

EFFECT OF REMANUFACTURING ON PERFORMANCE OF PLASTIC MANUFACTURING FIRMS IN NAIROBI COUNTY, KENYA

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Abstract: *This paper investigates the effect of remanufacturing on the performance of plastic manufacturing firms in Nairobi County, Kenya. Using a cross-sectional survey of 27 firms, data were collected through structured interviews and document analysis in August 2023. Remanufacturing was operationalized as remanufacturing with no loss of identity, with loss of identity, and repetitive with no loss of identity. Performance was assessed across financial, operational and market dimensions. Data were analyzed using categorical regression (dummy-coded orthogonal transformation). Results show that firms with good remanufacturing practices recorded higher mean performance ($M = 71.59\%$) than firms with moderate ($M = 56.58\%$, $SD = 7.18$) and poor remanufacturing ($M = 50.25\%$, $SD = 12.77$). Categorical regression found a significant effect of remanufacturing on performance ($F(2,18) = 5.801$, $p = .011$), with remanufacturing accounting for up to 32.4% of performance variance ($R^2_{adj} = .324$). The predictive model is $P_i = 56.581 + 15.013 \text{ RM-G} + \epsilon$. The study concludes that remanufacturing is a significant driver of performance for Nairobi's plastic manufacturers and recommends targeted investments in remanufacturing processes and policy support to scale adoption.*

Keywords: *Remanufacturing, Reverse Logistics, Firm Performance, Plastic Manufacturing, Nairobi County, Resource-Based View*

1. Introduction

Manufacturing industries worldwide are under increasing pressure to improve resource efficiency, reduce environmental impact, and adopt circular economy practices. One reverse logistics practice that addresses these pressures is remanufacturing — the process of restoring used products or components to like-new condition so they can be reintroduced into production and the market. Remanufacturing can conserve raw materials, reduce energy consumption, and lower production costs while preserving product quality (Eltayeb et al., 2010; Statham, 2006).

The Kenyan plastic manufacturing sector contributes substantially to the national economy but faces high raw material costs and environmental regulation pressures (KAM, 2016). Within this context, remanufacturing offers a potential pathway for firms to improve operational resilience and competitiveness. The Resource-Based View (RBV) suggests remanufacturing can become a valuable, rare, and inimitable capability—

transforming waste streams into productive inputs and thus improving firm performance (Wernerfelt, 1984; Barney, 1991). Institutional pressures (regulations, norms) further motivate adoption (Scott, 2001).

Despite its theoretical promise, empirical evidence on remanufacturing's impact on performance in Kenya's plastics sector is limited. This study fills that gap by empirically testing whether remanufacturing has a measurable effect on firm performance among plastic manufacturers in Nairobi County.

In addition to the global and national importance of sustainable manufacturing highlighted earlier, remanufacturing has emerged as one of the most strategic components of circular economy implementation worldwide. The transition from linear to circular models has positioned remanufacturing as a critical pathway for resource recovery, industrial efficiency, and low-carbon production (Bocken, De Pauw, Bakker, & van der Grinten, 2016). Remanufacturing, unlike recycling, retains a significant portion of a product's added value by restoring used components to like-new quality using standardized industrial processes. This enables firms to maximize resource utility while minimizing environmental impact, making it a central strategy for plastic manufacturers facing intense competition and rising input costs.

Globally, the remanufacturing market has expanded significantly. The United States remanufacturing industry, for example, is valued at over USD 43 billion annually, spanning automotive, electronics, and industrial machinery sectors (U.S. International Trade Commission, 2012). Similar growth is observed in the European Union, which has integrated remanufacturing into its Circular Economy Action Plan, citing its potential to conserve raw materials, reduce greenhouse gas emissions, and stimulate green job creation. However, the adoption of remanufacturing in Africa, including Kenya, remains comparatively low due to technological limitations, inadequate policy frameworks, and lack of awareness among manufacturers.

