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Effects of Green Manufacturing Practices on Sustainable Performance of Plastic Manufacturing Firms: A Case of Ndola District of Copperbelt Province, Zambia

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The study explored the relationship between green manufacturing practices and sustainable performance in plastic manufacturing firms across Ndola district, Zambia. Key findings include high assimilation of internal energy optimization and environmental auditing practices, but less common external partnerships around waste collection or water recycling. The study found a positive relationship between green manufacturing practices and sustainable performance, with educational backgrounds significantly influencing the adoption of sustainability practices. While there is a positive orientation towards eco-efficient operations, the study recommends expanding the scope of sustainability practices and performance indicators, underpinned by targeted education and training programs and policy emphasis to leverage the industry's full potential for sustainability.

Keywords: green manufacturing, sustainable performance, environmental performance, economic performance, social performance, plastic industry

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1. Introduction

The study investigates the impact of green manufacturing practices (GMPs) on the sustainable performance of plastic manufacturing firms in Zambia, highlighting the urgent need for these practices due to increasing environmental concerns stemming from industrial activities. As global awareness of climate change rises, manufacturers are urged to adopt sustainable supply chain management initiatives that prioritize ecological responsibility alongside economic gains (Beier et al., 2018; Gupta and Barua, 2018). The research emphasizes that while green manufacturing can enhance resource efficiency and minimize environmental harm, the plastic sector in Zambia faces significant challenges, including reliance on linear production models and limited external partnerships for waste management (Awan et al., 2021). In addition, the findings suggest that educational background influences the adoption of sustainability practices, indicating a need for targeted training programs to improve engagement with advanced GMPs (Henao, 2019). Overall, the study advocates for a comprehensive integration of sustainability into business strategies to fully leverage the potential for improved environmental, economic, and social outcomes in Zambia's plastic manufacturing industry.

2. Literature Review and Conceptual Framework

2.1 Green Manufacturing and its Concept

Green manufacturing, also known as sustainable manufacturing or cleaner production, has gained significant global attention as a critical approach to addressing environmental challenges in various industries (Chuang and Yang, 2014; Deif, 2011). This model emphasizes resource optimization and environmental sustainability throughout the product life cycle, driven by stakeholder pressures and regulatory frameworks (Bai et al., 2015). Emerging in the early 1990s, green manufacturing aims to maximize resource efficiency while minimizing negative environmental impacts, thereby enhancing economic and social benefits (Rusinko, 2007). It encompasses various practices, including the use of renewable energy sources and engagement in green supply chains (Lozano et al., 2018).

Despite its potential, the adoption of green manufacturing practices in developing countries like Zambia remains limited, highlighting the need for firms to integrate sustainability into their operations to achieve improved performance across environmental, economic, and social dimensions. As industries strive for competitiveness and operational efficiency, embracing green manufacturing can lead to significant advantages while addressing pressing ecological concerns (Fernando and Wah, 2017).

2.2 Green Manufacturing Practices (GMPs)

The study examines the impact of green manufacturing practices (GMPs) on the sustainable performance of plastic manufacturing firms in Zambia, highlighting the pressing need for these practices due to environmental degradation and resource depletion. Since the first industrial revolution, the manufacturing sector has faced challenges in balancing production with environmental sustainability, leading to significant ecological concerns (Beier et al., 2018). In Zambia, issues such as air and water pollution from mining and manufacturing activities have prompted government initiatives aimed at enhancing climate change mitigation and promoting sustainable management of natural resources (Gupta and Barua, 2018). The adoption of GMPs is seen as a crucial strategy for manufacturers to reduce negative environmental impacts while optimizing resource efficiency and achieving economic benefits (Alayon, 2016; Ghosh, 2017).

GMPs encompass various practices aimed at minimizing waste and pollution throughout the product life cycle, from design to disposal (Deif, 2011). These practices not only improve operational efficiency but also enhance corporate reputation and stakeholder engagement (Haleem et al., 2023). The study emphasizes that effective implementation of GMPs can lead to significant improvements in a firm's triple bottom line—economic, environmental, and social performance. However, challenges remain in the form of limited awareness and participation in recycling initiatives within the plastic industry (Mwanza and Mbohwa, 2019). Therefore, fostering a culture of sustainability through stakeholder involvement and reverse logistics is essential for developing a more circular economy in Zambia's plastic manufacturing sector.

