

Circular Economy Practices and Operational Efficiency among Air Conditioning Manufacturers and Distributors in the Philippines: Basis for Strategic Green Technology

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DOI: <https://doi.org/10.54476/apjaet/77604>

Abstract

This study examined the relationship between circular economy practices and operational efficiency among air conditioning manufacturers and distributors in the Philippines as a basis for developing a Strategic Green Technology Framework. Using a descriptive-correlational research design, data were collected from 100 employees directly involved in operations and sustainability-related functions. Circular economy practices were assessed in terms of sustainable design and resource efficiency, waste reduction and reverse logistics, green technology adoption, and organizational and policy support, while operational efficiency was measured through cost control, productivity, material utilization, and supply chain performance. Results revealed that respondents perceived a high level of implementation of circular economy practices and a high level of operational efficiency across all dimensions. Pearson correlation analysis indicated a significant positive relationship between circular economy practices and operational efficiency, suggesting that sustainability-oriented practices function as strategic organizational capabilities that enhance operational outcomes. Among the dimensions, waste reduction and reverse logistics demonstrated the strongest association with operational efficiency. Based on the findings, a Strategic Green Technology Framework anchored on four interrelated pillars was proposed to guide firms in integrating circular economy principles into their operational strategies. The study contributes empirical evidence from a developing economy context and offers practical insights for managers and policymakers seeking to align sustainability initiatives with operational performance.

Keywords: circular economy, operational efficiency, green technology, air conditioning industry, Philippines

Introduction

The increasing environmental impact of manufacturing and distribution activities has intensified global attention on sustainable production systems, particularly in energy-intensive industries such as air conditioning manufacturing and distribution. The air conditioning sector contributes significantly to electricity consumption, greenhouse gas emissions, and solid waste generation due to its reliance on energy-intensive components, refrigerants, and short product life cycles (Ghisellini et al., 2016; Kirchherr et al., 2017). As climate change concerns and regulatory pressures escalate, organizations are compelled to explore alternative operational models that balance economic performance with environmental responsibility.

One emerging approach that has gained substantial attention is the circular economy, which emphasizes the reduction of waste, reuse of materials, and regeneration of resources across the product life cycle. Unlike the traditional linear “take–make–dispose” model, circular economy practices promote closed-loop systems that enhance resource efficiency and minimize environmental degradation (Ellen MacArthur Foundation, 2015). In manufacturing and distribution contexts, circular economy practices such as eco-design, waste reduction, reverse logistics, and resource efficiency have been associated with improved operational outcomes, including cost savings and productivity gains (Geissdoerfer et al., 2018).

Operational efficiency remains a critical determinant of organizational competitiveness, particularly in industries characterized by intense competition and high operational costs. Operational efficiency refers to an organization’s ability to optimize the use of resources to achieve maximum output with minimal waste, cost, and time (Slack et al., 2022). For air conditioning manufacturers and distributors, operational efficiency encompasses cost control, productivity, material utilization, and supply chain performance. Enhancing these dimensions is essential not only for profitability but also for long-term sustainability in a rapidly evolving market environment.

Recent empirical studies suggest that the adoption of circular economy practices can positively influence operational efficiency by improving material flow management, reducing production costs, and enhancing supply chain resilience (Awan et al., 2021; Gopan & Balaji, 2023). However, much of the existing literature focuses on large-scale manufacturing firms in developed economies, with limited empirical evidence from developing countries, particularly within the Southeast Asian context. This gap is notable given the unique regulatory, infrastructural, and market conditions faced by firms in emerging economies such as the Philippines.

In the Philippine context, environmental sustainability has become a national priority, reinforced by government policies such as the Ecological Solid Waste Management Act (Republic Act No. 9003), the Energy Efficiency and Conservation Act (Republic Act No. 11285), and the Extended Producer Responsibility Act (Republic Act No. 11898). These policies mandate responsible waste management, energy conservation, and producer accountability, thereby encouraging firms to adopt circular economy principles. Despite these policy initiatives, the extent to which circular economy practices are implemented and how they influence operational efficiency in the air conditioning industry remains underexplored.

