

Effect of Waste Valorization Innovation on the Sustainability of Solid Waste Social Enterprises in Nairobi City County

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ABSTRACT

Solid waste social enterprises (SWSEs) through their innovative skills are striving to turn waste into value, yet empirical evidence on whether waste valorization innovation contributes to the sustainability of these enterprises in African cities remains limited. This study examined the effect of waste valorization innovation on the economic, environmental and social sustainability of SWSEs in Nairobi City County, Kenya, and tested whether the regulatory framework moderates that effect. A quantitative, cross-sectional explanatory design was used. Structured questionnaires were administered to founders, managers, supervisors and technical staff of 30 formally registered SWSEs, yielding 108 usable responses from 120 targeted (response rate 90%; Cronbach's alpha = .808). Data were analyzed using descriptive statistics, Pearson correlation, multiple regression and hierarchical regression. Waste valorization innovation was weakly adopted (item means 1.81 to 2.34 on a five-point scale) and correlated weakly and non-significantly with sustainability ($r = .172$, $p = .076$). Controlling for green product design and eco-friendly packaging, it was a significant positive predictor of sustainability ($\beta = .212$, $p = .028$), but the effect fell just short of significance once the regulatory framework was added to the model ($\beta = .183$, $p = .061$). The Waste Valorization and Regulatory Framework interaction was not significant ($B = .063$, $p = .747$), so no moderation was established. The study concludes that waste valorization innovation has a positive but statistically unconfirmed association with SWSE sustainability, constrained by low adoption. It recommends targeted incentives for resource-recovery technology, public-private partnerships that secure waste streams and markets, and capacity building for SWSEs.

Keywords: Waste valorization, solid waste social enterprises, sustainability, circular economy, Nairobi City County

INTRODUCTION

Rapidly changing consumption patterns have pushed global solid waste generation beyond two billion tonnes a year, and much of it in low- and middle-income countries is still dumped or burned (Sharma & Jain, 2020). Open dumping and burning release greenhouse gases, contaminate soil and water through leachate, and expose the poorest urban residents to disease (Abubakar et al., 2022). Policy and scholarship now favour innovation-led waste management built on reduction, reuse, recycling and resource recovery, and they link these practices to several Sustainable Development Goals (Awino & Apitz, 2024; Monfared et al., 2025).

Sub-Saharan African cities are where the gap between waste generation and effective management is widest. Collection is inadequate, recycling infrastructure is thin, and modern waste and circular economy policies

are weakly implemented because of limited finance, fragmented institutions and policies that are poorly adapted to local conditions (Abubakar et al., 2022; Muheirwe et al., 2022; Muriithi & Ngare, 2023). Nairobi City County largely experiences the problem. Large volumes of waste remain uncollected, especially in informal settlements, and the Dandora dumpsite continues to operate despite being declared full long ago. Organic material makes up a substantial share of the county's waste stream, which makes recovery through composting and conversion into useful products both feasible and urgent (Chamdimba et al., 2021).

Solid waste social enterprises (SWSEs) have emerged within this gap. They combine commercial activity with social and environmental missions, integrate informal waste pickers into recycling value chains, and transform waste into marketable products (Adu-sei-Gyamfi et al., 2022; Ahen & Amankwah-Amoah,

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2021). Among the innovations open to them, waste valorization, defined here as the transformation of waste into reusable materials, compost, energy, nutrients or other valuable outputs, is the most direct expression of the circular economy. It should in principle reduce landfill dependence, create new revenue streams and generate green jobs.

Whether it does so for SWSEs in African cities has seldom been tested quantitatively. Most evidence on valorization comes from Asia, Europe and North America and from engineering, life-cycle and techno-economic studies rather than from enterprise-level performance data (Arias et al., 2025; Park et al., 2025). Evidence on how regulation shapes the link between innovation and sustainability is also narrow for Kenya, even though the Sustainable Waste Management Act (2022) and the Extended Producer Responsibility Regulations (2024) are intended to support recovery.

This article addresses that gap. Its objective is to determine the effect of waste valorization innovation on the sustainability of SWSEs in Nairobi City County, and to establish whether the regulatory framework moderates that effect. It tests two hypotheses:

H01: Waste valorization innovation has no significant effect on the sustainability of solid waste social enterprises in Nairobi City County.

H02: The regulatory framework does not significantly moderate the relationship between waste valorization innovation and the sustainability of solid waste social enterprises in Nairobi City County.