For plastic manufacturing firms specifically, remanufacturing presents opportunities to mitigate challenges such as high resin costs, unreliable supply of virgin raw materials, and increasing pressure from environmental regulators. Plastics used in packaging, construction, consumer goods, and industrial applications often have components that can be remanufactured through processes that maintain or enhance original performance. The growth of Kenya's Extended Producer Responsibility (EPR) framework under the 2021 Sustainable Waste Management Act further encourages firms to adopt remanufacturing as part of product recovery obligations. As such, remanufacturing has the potential to reduce production costs, extend product lifecycles, stabilize supply chains, and strengthen compliance with sustainability regulations.

The theoretical underpinnings of remanufacturing reinforce its strategic relevance. The Resource-Based View (RBV) highlights that firms achieve superior performance by leveraging unique capabilities and resources—including waste streams that can be transformed into high-value inputs. Remanufacturing fits this logic by enabling firms to reduce reliance on external suppliers while generating internal efficiencies. The Natural Resource-Based View (NRBV) further extends the RBV to emphasize capabilities that generate environmental and economic benefits simultaneously (Hart, 1995). Under NRBV, remanufacturing serves as a pollution-prevention, product stewardship, and sustainable development capability, all of which contribute to long-term performance gains.

In addition, Institutional Theory suggests that environmental regulations, industry norms, and consumer expectations increasingly require firms to adopt sustainable practices. Kenya's plastic manufacturers face institutional pressures from NEMA regulations, county waste management bylaws, and international sustainability benchmarks. These pressures create an environment in which remanufacturing is not only

advantageous but also strategically necessary for legitimacy, compliance, and access to environmentally sensitive markets.

Despite these theoretical and practical benefits, empirical research linking remanufacturing to firm performance in Kenya's plastic manufacturing sector remains scarce. Most existing studies focus on recycling or general sustainability practices, leaving a gap in understanding the unique contribution of remanufacturing. Given the sector's heavy reliance on petroleum-based inputs and its exposure to volatile global markets, understanding how remanufacturing affects performance is both timely and essential.

This study therefore expands the knowledge frontier by empirically analyzing the effect of remanufacturing on the performance of plastic manufacturing firms in Nairobi County, incorporating financial, operational, and market performance dimensions. The expanded scope provides insights that are academically valuable and practically relevant for managers, policymakers, and sustainability practitioners.

2. Methodology

2.1 Research design and sample

A cross-sectional survey design was employed. The sampling frame consisted of registered plastic manufacturing firms in Nairobi County; 27 firms were targeted and data were collected through structured interviews and document analysis in August 2023. The final analytic sample used for the categorical regression was $N = 21$ firms for which complete performance and remanufacturing data were available.

2.2 Measures and operationalization

Remanufacturing (independent variable): Operationalized using three sub-indicators — remanufacturing with no loss of identity, remanufacturing with loss of identity, and repetitive remanufacturing with no loss of identity. Respondents answered Likert-type items; summed scores were categorized into Good, Moderate, and Poor remanufacturing status, then dummy-coded using orthogonal coding (Good = 1/not-good = 0; Poor = 1/not-poor = 0; Moderate used as the base category).

2.3 Analysis

Descriptive statistics summarized remanufacturing status and mean performance by category. Inferential analysis used categorical regression (dummy coding with orthogonal transformation) to test whether remanufacturing categories significantly predict firm performance. All regression assumptions (linearity, absence of multicollinearity, normality of residuals, homoscedasticity) were checked and satisfied. Significance was assessed at $\alpha = .05$.

3. Results

The objective of this study was to determine the effect of remanufacturing on performance of plastic manufacturing firms in Nairobi County. Remanufacturing was measured from with no loss of identity, with loss of identity and repetitive with no loss of identity. Respondents reacted to statements on these variables and their responses are summarized in sections 3.1 and 3.2.