2.3 Sustainable Performance (SP)

Sustainable performance (SP) is increasingly recognized as a critical measure of a firm's effectiveness in achieving the triple bottom line—profit, people, and planet—by focusing on three key dimensions: environmental, economic, and social performance (Gualandris et al., 2016; Henao et al., 2019). Environmental performance (ENP) assesses a firm's ability to minimize pollution, reduce waste, and enhance resource efficiency, which ultimately contributes to improved public health and compliance with regulations (Abdul-Rashid et al., 2017). Economic performance (EP) evaluates financial outcomes such as profits and cost reductions associated with adopting green manufacturing practices, which can lead to lower energy costs and waste management expenses (Zhu and Sarkis, 2004). Social performance (SP) measures an organization's impact on employee welfare and community quality of life, emphasizing corporate responsibility towards stakeholders.

The integration of these three pillars is essential for sustainable development, aiming to achieve inclusive economic growth while maintaining environmental quality and enhancing societal welfare. Successful implementation of sustainable practices can lead to improvements across all dimensions of sustainable performance, thereby fostering a holistic approach to business operations that benefits both the organization and the environment. Through prioritizing sustainability in their strategies, firms can not only enhance their competitive edge but also contribute positively to society and the planet.

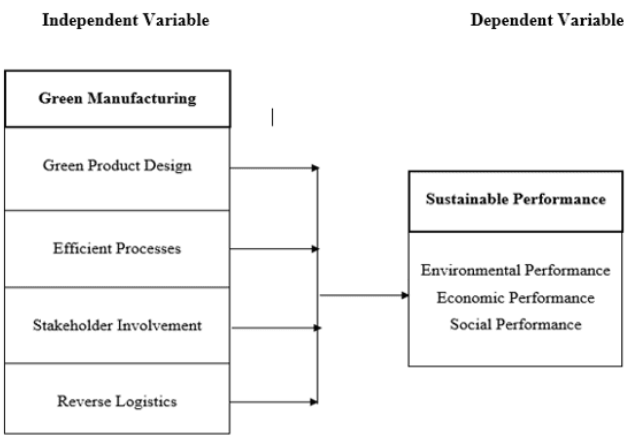
2.4 Sustainability KPIs and Green manufacturing Practices

Sustainability Key Performance Indicators (SKPIs) are essential for assessing organizational performance through the lens of the Triple Bottom Line (TBL) model, which encompasses economic, environmental, and social sustainability (Saadan, 2021). Stakeholder engagement plays a crucial role in promoting sustainable manufacturing practices, as businesses must balance profit generation with value creation for all stakeholders, including the environment and society. Green manufacturing practices (GMPs) are identified as vital initiatives that help firms minimize their environmental impact while optimizing production efficiency and enhancing overall performance (Hami et al., 2016; Ibrahim et al., 2019).

By adopting GMPs, companies can improve their sustainability performance across various dimensions, leading to better resource management and compliance with environmental regulations . In all, integrating sustainability into manufacturing processes not only benefits the environment but also enhances corporate reputation and stakeholder satisfaction.

Despite efforts by governments and manufacturing firms to adopt green manufacturing practices, numerous challenges hinder their implementation. Ghazilla et al. (2015) identified several barriers affecting the adoption of green manufacturing, including organizational obstacles, lack of environmental knowledge, adverse business environments, societal pressures, regulatory challenges, financial constraints, and supply chain issues. These challenges create significant hurdles for firms striving to integrate sustainable practices effectively into their operations, ultimately impacting their ability to achieve environmental and economic goals.