The article contributes social enterprise-level quantitative evidence from an African urban setting, shows to what extent SWSEs have actually adopted valorization practices, and shows how the estimated effect behaves when other product innovations and the regulatory environment are controlled.

2. Literature Review and Theoretical Framework

2.1 Theoretical framework

Three theories explain why valorization might affect sustainability and why that effect might depend on context. Resource-Based Theory holds that solid waste social enterprises gain lasting advantage from valuable, rare and hard-to-imitate resources and capabilities (Barney, 1991; Wernerfelt, 1984). For SWSEs, the ability to transform waste into marketable outputs is such a capability, but it pays off only when

it is deployed effectively. Ecological Modernization Theory argues that technological innovation, institutional reform and market change can reconcile economic development with environmental advancement (Mol & Spaargaren, 2000). Recovery systems that turn waste into materials, compost or energy are a core mechanism in that account. Institutional Theory explains how laws, norms and expectations shape organizational behaviour and legitimacy (DiMaggio & Powell, 1983), and it motivates the regulatory framework as a moderator: supportive and enforceable regulation may strengthen the sustainability returns to innovation (Jiatong et al., 2021).

2.2 Waste valorization and environmental sustainability

The literature integrates valorization to four environmental benefits. First, it diverts waste from landfill. Studies in Taiwan, Egypt, India and China report that collaborative recovery networks, well-allocated treatment routes and the diversion of recyclables and compostables reduce environmental burdens and dependence on final disposal (Abdallah et al., 2024; Chen et al., 2024; Mazzoli et al., 2024; Wu et al., 2021). Second, it mitigates greenhouse gas emissions; life-cycle studies in Algeria, Indonesia and China show lower climate impacts from recycling, energy recovery and better source separation than from dumping or landfilling (Cheniti et al., 2024; Gu et al., 2023; Liem et al., 2024). Third, it keeps materials in use longer, as closed-loop recycling of wool, glass, food waste and agricultural residues demonstrates (Glasper et al., 2024; Senga et al., 2024; Siddique et al., 2025; Yuan et al., 2024). Fourth, recovery potential depends on technology, transport, treatment allocation and the existence of output markets, not on the technology alone (Arias et al., 2025; Park et al., 2025).

The Kenyan evidence is cautionary. Weak sorting systems, limited incentives and low awareness slow circular waste practices even where recovery routes exist (Ishuga et al., 2024).

2.3 Waste valorization, economic and social sustainability

Valorization plays a critical role in enhancing economic viability. Recycling is associated with improved financial performance, while waste generation is associated with worse (Gull et al., 2022). Eco-innovation lowers waste intensity and strengthens reuse

and recycling (Albitar et al., 2024). In Ghana, upcycling and waste recovery were found to strengthen sustainability outcomes and financial stability in waste-sector firms (Agyapong et al., 2025). Socially, SWSEs create green jobs and bring informal waste pickers into recovery value chains (Adusei-Gyamfi et al., 2022; Ahen & Amankwah-Amoah, 2021). Innovation capability more generally has been related to environmental and financial performance (Farooq et al., 2022; Wandosell et al., 2021).

2.4 Research gap and conceptual expectation

Three gaps follow. Most evidence comes from outside Africa and from technical assessments rather than solid waste social enterprise performance data. Studies seldom treat sustainability as an integrated economic, environmental and social outcome. And the moderating role of the regulatory framework for SWSEs in Nairobi remains largely untested. The framework adopted here therefore treats waste valorization innovation as the independent variable, SWSE sustainability as the dependent variable, and the regulatory framework as a moderator. Green product design and eco-friendly packaging comes as control innovations, so that the estimate for valorization is not confounded by other product innovations.

METHODOLOGY

3.1 Research design and study area

The study used a quantitative, cross-sectional explanatory design, which suits the testing of hypothesized relationships among measurable variables (Maier et al., 2023; Slater & Hasson, 2025). Nairobi City County was chosen because it is Kenya's largest urban centre, faces acute solid waste pressure, has a high organic share in its waste stream, and hosts many solid waste social enterprises engaged in recovery and circular economy activity (Chamdimba et al., 2021; Muriithi & Ngare, 2023).

