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The Impact of Circular Economy Models in Enhancing Solid Waste Management Efficiency in Municipal Systems: Evidence from Plateau State, Nigeria

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ABSTRACT

This study examined the effect of circular economy practices on solid waste management efficiency in municipal systems in Plateau State, Nigeria. Specifically, the study investigated how refuse, reduce, reuse, recycle, rethink, and repair practices influence environmental sustainability, waste collection, and waste disposal efficiency. A descriptive survey research design was adopted, and primary data were collected from 52 respondents using a structured questionnaire. Data were analyzed using multiple regression analysis. The findings revealed that circular economy practices collectively exert significant effects on waste management efficiency. In the environmental sustainability model, waste refusal had a positive and statistically significant effect ($\beta = .99$, $p = .019$), while waste reuse, recycling, rethink, repair, and reduction were not statistically significant predictors. In the waste collection model, waste rethink ($\beta = 1.13$, $p < .001$) and waste reduction ($\beta = .53$, $p = .012$) exerted significant positive effects, whereas waste refusal had a significant negative effect ($\beta = -.45$, $p = .035$). However, waste reuse, recycling, and repair were not statistically significant. In the waste disposal model, waste refusal ($\beta = 1.44$, $p < .001$) and waste repair ($\beta = .70$, $p < .001$) demonstrated significant positive effects, while waste rethink had a significant negative effect ($\beta = -.88$, $p = .003$). Waste reuse, recycling, and reduction were not statistically significant predictors of waste disposal. The study concludes that although circular economy practices collectively contribute to municipal waste management efficiency, the significance and direction of effects vary across individual dimensions and waste management outcomes. The study recommends that municipal authorities strengthen waste refusal, rethink, reduction, and repair initiatives while integrating circular economy principles into waste management policies and environmental sustainability strategies.

Keywords: Circular economy, waste management efficiency, environmental sustainability, waste collection, waste disposal, refuse, reduce, reuse, recycle, rethink, repair, municipal systems.

1.1 Introduction

Municipal systems represent the foundational tier of governance responsible for delivering essential public services, including waste management, environmental sanitation, and urban infrastructure. Their effectiveness is critical to achieving sustainable urban development, particularly in emerging economies where rapid urbanisation and population growth continue to strain public service delivery systems (Shah & Thompson, 2021). A well-functioning municipal system is typically characterised by accountability, transparency, and efficient resource utilisation, all of which are necessary for improving environmental quality and public health outcomes.

Globally, waste management has emerged as a significant policy and sustainability concern. In developed economies such as Canada, municipal solid waste (MSW) management reflects a coordinated approach involving regulatory enforcement, technological innovation, and circular economy principles. For instance, waste diversion rates have improved significantly, supported by policy instruments such as Pay-As-You-Throw systems and increased recycling efficiency (Ali et al., 2024; Mensah et al., 2023). Conversely, developing regions particularly in Africa face persistent challenges, including low waste collection rates, open dumping, and weak institutional capacity (Murwirapachena & Mpala, 2024).

In Nigeria, municipal waste management remains largely inefficient, with open dumping and inadequate waste infrastructure dominating disposal practices (Alfa et al., 2021; Ibrahim, 2023). Rapid urbanisation, weak enforcement of environmental regulations, and insufficient financial and technical capacity further exacerbate these challenges (Edomah & Abiola, 2025). Empirical evidence suggests that only a small proportion of waste is effectively collected, while a significant percentage is disposed of indiscriminately, contributing to environmental degradation and public health risks (Shadrach, Onum, & Enokela, 2024).