From a theoretical standpoint, the Resource-Based View (RBV) provides a useful lens for examining the relationship between circular economy practices and operational efficiency. RBV posits that organizational capabilities that are valuable, rare, inimitable, and non-substitutable can serve as sources of sustained competitive advantage (Barney, 1991). Circular economy practices, when embedded into organizational routines and processes, may function as strategic capabilities that enhance operational efficiency and long-term performance.

Although prior studies have examined sustainability practices and operational performance, there is a paucity of research that integrates circular economy practices and operational efficiency within the specific context of air conditioning manufacturers and distributors in the Philippines. Moreover, existing studies often examine sustainability outcomes in isolation, without proposing actionable frameworks that organizations can adopt. This study seeks to address these gaps by empirically examining the level of circular economy practices and operational efficiency and by developing a

Therefore, this study aims to assess the relationship between circular economy practices and operational efficiency among air conditioning manufacturers and distributors in the Philippines. By generating empirical evidence and proposing a strategic framework, the study contributes to both theory and practice, offering insights for industry practitioners, policymakers, and researchers interested in sustainable operations and circular economy implementation.

Objectives of the Study

This study aimed to examine circular economy practices and operational efficiency among air conditioning manufacturers and distributors in the Philippines. Specifically, it sought to:

1. Determine the level of circular economy practices as to sustainable design and resource efficiency, waste reduction, reverse logistics, green technology adoption, organizational and policy support
2. Determine the level of operational efficiency in terms of cost control such as productivity, material utilization, and supply chain performance
3. Examine the significant relationship between circular economy practices and operational efficiency.

Methodology

Research Design. The study employed a descriptive-correlational research design, which is appropriate for examining the characteristics of variables and determining the relationship between them without manipulating the research environment (Creswell & Creswell, 2018). This design enabled the researcher to describe the level of circular economy practices and operational efficiency as perceived by respondents and to analyze the relationship between these variables. The design is consistent with prior studies investigating sustainability practices and operational outcomes (Awan et al., 2021; Geissdoerfer et al., 2018).

Respondents and Sample. The respondents consisted of 100 employees from air conditioning manufacturing and distribution firms operating in the Philippines. The respondents were predominantly mid-level employees with operational responsibilities, indicating that the data were obtained from individuals directly involved in day-to-day organizational processes. The length of service suggests adequate familiarity with organizational practices, enhancing the credibility of the responses.

Purposive sampling was employed to ensure that respondents had sufficient knowledge and involvement in operational and sustainability-related activities. Inclusion criteria required respondents to be at least one year employed in their organization and directly involved in operations, supply chain management, production, or administrative decision-making.

Research Instrument. Data were collected using a structured, self-administered questionnaire developed from relevant literature and aligned with the study variables. The questionnaire consisted of three parts: demographic profile, circular economy practices, and operational efficiency. Circular economy practices were measured across four dimensions, while operational efficiency was assessed across four operational dimensions. A four-point Likert scale ranging from 1 (Very Low) to 4 (Very High) was used to avoid neutral responses and encourage clear perceptions. The instrument underwent face and content validation by three experts in operations management and environmental sustainability. A pilot test involving 30 respondents yielded Cronbach's alpha values ranging from 0.81 to 0.89, indicating good internal consistency.

Data Gathering Procedure. Data collection was conducted through online and in-person distribution of questionnaires. Permission was secured from participating organizations prior to data collection. Respondents were informed of the study's purpose and provided informed consent. Data collection was completed within four weeks.

Research Ethics. Ethical considerations were strictly observed throughout the study. Participation was voluntary, anonymity was ensured, and respondents were informed of their right to withdraw at any time. The study complied with institutional ethical standards for research involving human participants.

Data Analysis. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to analyze demographic data and assess the level of circular economy practices and operational efficiency. Pearson's product-moment correlation coefficient was employed to examine the relationship between the two main variables. Statistical significance was set at the 0.05 level.