3.2 Population and sampling

The sampling frame comprised 30 formally registered SWSEs in Nairobi City County that had operated for at least one year and were engaged in product innovation such as recycling, upcycling, product redesign or eco-friendly packaging. The list was compiled from official registration records and a county waste management database validated by the National Environment Management Authority (NEMA). A census of

all 30 solid waste social enterprises was taken. Four key informants per social enterprise (the founder, a manager, a supervisor and a technical staff member) were purposively selected for their direct involvement in decision-making and operations (Van Quaquebeke et al., 2022), giving 120 targeted respondents. In total, 108 usable questionnaires were returned, a 90% response rate.

3.3 Instrument, validity and reliability

Data were collected with a structured, self-administered questionnaire using closed-ended items on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree) (Cheung, 2021). Waste valorization innovation was measured by four items covering the transformation of waste into high-value products or inputs, the integration of recycling into product development, the reuse of waste as primary production input, and the development of technologies to recover energy or nutrients. Sustainability was measured through the triple bottom line, with one item each for economic, environmental, social and operational performance. The regulatory framework was measured by four items on government incentives, compliance and legitimacy, public-private partnerships, and enforcement by NEMA. Green product design and eco-friendly packaging innovation, four items each, served as controls.

Content validity was assessed through expert review, construct validity through exploratory factor analysis, and internal consistency through Cronbach's alpha, interpreted alongside other validity evidence (Cho, 2023). A pilot with 16 participants from 8 SWSEs, excluded from the main sample, informed revisions to unclear items. Internal consistency for the full 20-item instrument was acceptable ($\alpha = .808$).

3.4 Data collection and ethics

Fieldwork ran for about eight weeks. Questionnaires were administered on paper and online through KoboToolbox. Ethical clearance was obtained from Tangaza University and a research permit from the National Commission for Science, Technology and Innovation (NACOSTI). Participation was voluntary, informed consent was obtained, and responses were anonymized and stored securely, consistent with the Declaration of Helsinki (World Medical Association, 2024).

3.5 Data analysis

Data were screened for completeness and entry errors (Kotronoulas et al., 2023) and analyzed in SPSS. Skewness and kurtosis fell within accepted limits of ± 2 and ± 7 (Hair et al., 2019; Kline, 2011); for waste valorization they were 1.042 and 0.315. Descriptive statistics (frequencies, percentages, means) summarized adoption. Pearson correlation assessed bivariate association. Multiple regression estimated the effect of waste valorization on sustainability, first with green product design and eco-friendly packaging as controls (Model 1) and then with the regulatory framework added (Model 2). Hierarchical regression with interaction terms tested moderation (Model 3), following Baron and Kenny (1986) and Aiken and West (1991). The significance threshold was $p < .05$. The full specification, with WV = waste valorization, GPD = green product design, EPI = eco-friendly packaging innovation, RF = regulatory framework and S = sustainability, was:

$$S = \beta_0 + \beta_1 WV + \beta_2 GPD + \beta_3 EPI + \beta_4 RF + \beta_5 (WV \times RF) + \beta_6 (GPD \times RF) + \beta_7 (EPI \times RF) + \varepsilon$$

RESULTS AND DISCUSSION

4.1 Response rate and respondent profile

Of 120 questionnaires distributed, 108 were returned and usable (90%), well above the 70% commonly regarded as very good for survey analysis. Respondents were 60.2% male and 39.8% female. Most (69.4%) had more than six years of sector experience, and 66.7% held a bachelor's degree. 51.9% of respondents worked in solid waste social enterprises with fewer than five employees. Waste collection was the primary activity for 69.4% of respondents, followed by upcycling (23.1%), recycling (3.7%), composting (1.9%) and e-waste management (1.9%). Only about three in ten respondents therefore worked in activities that transform waste into new outputs.

4.2 Extent of waste valorization innovation

Adoption of waste valorization was low on every indicator (Table 1). Item means ranged from 1.81 to 2.34, and the average of the four item means was 2.16, below the scale midpoint of 3. Between 73% and 86% of respondents disagreed with each statement. Technology for recovering energy or nutrients was the least developed in terms of disagreement (86.1%), and reuse of waste as primary production input had the

lowest mean (1.81). Responses on the reuse item were polarized: 65.7% strongly disagreed while 12.0% strongly agreed, which suggests that a small group of solid waste social enterprises has built reuse into production while most have not.