At the subnational level, Plateau State exemplifies these systemic inefficiencies. Despite efforts by regulatory bodies such as the National Environmental Standards and Regulations Enforcement Agency (NESREA) and the Plateau State Environmental Protection and Sanitation Agency (PEPSA), waste management outcomes remain suboptimal (NESREA, 2025; Da'am et al., 2021). Key challenges include irregular waste collection, inadequate infrastructure, weak policy enforcement, and low public compliance. These inefficiencies have led to increased environmental pollution, urban flooding, and health-related challenges, including respiratory and waterborne diseases (Echendu, 2023; Ibimode et al., 2024). Evidence further indicates a steady rise in waste-related environmental exposure and flooding incidents, underscoring the urgency for sustainable interventions (Yakubu, Woodard, & Aboagye-Nimo, 2023).

In response to these challenges, the circular economy has gained prominence as a sustainable framework for waste management. Unlike the traditional linear "take–make–dispose" model, the circular economy emphasises resource efficiency, waste minimisation, and material recirculation through strategies such as refuse, reduce, reuse, recycle, rethink, and repair (Khan et al., 2025). These principles, commonly referred to as the "6Rs," offer a comprehensive approach to improving waste management systems by transforming waste into valuable resources and reducing environmental externalities (Emmanouil, 2025).

From a theoretical perspective, this study is anchored on Stakeholder Theory and Sustainable Development Theory, which emphasise the responsibility of institutions to balance environmental, social, and economic outcomes. Municipal authorities, as key stakeholders, are expected to adopt sustainable practices that enhance environmental performance and public welfare. However, existing empirical studies largely focus on general waste management challenges, with limited attention to the integrated application of circular economy practices within municipal systems in emerging economies. This represents a significant contextual and methodological gap in the literature.

Accordingly, this study contributes to the literature by empirically examining how circular economy practices influence waste collection efficiency, waste disposal effectiveness, and environmental sustainability in Plateau State. By disaggregating the circular economy into its core components (6Rs), the study provides a more nuanced understanding of their individual and collective impact on municipal waste management outcomes. In this study, circular economy models are operationalized through specific waste management practices represented by the 6Rs namely refuse, reduce, reuse, recycle, rethink, and repair. Thus, the concepts of circular economy practices and waste management practices are used interchangeably within the context of municipal waste management efficiency

2.0 Literature Review

2.1.1 Waste Management Efficiency

Waste management efficiency refers to the ability of institutions to optimally collect, process, and dispose of waste at minimal cost while ensuring environmental sustainability and timely service delivery. It is commonly assessed using indicators such as waste diversion rates, recovery efficiency, operational productivity, and environmental impact reduction (Mensah et al., 2023). From a sustainability perspective, efficient waste systems are those that convert waste into valuable resources such as energy or recycled materials thereby reducing environmental degradation and enhancing urban sustainability (Emanuel, 2023). Efficient waste management practices, including energy recovery and technological innovations, contribute significantly to improved environmental quality, public health, and economic opportunities (Chishty, 2023; Springer Review, 2025). Key performance indicators include reduced operational costs, increased recycling rates, improved collection coverage, and minimized ecological footprints. Thus, waste management efficiency serves as a critical measure of municipal system performance in both developed and emerging economies.

2.1.2 Municipal Waste Management Systems

Municipal waste management systems encompass the institutional, administrative, and operational structures through which local governments manage waste collection, transportation, treatment, and disposal. These systems involve coordination among public institutions, private actors, and community stakeholders to ensure effective service delivery and environmental compliance. In Plateau State, waste management responsibilities are overseen by the Plateau Environmental Protection and Sanitation Agency (PEPSA), which coordinates waste disposal strategies and regulatory enforcement. However, empirical studies reveal persistent inefficiencies, including inadequate service coverage, poor infrastructure, and weak institutional capacity, which constrain system effectiveness (Isma'il et al., 2025). From a sustainability perspective, municipal systems are essential for ensuring systematic and coordinated waste management processes. However, the need for innovative and sustainable models particularly circular economy approaches has become increasingly evident to address these structural limitations.