Results and Discussion

1. Level of Circular Economy Practices

Among the dimensions, eco-design obtained the highest mean score ($\bar{x} = 3.42$), indicating that respondents perceived strong integration of environmentally responsible design practices in products and

processes. This finding suggests that firms prioritize energy-efficient designs, environmentally friendly materials, and product configurations that reduce environmental impact. Consistent with circular economy literature, eco-design serves as a foundational strategy that enables downstream practices such as recycling, remanufacturing, and efficient resource utilization (Ghisellini et al., 2016; Geissdoerfer et al., 2017).

Reverse logistics ranked second ($\bar{x} = 3.24$), reflecting a high level of implementation of activities related to product returns, recycling, and recovery of materials. This result implies that firms have begun establishing mechanisms for handling end-of-life products and reusable components, which is critical in industries such as air conditioning, where equipment contains valuable and regulated materials. Prior studies have emphasized that effective reverse logistics contributes to cost savings and improved supply chain efficiency by recovering residual value from used products (Kirchherr et al., 2017).

Waste reduction recorded a mean score of 3.14, indicating that while firms actively engage in waste minimization practices, there remains room for improvement. This suggests that waste reduction initiatives such as material optimization, reduction of process inefficiencies, and improved waste segregation are present but not yet maximized. The finding aligns with empirical evidence that waste reduction is often implemented incrementally, as it requires continuous process monitoring and employee involvement (Awan et al., 2021).

Lastly, resource efficiency obtained the lowest mean score ($\bar{x} = 3.10$), though still within the high level of implementation. This result indicates that respondents perceive challenges in fully optimizing the use of raw materials, energy, and other operational inputs. Resource efficiency often requires substantial investments in technology, process redesign, and performance monitoring systems, which may explain its comparatively lower rating. Nonetheless, maintaining a high level of resource efficiency is essential, as it directly affects operational costs and long-term sustainability (Slack et al., 2022).

Overall, the results suggest that air conditioning manufacturers and distributors in the Philippines demonstrate a strong commitment to circular economy practices, particularly in eco-design and reverse logistics. However, the relatively lower ratings for waste reduction and resource efficiency highlight potential areas for strategic improvement. Strengthening these dimensions may further enhance operational efficiency and support the transition toward more sustainable and competitive business operations.

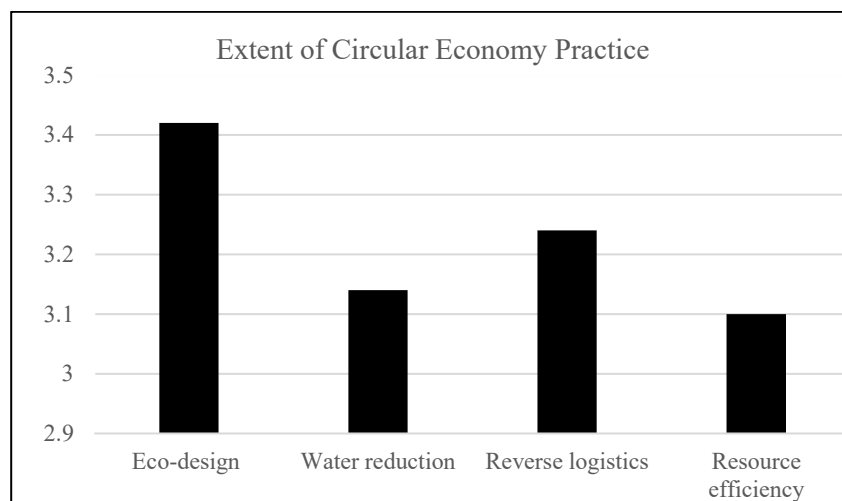


Figure 1. Extent of Circular Economy Practice

Figure 1 presents the extent of circular economy practices as perceived by respondents in terms of eco-design, waste reduction, reverse logistics, and resource efficiency. The results indicate that all four dimensions were implemented at a high level, with mean scores ranging from 3.10 to 3.42 on a 4-point Likert scale, suggesting a generally positive adoption of circular economy principles among air conditioning manufacturers and distributors.