A focus on the empirical literature maps out the theoretical underpinnings of the study, drawing on three key theories: Ecological Modernization Theory (EMT), Natural Resource-Based View (NRBV), and Stakeholder Theory (ST). EMT posits that environmental problems can be addressed through technological innovation and economic growth. It emphasizes resource efficiency and product innovation, arguing that environmentally conscious organizations perform better. NRBV asserts that a firm's competitive advantage stems from its natural resources and capabilities. This focusing on sustainability and operational efficiency, helps firms to enhance their competitive edge. Stakeholder Theory highlights the importance of considering the interests of various stakeholders in organizational decision-making. It emphasizes the need for firms to balance their goals with the concerns of customers, suppliers, employees, shareholders, communities, and governments. And drawing up on these theories, a conceptual framework below was developed where green manufacturing is the independent variable and organizational performance as the dependent variable. The framework also demonstrates the relationship among interlinked concepts and explains the possible connection between the variables as shown below:



3. Research Methodology

The study adopted a positivist research philosophy, aligning with its objective of investigating the relationship between green manufacturing practices and sustainability performance in plastic manufacturing companies in Ndola, Zambia. According to Cooper and Schindler (2006), positivism emphasizes the use of structured data collection methods and statistical analysis to quantify relationships between variables. This approach was consistent with the study's directional hypotheses, which proposed positive connections between green strategies and sustainability performance. A quantitative, descriptive survey design was employed, capturing in-depth information about the characteristics of green manufacturing practices in the industry. As noted by Bhattacherjee (2011), descriptive designs are effective for profiling subject areas.

The survey utilized a structured questionnaire with closed-ended questions to gather data on demographics, green manufacturing practices, sustainability performance indicators, and perceived benefits. This quantitative approach allowed for standardized data collection and analysis, enabling the identification of relationships between variables and the evaluation of the role of green practices in sustainability advancements.

4. Reliability and Validity

To ensure the validity of the research instrument, a pilot study was conducted, allowing for necessary adjustments and improvements. Reliability was assessed using Cronbach's Alpha, a statistical measure that evaluates the internal consistency of the instrument.

These steps helped to ensure that the data collected accurately measured the intended constructs, enhancing the overall reliability and validity of the study.

5. Ethical Considerations

The study obtained ethical clearance from the University of Zambia's Humanities and Social Sciences Research Ethics Committee. It adhered to ethical principles such as informed consent, voluntary participation, anonymity, and confidentiality. Participants were informed of the study's academic purpose and could opt out at any time. Anonymity was maintained by avoiding the collection of personal information. Confidentiality was ensured through secure data storage and the presentation of aggregated results.

6. Analysis of the Results

6.1 Response Rate

The research findings were based on an initial sample target of 67 participants obtained from a target population of 80 participants from 8 companies by the Slovin’s formula. Although the study had intended to collect data from all the 8 plastic manufacturers represented 67 participants. Only 51 participants responded from 6 companies. This represents a 76.1% which is well above the typical 60-70% benchmark for external surveys (Sivo et al., 2006). Thus, a sample of 51 provided adequate representation. Further, this exceeds the minimum threshold of 50 required for enabling intended correlation analysis and model development to meet study objectives (ibid). The high response rate enhances generalizability of the findings. This is a higher response rate than those of similar studies conducted by Gachunga (2010) 62%, Kinoti (2012) 67.5% and Murphy (2012) 33.1%.

6.2 Demographic Profile of Respondents

The demographic profile of the 51 respondents from six plastic manufacturing companies in Ndola, Zambia, reveals a male-dominated workforce, with 74.5% males and 25.5% females. The age distribution shows a concentration of middle-aged professionals, with 66.6% of respondents falling between 31 to 50 years. Educational attainment among the respondents indicates that nearly half (49%) had vocational training, while 19.6% held diplomas, and a small percentage had degrees (15.7%) or higher qualifications.

Most employees had significant experience in their respective companies, with 41.2% having worked for 6-10 years and 33.3% for over a decade, indicating a well-established workforce.

In terms of job titles, the survey found that 31.4% held general roles within targeted departments, followed by 29.4% who were supervisors or foremen. The remaining respondents were distributed across managerial roles such as production managers (13.7%), general managers (7.8%), and operations, logistics, and plant managers (5.9% each). The companies themselves were predominantly well-established, with 88% having been in operation for over 10 years, highlighting the mature nature of the plastic manufacturing industry in Zambia. These demographic insights provide a useful context for understanding how this experienced, male-majority workforce perceives the adoption of green manufacturing practices.