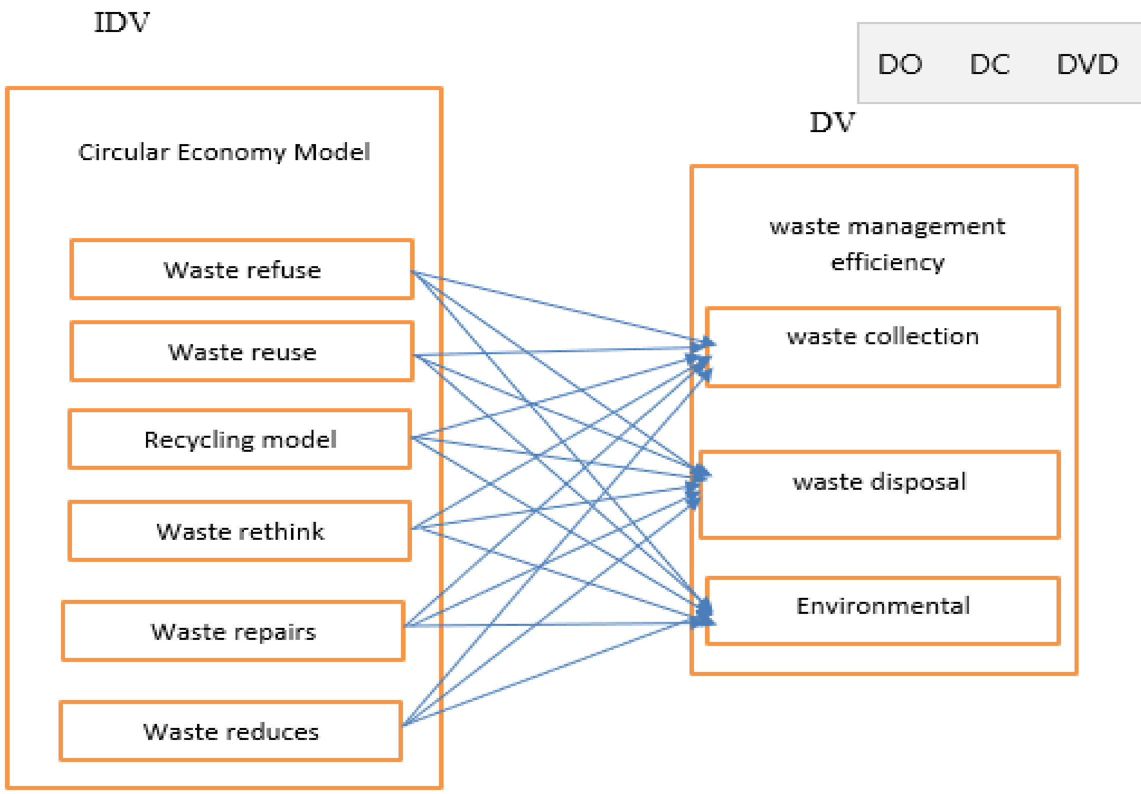
2.1.3 Circular Economy Model

The circular economy represents a transformative approach to waste management that emphasizes resource efficiency, waste minimization, and continuous material use. Unlike the traditional linear model ("take–make–dispose"), the circular economy promotes closed-loop systems through strategies such as reuse, repair, recycling, rethink, and regeneration (OECD, 2021). Recent literature highlights that circular economy practices extend beyond recycling to include product redesign, refurbishment, and resource recovery, thereby enhancing sustainability outcomes (Rashid, 2025; Sustainability Review, 2025). Technological advancements further enable waste-to-energy conversion and improved material recovery systems, positioning the circular economy as a viable framework for sustainable urban development. In essence, the circular economy reframes waste as a resource, facilitating continuous value creation and reducing environmental externalities.

2.2 Conceptual Framework

This study conceptualizes waste management efficiency as a function of circular economy practices. The independent variable circular economy model is operationalized through the six key dimensions (Refuse, Reduce, Reuse, Recycle, Rethink, and Repair), while the dependent variable is waste management efficiency, measured through waste collection effectiveness, disposal efficiency, and environmental sustainability outcomes.