2. Level of Operational Efficiency

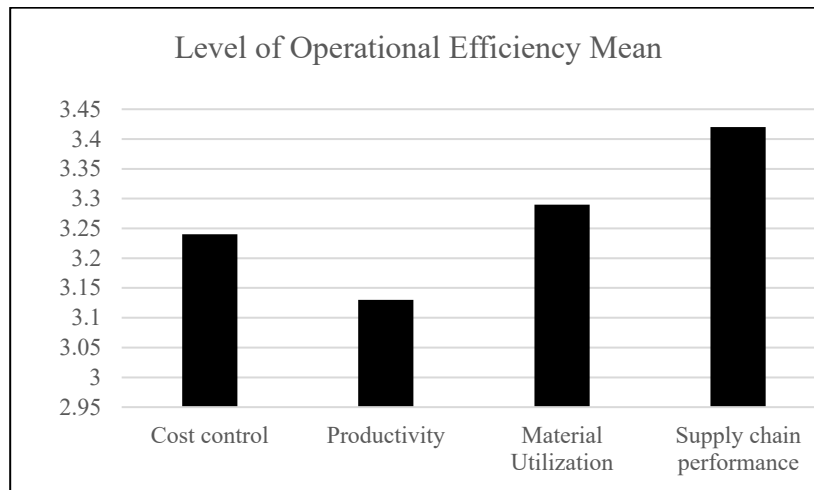


Figure 2. Level of Operational Efficiency Mean

Figure 2 illustrates the level of operational efficiency of air conditioning manufacturers and distributors as perceived by the respondents in terms of cost control, productivity, material utilization, and supply chain performance. The results show that all four dimensions were rated at a high level, with mean scores ranging from 3.13 to 3.42 on a 4-point Likert scale. This indicates that respondents generally perceived their organizations as operating efficiently across key operational domains.

Among the dimensions, supply chain performance recorded the highest mean score ($\bar{x} = 3.42$), suggesting that firms demonstrate strong capabilities in coordinating procurement, distribution, inventory management, and logistics activities. This finding implies that air conditioning manufacturers and distributors have placed considerable emphasis on strengthening supply chain integration and responsiveness, which is critical in managing complex product components and fluctuating market demand. Prior studies have emphasized that effective supply chain performance enhances operational flexibility and cost efficiency, particularly in manufacturing and distribution sectors (Slack et al., 2022).

Material utilization ranked second ($\bar{x} = 3.29$), indicating a high level of efficiency in the use of raw materials and production inputs. This result suggests that firms have implemented measures to minimize material wastage and optimize resource usage, which contributes to cost reduction and environmental sustainability. Efficient material utilization is closely associated with lean operations and circular economy

practices, as it supports the reduction of non-value-adding activities and promotes resource conservation (Ghisellini et al., 2016).

Cost control obtained a mean score of 3.24, reflecting effective management of operational expenses such as production costs, energy consumption, and logistics expenditures. This finding indicates that firms are able to monitor and regulate costs while maintaining operational effectiveness. Effective cost control is essential for sustaining competitiveness, especially in industries facing rising energy prices and environmental compliance costs (Slack et al., 2022).

Productivity received the lowest mean score ($\bar{x} = 3.13$), although it remained within the high level of implementation. This suggests that while firms maintain acceptable productivity levels, there may be constraints related to workforce capacity, process efficiency, or technology utilization. Productivity improvements often require continuous training, process innovation, and investment in advanced technologies, which may explain its comparatively lower rating. Previous research indicates that productivity gains are typically realized gradually as organizations align human resources, technology, and operational processes (Awan et al., 2021).

Overall, the findings indicate that air conditioning manufacturers and distributors in the Philippines exhibit a high level of operational efficiency, with particular strengths in supply chain performance and material utilization. However, the relatively lower rating for productivity highlights an area for further improvement. Enhancing productivity through technology adoption and skills development may further strengthen overall operational efficiency and support sustainable business performance.