3.1 Descriptive results

Respondents were asked to respond to 7 statements on remanufacturing. The statements were used to determine the status of remanufacturing in plastics manufacturing firms in Nairobi County. The responses are summarized in Table 1.

Table 1: Summary of Responses on Remanufacturing in Plastic Manufacturing Firms in Nairobi County

	Yes		No		Not Sure		0%-24%		25%-49%		50%-74%		75%-100%		0%-20%		21%-40%		41%-60%		61%-80%		81%-100%		Mean	Std. v.
	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	F	%	f	%	f	%		
Company engages in remanufacturing	19	90.5%	2	9.5%	0	0.0%																			2.81	.602
Proportion of goods remanufactured							3	14.3%	3	14.3%	5	23.8%	10	47.6%											3.05	1.12
Remanufacturing approaches	1		2		3																				1.57	.811
	13	61.9%	4	19.0%	4	19.0%																				
With no loss of identity													1	4.8%	2	9.5%	2	9.5%	5	23.8%	1	5.2%	1	5.2%	4.09	1.22
With loss of identity													3	14.3%	8	38.1%	5	23.8%	3	14.3%	2	9.5%			2.67	1.19
Repetitive with no loss of identity													3	14.3%	4	19.0%	3	14.3%	3	14.3%	8	38.1%			3.43	1.54
Remanufacturing is a successful strategy in the company	20	95.2%	1	4.8%	0	0.0%																			2.90	.436
Total																									2.93	.988

Source: Researcher, Field Data, 2025.

Table 1 summarizes descriptive statistics on responses on the 7 statements on remanufacturing in plastic manufacturing firms in Nairobi County. When asked on whether company engages in remanufacturing, a majority of the respondents (90.5%) agreed that that the company engages in remanufacturing. And when asked whether remanufacturing is a successful strategy in the company, a larger majority (95.2%) responded in the affirmative. Therefore most plastic manufacturing firms engage in remanufacturing and they benefit from it. On the proportion of goods remanufactured, most companies (47.6%) remanufacture at least 75% of the products they produce. In fact, only 28.6% of the companies remanufacture less than 49.0% of their products. The rest 71.4% of all products of plastics manufacturing companies are remanufactured. However, a majority of the firms (61.9%) rely on just one method of remanufacturing. This suggests low adoption of remanufacturing by technology in the firms. The most popular remanufacturing method is the remanufacturing with no loss of identity which 52.4% of the firms use between 81%-100%. The second popular method of remanufacturing is remanufacturing repetitive with no loss of identity which 38.1% of the firms use 81%-100%. The least popular remanufacturing method is remanufacturing with loss of identity which 38.1% of the firms use only 21%-40%. Overall, remanufacturing attained a performance of 2.93 ($SD = .988$). Therefore the status of remanufacturing is only average in the plastic manufacturing firms in Nairobi County.

3.2 Inferential Analysis

The plastic manufacturing firms were grouped into good, moderate and poor based on the status of remanufacturing by the firm. The mean performance of plastic manufacturing firms in each category was then

determined. The performances of plastic manufacturing firms with good, moderate and poor remanufacturing are summarized in Table 2.

Table 2: Performances of Plastic Manufacturing Firms against Remanufacturing

Remanufacturing	Mean Performance	N	N-Percent	SD
Poor	50.25%	11	52.4%	12.77
Moderate	56.58%	9	42.8%	7.175
Good	71.59%	1	4.8%	-
Total	64.14%	21	100.0%	12.96

Source: Researcher, Field Data, 2025.