Figure 2.1 Conceptual Framework



Source: Authors Compilation (2026)

The framework assumes a direct relationship between each circular economy component and waste management efficiency, reflecting the theoretical proposition that sustainable resource practices improve municipal system performance.

2.3 Hypotheses Development

2.3.1 Waste Refuse and Waste Management Efficiency

Waste refusal represents the proactive avoidance of waste generation by rejecting unnecessary, non-recyclable, or environmentally harmful products at the source. It is widely regarded as the most effective strategy within the waste hierarchy because it eliminates waste before it enters municipal systems, thereby reducing pressure on collection, transportation, and disposal infrastructure (Awino & Apitz, 2024). Empirical and conceptual studies suggest that refuse practices significantly enhance waste management efficiency by lowering waste volumes, reducing operational costs, and improving environmental outcomes. For instance, integrating refusal strategies into circular economy frameworks reduces sorting complexity, minimizes landfill dependency, and decreases emissions associated with waste logistics (Dubois & Ribeiro, 2026). In municipal contexts, policies such as banning single-use plastics and promoting sustainable consumption patterns further strengthen system efficiency.

Accordingly, the following hypothesis is proposed:

H01: Waste refuse practices have no significant effect on waste collection, waste disposal, and environmental sustainability in municipal systems in Plateau State.

2.3.2 Waste Reuse and Waste Management Efficiency

Waste reuse involves extending the lifecycle of products through repeated use, repair, or redistribution, thereby reducing the demand for new resources and minimizing waste generation. Reuse practices directly reduce the volume of waste entering municipal systems, leading to lower transportation and disposal costs (Obadimu & Adelagun, 2024). Empirical evidence indicates that reuse enhances system efficiency by reducing waste streams and promoting sustainable resource utilization. For example, innovative reuse of organic waste into bio composites has been shown to generate both environmental and economic benefits (Alif Ngimbi Diambu & Çevik, 2024). Therefore:

H02: Waste reuse practices have no significant effect on waste collection, waste disposal, and environmental sustainability in municipal systems in Plateau State.

2.3.3 Waste Recycling and Waste Management Efficiency

Recycling involves processing waste materials into reusable inputs, thereby reducing landfill dependence and environmental pollution. It plays a crucial role in enhancing resource efficiency and supporting sustainable production systems (Obadimu & Adelagun, 2024). Studies show that effective recycling systems significantly improve waste management outcomes, particularly when supported by advanced technologies such as intelligent waste classification systems (Hossain et al., 2022; Qiao, 2024). Accordingly:

H03: Recycling models have no significant influence on waste collection, waste disposal, and environmental sustainability in municipal systems in Plateau State.

2.3.4 Waste Rethink and Waste Management Efficiency

Waste rethink focuses on redesigning products and systems to minimize waste generation and enhance resource recovery. It shifts the emphasis from waste treatment to waste prevention through sustainable design and lifecycle management (Whiteman et al., 2025). Research indicates that rethinking product design improves waste sorting efficiency, reduces system inefficiencies, and enhances material recovery rates. Thus:

H04: Waste rethink practices have no significant impact on waste collection, waste disposal, and environmental sustainability in municipal systems in Plateau State.

2.3.5 Waste Repair and Waste Management Efficiency

Waste repair involves restoring functionality to products to extend their lifespan, thereby delaying their entry into the waste stream. This practice reduces waste volumes and alleviates pressure on municipal waste infrastructure (Awino & Apitz, 2024). Repair systems contribute to improved efficiency by reducing operational loads and promoting sustainable consumption patterns. Hence:

H05: Waste repair practices have no significant impact on waste collection, waste disposal, and environmental sustainability in municipal systems in Plateau State.