Table 1: Adoption of Waste Valorization Innovation (N = 108)

Statement Disagree (SD + D), % Undecided, % Agree (A + SA), % Mean

We successfully transform waste streams into high-value products or inputs 83.3 8.3 8.3 2.23

Recycling processes are fully integrated into our product development cycle 73.1 19.4 7.4 2.34

We reuse waste materials as primary production inputs to reduce landfill reliance 78.7 8.3 13.0 1.81

Our enterprise has developed specific technologies to recover energy or nutrients from waste 86.1 4.6 9.3 2.26

Source: Field data (2026). Percentages computed from response counts; scale 1 = strongly disagree to 5 = strongly agree.

4.3 Sustainability performance

Sustainability ratings were uneven. Operational efficiency ($M = 4.72$) and social contribution through green jobs and community wellbeing ($M = 4.34$) were rated very high, whereas environmental performance ($M = 2.36$) and economic performance ($M = 2.25$) were rated low. Respondents did not generally agree that their operations had significantly reduced waste and pollution (69.4% disagreed) or that product innovation had produced stable revenue and growth (62.0% disagreed).

4.4 Effect of waste valorization innovation on sustainability

Waste valorization had a weak, positive and statistically non-significant bivariate correlation with sustainability ($r = .172$, $p = .076$). Regression gave a fuller picture (Table 2). With green product design and eco-friendly packaging controlled (Model 1), waste valorization was a significant positive predictor ($B = 0.233$, $\beta = .212$, $t(104) = 2.222$, $p = .028$), and the model was significant, $F(3, 104) = 3.472$, $p = .019$, $R^2 = .091$. When the regulatory framework was added (Model 2), the coefficient fell to $B = 0.201$ ($\beta = .183$, $t(103) = 1.895$, $p = .061$); the model remained

significant, $F(4, 103) = 3.322$, $p = .013$, $R^2 = .114$. In Model 2, green product design ($\beta = .327$, $p = .004$) was the only significant predictor.

Table 2: Regression of Sustainability on Waste Valorization Innovation (N = 108)

Model Predictors entered R^2 Model F (df), p B (SE) β t p 95% CI for B

1 WV, GPD, EPI .091 3.472 (3, 104), .019 0.233 (0.105) .212 2.222 .028 0.025 to 0.441

2 Model 1 + RF .114 3.322 (4, 103), .013 0.201 (0.106) .183 1.895 .061 -0.009 to 0.411

Note: B, SE, β , t and p refer to waste valorization (WV). GPD = green product design; EPI = eco-friendly packaging innovation; RF = regulatory framework. Confidence intervals were computed from the reported B and SE. Dependent variable: sustainability of SWSEs. Source: Survey data (2026).

Because the final model does not reach significance at the 5% level, H01 is not rejected. The evidence is better described as borderline than as absent: the estimates in the two models are close in size, and the 95% interval in Model 2 only just includes zero.

4.5 Moderating role of the regulatory framework

Adding the three interaction terms raised R^2 from .114 to .138, a change that was not significant ($\Delta R^2 = .024$, $F(3, 100) = 0.929$, $p = .430$). The Waste Valorization and Regulatory Framework interaction was itself non-significant ($B = .063$, $p = .747$). H02 is therefore not rejected: the data give no evidence that the regulatory framework changes how waste valorization relates to sustainability. Waste valorization and the regulatory framework were negatively correlated ($r = -.244$, $p = .011$).

4.6 Discussion

Waste valorization relates positively to sustainability in every specification ($r = .172$; $B = 0.233$ and 0.201). The shift from significance in Model 1 to non-significance in Model 2 reflects a small drop in the point estimate rather than a different effect, since the two confidence intervals overlap almost completely. The coefficient shrank slightly once the regulatory framework entered, which fits the negative correlation between valorization and regulatory perceptions. The result therefore supports the direction predicted by the circular economy literature (Abdallah et al., 2024;

Agyapong et al., 2025; Gull et al., 2022) but does not confirm it at the conventional threshold.

Why the effect is not stronger. Three reasons are plausible. First, adoption is so low that most respondents sit at the bottom of the scale; a restricted range weakens correlation and regression estimates regardless of the true effect. Second, Resource-Based Theory predicts that a capability pays off only when it is mature and deployed, and valorization demands capital, technology, secure feedstock and output markets (Arias et al., 2025; Park et al., 2025). Small solid waste social enterprises, most of them with fewer than five employees, often lack these. Third, the sample is dominated by collection-focused social enterprises (69.4%), for whom valorization is not yet part of the core business model. Kenyan evidence on weak sorting, limited incentives and low awareness points the same way (Ishuga et al., 2024).