6.3 Analysis of Green Manufacturing Practices

The analysis of green manufacturing practices among plastic industry professionals in Ndola, Zambia, reveals that the most widely adopted practices are "Energy Conservation" and "Environmental Effect Assessments," with mean scores exceeding 4.0, indicating a strong focus on internal operational efficiencies and environmental compliance. Practices such as "Plastic Waste Collection" and "Water Recycling" scored lower, with means of 2.53 and 2.84, respectively, reflecting a gap in the adoption of external green practices. The varying standard deviations for practices like "Green Materials Usage" and "Plastic Waste Collection" suggest inconsistent implementation across companies. Overall, the data shows a higher engagement in internal sustainability measures compared to external, supply chain-related initiatives.

A further analysis examined the correlation between education levels and the adoption of green practices. It was found that respondents with higher education, particularly those with degrees or higher, are more likely to adopt advanced practices like energy conservation and environmental assessments. In contrast, those with vocational training showed stronger engagement with practical actions like waste reduction.

This points to the need for more targeted training and awareness programs to bridge the gap between theoretical knowledge and practical application, especially in areas like plastic waste collection and water recycling, which had lower adoption rates across all educational backgrounds, as shown in the table below;

Table 1: Descriptive Statistics for Green Practices

Green Manufacturing Practice	Mean	Std. Deviation
Energy Conservation	4.12	0.91
Waste Reduction	3.90	1.02
Green Materials Usage	3.35	1.28
Green Technology Adoption	3.39	1.05
Environmental Effect Assessments	4.06	0.88
Plastic Waste Collection	2.53	1.25
Water Recycling	2.84	1.07

Table 1 above offers a detailed statistical overview of the adoption levels of various green manufacturing practices in the plastic industry of Ndola, Zambia. The Table reveals that 'Energy Conservation' and 'Environmental Effect Assessments' are the most widely adopted practices, with mean scores exceeding 4.0. This suggests a significant focus on energy efficiency and environmental scrutiny within the manufacturing processes. On the other hand, practices like 'Plastic Waste Collection' and 'Water Recycling' have lower mean scores of 2.53 and 2.84, respectively, indicating a less prevalent adoption.

6.3.1 Trends in Green Manufacturing Practices Adoption

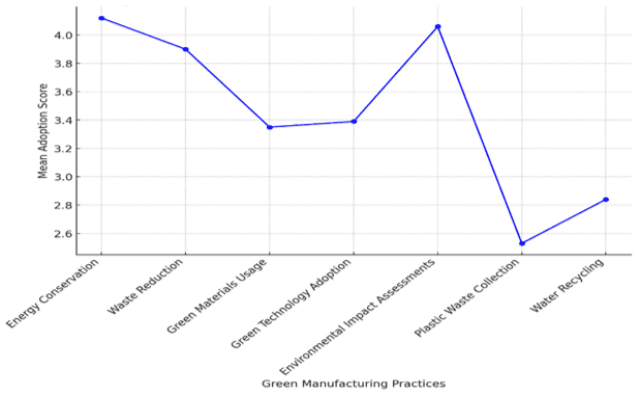


Figure 1 above visually represents the trend in the adoption of green manufacturing practices among plastic manufacturers in Ndola. The line graph clearly shows a higher adoption rate for internal practices like 'Energy Conservation' and 'Environmental Effect Assessments', with mean scores above 4.0.

This trend underscores the industry's prioritization of internal operational efficiencies and compliance with environmental regulations.