3. Relationship Between Circular Economy Practices and Operational Efficiency

Table 1
 Relationship between Circular Economy Practices and Operational Efficiency

Variables	r-value	Sig. value	Decision on H ₀	Interpretation
Eco design	0.50	0.01	Reject H ₀	Significant
Waste Reduction	0.60	0.01	Reject H ₀	Significant
Reduce Logistics	0.55	0.01	Reject H ₀	Significant
Resource Efficiency	0.50	0.01	Reject H ₀	Significant

Table 1 presents the results of the correlation analysis examining the relationship between circular economy practices and operational efficiency among air conditioning manufacturers and distributors in the Philippines. Pearson’s product–moment correlation coefficient was employed to determine the strength and significance of the relationships between each dimension of circular economy practices and overall operational efficiency.

The results reveal that all four dimensions of circular economy practices exhibited statistically significant positive relationships with operational efficiency at the 0.01 level of significance. The null hypothesis was rejected for all variables, indicating that higher levels of circular economy practice implementation are associated with higher levels of operational efficiency.

Among the dimensions, waste reduction demonstrated the strongest relationship with operational efficiency ($r = 0.60$, $p = 0.01$), indicating a moderate to strong positive correlation. This finding suggests that firms that actively minimize waste, improve material recovery, and reduce process inefficiencies tend to achieve better operational outcomes. Waste reduction directly contributes to cost savings, improved material utilization, and streamlined processes, which are critical drivers of operational efficiency. This result is consistent with prior studies emphasizing waste reduction as a central mechanism through which circular economy initiatives enhance operational performance (Ghisellini et al., 2016; Awan et al., 2021).

Reverse logistics also showed a significant positive relationship with operational efficiency ($r = 0.55$, $p = 0.01$). This implies that effective management of product returns, recycling, and recovery of end-of-life components contributes to improved supply chain performance and resource optimization. In the air conditioning industry, where products contain valuable and regulated materials, reverse logistics enables firms to recover residual value and reduce disposal costs, thereby enhancing overall operational efficiency. This finding supports existing literature highlighting the role of reverse logistics in improving both environmental and operational outcomes (Kirchherr et al., 2017).

Eco-design and resource efficiency both exhibited moderate positive correlations with operational efficiency ($r = 0.50$, $p = 0.01$). These results indicate that environmentally conscious product design and efficient use of resources are significantly associated with improved operational performance. Eco-design facilitates energy efficiency, ease of maintenance, and recyclability, which can reduce production and lifecycle costs. Similarly, resource efficiency minimizes input wastage and optimizes energy and material consumption, contributing to cost control and productivity improvements. These findings align with the Resource-Based View, which posits that sustainability-oriented capabilities can function as strategic resources that enhance organizational performance (Barney, 1991).

Overall, the results demonstrate that circular economy practices are not merely environmental initiatives but are strategically linked to operational efficiency. The significant positive relationships observed across all dimensions suggest that integrating circular economy principles into operational strategies can support efficiency improvements in manufacturing and distribution contexts. These findings reinforce the importance of adopting a holistic approach to circular economy implementation, wherein multiple practices work synergistically to enhance operational performance.

Conclusions

The study concluded that air conditioning manufacturers and distributors in the Philippines exhibit a high level of circular economy practices and operational efficiency. Circular economy practices are significantly associated with operational efficiency, confirming their strategic value. Waste reduction and reverse logistics showed the strongest relationship with efficiency outcomes. The proposed Strategic Green Technology Framework offers a practical guide for integrating sustainability into operational strategies.

Recommendations

Organizations should strengthen waste reduction and reverse logistics initiatives to maximize efficiency gains. Management should invest in green technologies and employee training to sustain circular economy practices. Policymakers may support firms through incentives and technical assistance. Future studies may employ longitudinal or mixed-method approaches to further explore causal relationships.

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