Contrast with green product design and with sustainability outcomes. Green product design was the only significant predictor in the full model. Design capabilities are cheaper and closer to hand than recovery infrastructure, which may explain why they already deliver measurable returns while valorization does not. The sustainability profile is consistent with the same story. Valorization is the practice through which landfill diversion, emission reductions and revenue from recovered outputs are expected to arise, and the sector rates environmental ($M = 2.36$) and economic ($M = 2.25$) performance lowest while also reporting weak valorization. This is a descriptive coincidence in cross-sectional data and not evidence of causation. It is nonetheless in line with Ecological Modernization Theory, which expects environmental gains to follow only where recovery systems are actually in place (Mol & Spaargaren, 2000).

No moderation by regulation. Respondents viewed incentives, public-private partnerships and enforcement favourably, yet these perceptions did not alter the valorization-sustainability relationship. This is consistent with the Kenyan literature on fragmented institutions and uneven enforcement (Muheirwe et al., 2022; Muriithi & Ngare, 2023), and with the Resource-Based argument that internal capability matters more than external pressure. It contrasts with studies in which institutional support strengthened the link between green innovation and performance (Jia-tong et al., 2021). The negative correlation between valorization and regulatory perceptions may mean

that social enterprises doing more recovery work meet heavier licensing and compliance demands, but the present data cannot test that conjecture.

4.7 Limitations

Four limitations qualify these findings. Data are self-reported perceptions from one county at one point in time; therefore, causal claims are not warranted. Sustainability was measured with a single item per dimension, which limits construct depth. The 108 respondents are nested within 30 solid waste social enterprises and the analysis did not model this clustering, so standard errors may be understated. Finally, the sample is modest, so a true effect of the observed size could go undetected.

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Waste valorization innovation is weakly adopted by solid waste social enterprises in Nairobi City County: all four indicators averaged below the scale midpoint, and reuse of waste as a primary production input was the weakest practice. Its association with sustainability is positive in every analysis but not statistically confirmed in the full model ($\beta = .183$, $p = .061$), having reached significance only in the model without the regulatory framework ($\beta = .212$, $p = .028$). The regulatory framework did not moderate the relationship ($p = .747$ for the interaction). The study therefore concludes that the potential of valorization to sustain SWSEs has not yet been realized, because the practice has not been adopted at a scale or depth that would show up as a reliable performance effect. Adopting innovation does not by itself guarantee sustainability gains; it needs complementary capability, finance, markets and enforcement.

5.2 Recommendations for policy

National and county authorities should offer targeted tax incentives, innovation grants and subsidies tied to specific recovery investments (sorting and processing equipment, composting, and energy or nutrient recovery) rather than general support.

NEMA should enforce waste regulations consistently and predictably and pair enforcement with clear compliance guidelines and technical assistance, so that compliance does not become a burden on solid waste social enterprises that invest in recovery.

Nairobi City County should streamline licensing and reduce administrative barriers for small solid waste social enterprises.

Public-private partnerships should be strengthened to give SWSEs access to waste streams, technology, finance and markets for recovered materials.

5.3 Recommendations for practice

SWSEs should prioritize the weakest practices identified here: Transforming waste into productive inputs, building recycling into product development, reusing waste materials in production, and adopting recovery technologies suited to their scale.

Solid waste social enterprises should transform their strong operational and social performance into economic and environmental results through market development, product commercialization, cost management and monitoring of environmental performance.

Solid waste social enterprises should invest in staff skills and in networks with recyclers, manufacturers and green finance providers, since capability and market linkage appear to limit the return on valorization.

5.4 Recommendations for further research

Future studies should use longitudinal and multi-county designs, measure sustainability with multi-item economic, environmental and social scales, and account for respondents being grouped within SWSEs. They should test why the effect of valorization appears to depend on model specification, examine finance, technology and market access as explanatory factors, and test individual regulatory instruments (tax incentives, licensing, grants and partnerships) separately rather than as one composite framework.

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CONFLICT OF INTEREST

No financial or non-financial conflict of interest related to this study.

Ethics Approval

Ethical clearance was granted by Tangaza University, and a research permit was obtained from NACOSTI. All participants provided informed consent and were informed about the study's purpose and the confidentiality of their information. Participants' safety and confidentiality were prioritised throughout the research process.

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