6.4 Analysis of Sustainability KPIs

The analysis of sustainability Key Performance Indicators (KPIs) in Ndola's plastic manufacturing sector shows that 'Stakeholder Safety and Health' is the most widely adopted KPI, with a near-universal mean score of 4.92, indicating strong adherence across companies. 'Regulatory Compliance' also ranks high, with a mean of 4.12, suggesting a focus on meeting legal requirements. However, other KPIs, such as 'Customer Complaints' (mean score of 3.01) and 'Energy/Water Efficiency' (3.06), show lower levels of monitoring, with more variability in their adoption. The high standard deviations, particularly for 'Economic Benefits' (1.36), point to inconsistent implementation of these KPIs among different companies, as the table below shows:

Table 2: Descriptive Statistics for Adoption of Sustainability KPIs

Sustainability KPI	Mean	Std. Deviation
Solid Waste Reduction	3.90	1.11
Carbon Footprint	3.25	0.79
Energy/Water Efficiency	3.06	1.43
Economic Benefits	3.12	1.36
Stakeholder safety and Health	4.92	0.28
Regulatory Compliance	4.12	0.74
Customer Complaints	3.01	1.29

An analysis of KPI adoption shown above reinforces these findings, highlighting a strong focus on internal measures like health and safety, which consistently scored in the 4 to 5 range. In contrast, KPIs related to external factors, such as customer feedback and resource efficiency, show more dispersed adoption patterns, with scores clustering around the average range. This reflects a broader trend observed in green manufacturing practices, where companies prioritize internal sustainability efforts but lag in addressing external or stakeholder-related concerns, indicating a need for a more balanced approach to sustainability.

6.5 Effect of Green Manufacturing on Sustainable Performance

The study explores the impact of green manufacturing practices on the sustainable performance of plastic companies, focusing on environmental, economic, and social dimensions.

The analysis reveals that green practices positively influence environmental performance, with initiatives like reducing negative environmental effects showing a strong correlation (0.63). Other areas, such as improving waste management (0.57) and reducing air pollution (0.52), also demonstrate meaningful correlations with sustainability efforts. A regression analysis shows that 35.6% of environmental performance variability can be attributed to green manufacturing practices, underscoring their significant role in enhancing eco-efficiency within the industry.

Table 3: Correlation Matrix for Environmental Sustainability

Environmental Performance Variables	Correlation with GM Practices
Reduced negative environmental effects	0.63
Better resource conservation	0.41
Improvement in waste management	0.57
Reduced air pollution	0.52
Reduced environmental compliance costs	0.44

Through the table above, the study also investigates the economic and social benefits of green manufacturing. Economically, reducing operational costs shows the strongest correlation (0.57), with increased revenue (0.53) and productivity (0.51) also tied to sustainable practices. A regression model suggests that these practices explain 41.2% of the variance in economic performance. Socially, enhancing employee knowledge shows the highest correlation (0.52) with social sustainability outcomes, while initiatives like improving supplier sustainability and community engagement also play key roles. Across all three dimensions—environmental, economic, and social—green manufacturing practices are shown to significantly contribute to the overall sustainability of plastic manufacturers, supporting a holistic approach to sustainability.

7. Discussion of Results

7.1 Interpreting Green Manufacturing Practices

The assessment of green manufacturing practices shows that companies in Zambia’s plastic industry have adopted inward-looking strategies such as process efficiency, waste minimization, and compliance monitoring.

Practices like energy optimization, which correlates strongly with sustainability metrics (0.63), and waste reduction demonstrate higher levels of adoption. However, external practices, such as supply chain coordination for recycling and eco-material procurement, are less prevalent, highlighting untapped potential for circular economy outcomes. Cross-tabulation analysis further reveals that professionals with higher education are more likely to adopt advanced, regulation-driven practices like energy optimization and environmental assessments, as supported by Kumar et al. (2022) and Mangla et al. (2022). This aligns with Dunphy's (2007) theory of corporate sustainability, where companies first address internal efficiencies before extending sustainability efforts to broader systemic changes.

The distinction between internal and external green practices has implications for profitability, environmental sustainability, and regulation compliance. Companies focusing on internal eco-efficiencies gain cost savings and meet regulatory demands, such as water use and fossil fuel reduction. However, broader circular economy initiatives remain underdeveloped due to the lack of external pressures, like reuse/recycle mandates or strong customer demand for sustainable products. This reflects the cost-sensitive nature of domestic markets and the absence of external incentives for product stewardship. The current reactive stance offers policy opportunities for national circular economy roadmaps, which could drive businesses towards product-service innovation through incentives and regulations, echoing the need for systemic solutions discussed by Chabowski (2020).