Table 2 shows the variation in performance of plastic manufacturing firms with the status of remanufacturing. The table shows a general increase in mean performance from plastic manufacturing firms with poor remanufacturing to plastic manufacturing firms with good remanufacturing. Plastic manufacturing firms with good remanufacturing have a higher performance ($M = 71.59\%$), than plastic manufacturing firms with moderate remanufacturing ($M = 56.58\%$, $SD = 7.175$) and plastic manufacturing firms with poor at remanufacturing, $M = 50.25\%$, $SD = 12.770$. a majority of plastic manufacturing firms (52.4%) surveyed had poor remanufacturing. Only 4.8% of the plastic manufacturing firms surveyed had good remanufacturing. The study established that plastic manufacturing firms in Nairobi County are generally poor at remanufacturing. The data in Table 2 suggest that performance of plastic manufacturing firms vary with remanufacturing and that good remanufacturing is associated with high performance and vice-versa.

The data in Table 2 was tested using simple linear categorical regression (with orthogonal transformation) to determine if remanufacturing had a significant effect on performance of plastic manufacturing firms in Nairobi County. The study tested the null hypothesis that:

There is no significant difference in the performance of plastic manufacturing firms in Nairobi Country with good, moderate and poor remanufacturing.

$$H_{01}: R_{P*RM-G, RM-P} = 0$$

$$H_{a1}: R_{P*RM-G, RM-P} \neq 0$$

where P = performance, RM-G = remanufacturing (good), RM-P = remanufacturing (poor). The results of regression analysis with categorical predictors summarized in Table 3 were obtained.

Table 3: Summary of Categorical Regression of Performance on Remanufacturing in Plastic Manufacturing Firms in Nairobi County

Variable	B	R	R ²	R ² _{adj.}	Std. ϵ	t	Sig.	F
Constant	56.581				3.553	15.924	.000	
RM-P	-.6331				11.236	-.563	.580	
RM-G	15.013				3.134	3.134	.006	
Model Summary		.626	.392	.324	10.659		.011	5.801

Note. RM-G = remanufacturing (good), RM-P = remanufacturing (poor).

Table 3 presents categorical regression results of performance of plastic manufacturing firms in Nairobi County on remanufacturing. Analysis of the F -statistic shows that there is a significant regression effect. There is a significant difference in the performance of plastic manufacturing firms in Nairobi County with good, moderate and poor remanufacturing, $F(2, 18) = 5.801, p = .011$. Hence a regression model exists and at least one of the predictor dummy variables is a significant predictor of performance in the model. Analysis of the t statistics shows that RM-G is a significant predictor of performance in the model [$t(18) = 3.134, p = .006$], but RM-P is not, $t(18) = -.563, p = .580$. The general model for predicting performance from remanufacturing is depicted in Equation 1.

$$P^1 = 56.581 + 15.013 \text{ RM-G} + \varepsilon \dots (1)$$

where P^1 is the predicted performance and RM-G is good remanufacturing .

The model in Equation 1 indicates that if remanufacturing changes by 15.013 units, the performance of the firm changes by one (1) unit, other factors remaining constant. For a unit change in performance of a plastic manufacturing firm, 15.013 units of good remanufacturing are required, other factors being constant. The performances of plastic manufacturing firms with good remanufacturing are 15.013 units above the performances of plastic manufacturing firms with moderate remanufacturing. In the overall analysis, remanufacturing accounts for up to 32.4% of the variance in the performance of a plastic manufacturing firm, if other factors remained constant, $R^2 \text{ adj.} = .324, p = .011$. The study therefore established that remanufacturing has a positive effect on performance of plastic manufacturing firms of up to 32.4%. The null hypothesis was rejected.

The finding that remanufacturing has a positive effect on performance of plastic manufacturing firms can be understood from the various advantages of remanufacturing. This is because, as Eltayeb et al. (2010) point out, remanufacturing is a way to improve operational performance and recapture the value that would have been lost. In further, as Statham (2006) also points out, remanufacturing saves the cost of acquiring materials as well as other costs associated with energy such as electricity costs by preserving about 85% or more of the original energy and materials. Remanufacturing also leads to beneficial effects through improving design and functionality and product quality. In any case, as Salim (2006) points out, it is easier to remanufacture than to produce from scratch. These benefits makes the finding that remanufacturing has a positive effect on performance of plastic manufacturing firms direct to understand. It also explains why remanufacturing has remained an important domain of manufacturing industry.

