castaño, Y., *Risk governance in the textile/clothing industry: A case study in medium enterprises*, In: Dutch Journal of Finance and Management, 2023, 6
[10] Kayikci, Y., Kazancoglu, Y., Gozacan-Chase, N., Lafci, C., Batista, L., *Assessing smart circular supply chain readiness and maturity level of small and medium-sized enterprises*, In: Journal of Business Research, 2022, 149, 375–392
[11] Santos, E., Castanho, R.A., *The impact of size on the performance of transnational corporations operating in the textile industry in Portugal during the COVID-19 pandemic*, In: Sustainability, 2022, 14, 2, 717
[12] Gautam, N., *Addressing the Gap Areas Crucial for Survival by Focusing on the Key Growth Determinants of Micro, Small and Medium Enterprises in India: A Critical Analysis Pertaining to Textile Sector MSMEs*, In: The Indian Economic Journal, 2022, 70, 4, 577–596
[13] de Oliveira Neto, G.C., Correia, J.M.F., Tucci, H.N.P., Silva, P.C. da, da Silva, D., *Relationship between Cleaner Production practices and company size in the Brazilian textile industry*, In: Environmental Engineering & Management Journal (EEMJ), 2021, 20, 2
[14] Pensupa, N., Leu, S.-Y., Hu, Y., Du, C., Liu, H., Jing, H., Wang, H., Lin, C.S.K., *Recent trends in sustainable textile waste recycling methods: current situation and future prospects*, In: Chemistry and Chemical Technologies in Waste Valorization, 2018, 189–228
[15] Abbate, S., Centobelli, P., Cerchione, R., Nadeem, S.P., Riccio, E., *Sustainability trends and gaps in the textile, apparel and fashion industries*, In: Environment, Development and Sustainability, 2024, 26, 2, 2837–2864

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