7.2 Sustainability Performance Indicators

The sustainability performance measurement framework in Zambia's plastic industry largely focuses on internal metrics, such as energy consumption, water usage, and regulatory compliance, with limited adoption of external measures like circular economy practices or closed-loop partnerships. Analysis shows a strong reliance on safety management and environmental control, particularly among professionals with higher education, who prioritize operational sustainability measures. However, the integration of external sustainability practices, essential for circular economy advancements, remains underdeveloped. This gap presents an opportunity to broaden sustainability education and policies.

Aligning with global standards, such as life-cycle thinking (Kumar et al., 2021) and circular economy guidelines, would enhance transparency and drive innovation, particularly as initiatives like the Africa Circular Economy Alliance gain traction (African Business Pages, 2023).

7.3 Effect of Green Manufacturing on Sustainability

The environmental implications of green manufacturing practices in Ndola's plastic industry demonstrate a significant positive impact on sustainability. Specific measures such as waste reduction, reuse, and recycling showed high correlations with improvements in conservation and emission control, with these green practices accounting for 35% of environmental performance improvements. These findings align with global research, including studies by Zhu et al. (2022), which highlighted the environmental benefits of waste management and recycling in various industries. While the data show the positive effects of internally focused practices like energy efficiency and compliance monitoring, external sustainability efforts—such as customer feedback and community engagement—remain underdeveloped. Expanding sustainability to include value chain-wide practices, such as material circularity, could further accelerate environmental performance.

Economically, the analysis reveals that green manufacturing positively influences financial outcomes such as revenue growth, productivity improvements, and cost reductions, with operational cost reduction showing the highest correlation (0.57). These findings support prior research, such as Mwanza and Mbohwa (2017), which documented productivity gains in green manufacturing. Socially, the assimilation of green practices correlates with enhanced employee welfare, safety, and knowledge development, with investments in employee training showing significant correlations with social sustainability indicators. However, similar to environmental outcomes, social sustainability in Ndola's plastic industry primarily focuses on internal improvements without extensive community or supply chain engagement. Expanding green practices to include external stakeholders could enhance social and economic benefits across the value chain.

8. Conclusions and Recommendation

The conclusion of the study highlights the significant role of green manufacturing practices in enhancing the economic, social, and environmental sustainability of plastic manufacturing companies in Ndola. The findings show that while internal sustainability measures like energy conservation and environmental audits are widely adopted, external interventions, such as partnerships for plastic waste retrieval, are less common. Educational levels of professionals play a role in the adoption of these practices, indicating that a more holistic approach to sustainability education is needed. The study also revealed a reactive, compliance-driven orientation among firms, with an emphasis on internal operations rather than broader, holistic environmental stewardship.

The study's second and third objectives focused on the key performance indicators (KPIs) used to track sustainability and the impact of green manufacturing on overall performance. The analysis found that companies prioritize internal safety, health, and regulatory metrics while giving minimal attention to external, stakeholder-focused parameters. Furthermore, green manufacturing practices were linked to improvements in environmental, economic, and social performance. However, companies are yet to fully capitalize on competitive advantages through product differentiation and strategic sustainability integration. The study recommends that Ndola's plastic industry adopt a more holistic approach to sustainability, expand external practices like waste collection, broaden KPIs to reflect stakeholder interests, and integrate sustainability into core business strategies for long-term resilience and success.

The study has notable limitations, including its reliance on cross-sectional data and a narrow focus on plastic manufacturing companies in Ndola, Copperbelt Province, which limits the generalizability of the findings to the broader industry or national level. Future research could improve reliability and validity by employing a longitudinal design and a larger, more representative sample.

Additionally, incorporating both qualitative and quantitative methods would provide a more comprehensive understanding of the relationship between green manufacturing practices and sustainable performance, offering richer insights beyond the current study's quantitative approach.

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