The positive effect can also be understood from the capacity of manufacturing to protect shortage of resources and protect the environment (Yenipazarli, 2016), and as a strategy for closing the loop by enhancing resource efficiency, through reuse of components and products, as input materials (Deng et al., 2017). Many studies have confirmed this outcome. Regardless of the type of remanufacturing, remanufacturing is cost-effective and promotes sustainability due to the repurposing of parts and components. For example, the finding supports the positions of Liu et al. (2022) who found that the optimal decisions of the two models vary with the proportion of new products' production cost and remanufactured products' production cost, but the government subsidy for process innovation does not necessarily improve the profits of the manufacturer, the retailer, and the supply chain system. They concluded that government subsidy for process innovation does improve overall social welfare and has a lesser environmental impact. Improvement of overall social welfare and lesser environmental impact are aspects of improved performance.

The finding also agrees with the findings of Lv et al. (2021) who studied the impact of remanufactured products' similarity on purchase intention of new products. Lv et al. (2021) found that the similarity of remanufactured products has a significant negative impact on the purchase intention of new products, and that the perceived quality of new products plays a partial mediating role between similarity and purchase intention. The findings also supports the findings of Ferrer and Ayres (2000) who investigated the impact of remanufacturing in the economy and found that remanufacturing sectors substitute labor and transport services for the usual inputs, and that remanufacturing may satisfy the same final demand from all sectors requiring fewer intermediate resources. These are aspects of improved performance.

The researcher concurs with Salah et al. (2021) that remanufacturing is still evolving and is still relatively poorly understood. They focused on the remanufacturing systems' definition, relevance, main phases, case studies, and solution methods proposed by various researchers. Based on bibliometric systematic methods, Salah et al. (2021) found that researchers focused on some phases more as compared with others, and that common solutions methods applied in this domain are optimization techniques.

4. Discussion

4.1 Main findings and interpretation

The study found that good remanufacturing practices significantly improve firm performance among Nairobi's plastic manufacturers. Firms classified as having good remanufacturing scored, on average, ~15.0 percentage points higher in the performance index than firms with moderate remanufacturing (coefficient = 15.013). The model ($P_1 = 56.581 + 15.013 \text{ RM-G}$) implies that adopting and institutionalizing "good" remanufacturing practices is associated with a meaningful uplift in performance. Overall, remanufacturing accounted for 32.4% of the explained variance in performance, a substantively important effect in the manufacturing context.

These results align with theoretical expectations from RBV: remanufacturing allows firms to convert waste and returned products into productive assets, reducing input costs and increasing operational flexibility (Wernerfelt, 1984; Barney, 1991). Empirically, the findings are consistent with literature that links remanufacturing to operational efficiency gains, energy savings, and value recovery (Statham, 2006; Eltayeb et al., 2010). The thesis's discussion further explains these mechanisms, noting energy and material savings as drivers of improved performance.

4.2 Practical implications

1. Managerial: Firms should treat remanufacturing as a strategic capability — invest in processes, worker training, quality assurance, and redesign for remanufacturability. Even incremental improvements toward "good" remanufacturing practices have measurable payoffs.
2. Technological: Given that most firms rely on limited remanufacturing approaches and a majority use one method only, targeted investments in remanufacturing technologies and modular design can increase throughput and product quality.
3. Policy: Government incentives (capital grants, tax breaks, favorable energy tariffs) and policies encouraging product take-back and supplier collaboration could accelerate adoption, improving national circularity and industrial competitiveness.

4.3 Relation to other reverse logistics elements

While remanufacturing alone explains a substantial share of performance variance, the thesis also reports that, when combined with other reverse logistics practices (recycling, repackaging, product recall), the overall model explains up to 57.7% of performance variance (multiple regression), with recycling and product recall also emerging as significant predictors in that multiple model (see thesis). This suggests remanufacturing works best as part of an integrated reverse logistics strategy.

4.4 Deeper Interpretation and Global Comparison

The finding that firms with good remanufacturing practices achieve higher performance aligns with studies in Europe and Asia demonstrating cost savings of up to 40–60% compared to manufacturing new products (Ijomah, Danis, & Bennet, 2014). In plastic-intensive industries such as consumer goods and automotive manufacturing, remanufacturing has been linked to improvements in product reliability, raw material stability, and operational efficiency. These advantages resonate with the Kenyan context, where firms face high import costs of virgin polymer materials and fluctuating global oil prices.

Similar studies in China and India have established that remanufacturing significantly enhances competitive advantage by increasing access to low-cost inputs and stabilizing supply chains (Wang & Che, 2018). In South Africa, remanufacturing in the plastics and automotive sectors has been associated with reduced carbon emissions and improved corporate reputation, further strengthening market performance. The findings in Nairobi County therefore reflect a global trend where remanufacturing contributes to sustainability and strategic differentiation.

4.5 Implications within Circular Economy Transitions

As Kenya gradually moves toward circular economy frameworks, remanufacturing serves as a major enabler of closed-loop systems. Unlike recycling, which breaks down products into raw materials, remanufacturing retains much of the embedded energy and labor—yielding greater environmental and economic efficiency. Studies by Körner & Matsumoto (2019) show that remanufacturing generates higher resource productivity per unit of input compared to recycling or disposal.

In Nairobi’s plastic manufacturing sector, where waste collection and sorting systems are still developing, remanufacturing offers a practical intermediate solution that leverages internal production waste streams before waste reaches the consumer. Firms can therefore move toward circularity even without fully developed national waste infrastructure.

4.6 Expanded Theoretical Implications

Under the Natural Resource-Based View (NRBV), remanufacturing enhances firm performance through three core capabilities:

1. **Pollution Prevention:** Reduces waste sent to landfills and minimizes emissions from virgin material production.
2. **Product Stewardship:** Encourages better product design, material selection, and lifecycle management.
3. **Sustainable Development:** Positions firms to respond to long-term environmental constraints and regulatory pressures.

These capabilities give firms strategic advantage by lowering operational costs, enhancing regulatory compliance, and improving market positioning. The Nairobi findings support NRBV by demonstrating measurable performance improvements stemming from remanufacturing efforts.

Institutional pressures further shape the adoption of remanufacturing. Kenya's EPR regulations, increased consumer demand for eco-friendly products, and international market requirements (e.g., ISO 14001 certification) push firms toward remanufacturing as a compliance and legitimacy strategy. Thus, remanufacturing's effect on performance is both capability-driven (RBV/NRBV) and institutionally reinforced.

5. Conclusion

Remanufacturing has a statistically significant and practically meaningful positive effect on the performance of plastic manufacturing firms in Nairobi County. Firms classified as practicing good remanufacturing outperform those with moderate or poor practices; remanufacturing explains approximately 32.4% of the variance in performance in the simple categorical model. Policymakers and managers should therefore prioritize remanufacturing as part of circular economy strategies to boost firm competitiveness and sustainability.

Limitations and directions for future research

Sample size and scope: The sample is modest (n=27 firms; analytic n=21) and limited to Nairobi County. Future research should expand geographically and increase sample size to improve generalizability.

Cross-sectional design: Causality cannot be strictly inferred. Longitudinal studies could track performance before and after remanufacturing investments.

Depth of remanufacturing measures: The "good/moderate/poor" categories are helpful but future studies could measure remanufacturing intensity, technologies used, and cost savings in monetary terms.

Interaction effects: Future research could examine interactions between remanufacturing and other reverse logistics practices to identify complementarities.

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