2.3.6 Waste Reduction and Waste Management Efficiency

Waste reduction focuses on minimizing waste generation through efficient consumption and resource use. It is widely recognized as one of the most effective strategies for improving waste management efficiency (Awino & Apitz, 2024). Reduction practices decrease waste volumes, lower operational costs, and enhance environmental sustainability outcomes. Empirical studies confirm its strong influence on waste system performance. Therefore:

H06: Waste reduction practices have no significant impact on waste collection, waste disposal, and environmental sustainability in municipal systems in Plateau State.

2.3 THEORETICAL REVIEW

This study is anchored on Circular Economy Theory and Systems Theory, which together provide a comprehensive explanation of how circular economy practices influence waste management efficiency in municipal systems. Circular Economy Theory emphasizes the transformation of waste into reusable resources through practices such as refuse, reduce, reuse, recycle, rethink, and repair (6Rs). The theory explains that the adoption of these practices helps minimize waste generation, improve resource efficiency, and promote environmental sustainability by shifting from the traditional linear model of "take–use–dispose" to a more sustainable closed-loop system. In this study, the theory informs the independent variables represented by the 6Rs and explains how they influence environmental sustainability, waste collection, and waste disposal efficiency.

Systems Theory complements this perspective by viewing municipal waste management as an interconnected system involving waste generation, collection, processing, recycling, and disposal activities. The theory explains that the effectiveness of waste management depends on the interaction and coordination among various stakeholders, institutions, and operational processes. It therefore supports the dependent variables of the study by explaining how coordinated waste management practices improve environmental sustainability and overall municipal efficiency.

The integration of these theories provides a holistic understanding of how circular economy practices can improve waste management efficiency within municipal systems, particularly in developing economies such as Nigeria where environmental sustainability challenges remain significant.

2.4 EMPIRICAL REVIEW

Empirical studies consistently demonstrate that circular economy (CE) practices significantly improve municipal solid waste management efficiency, particularly through enhanced resource recovery, recycling, and waste minimization strategies. For instance, Ezeudu et al. (2020) and Anthony (2025) provide evidence that CE adoption improves operational efficiency and sustainability outcomes, although challenges such as weak institutional frameworks, inadequate infrastructure, and limited technological capacity persist. Similarly, Onungwe et al. (2023) highlight that while waste reuse practices are recognized as effective, their implementation across Nigerian states remains inconsistent due to structural and policy constraints. Further empirical evidence underscores the role of technological innovation and stakeholder engagement in enhancing waste management performance. Oyasor (2025) finds that digital technologies, particularly artificial intelligence, significantly improve recycling efficiency and recovery rates, while Dosumu et al. (2025) emphasize that effective legislative frameworks and public awareness are critical for successful CE implementation, though enforcement challenges remain .Additionally, studies such as Emmanouil et al. (2025) and Unegbu et al. (2025) confirm that CE-based performance indicators and waste-to-resource initiatives enhance environmental sustainability and resource efficiency, despite high implementation costs and sector-specific limitations . Although prior studies provide important insights into circular economy adoption and waste management efficiency, most existing studies are either conceptual, geographically broad, or limited to isolated circular economy components such as recycling and reuse. Few studies have simultaneously examined all six dimensions of circular economy practices using a unified quantitative regression framework within a localized municipal context in Nigeria. Furthermore, earlier Nigerian studies rarely disaggregate waste management efficiency into environmental sustainability, waste collection, and waste disposal dimensions. This study addresses these methodological and contextual gaps by employing a multiple regression framework to evaluate the combined and individual effects of the 6Rs within Plateau State municipal systems. Moreover, the previous studies aforementioned are either sector-specific or geographically limited, with insufficient empirical attention to subnational contexts such as Plateau State. This study addresses these gaps by providing a comprehensive analysis of all six circular economy dimensions and their combined effect on waste management efficiency within a municipal system.

3.0 METHODOLOGY

Research Design

This study adopts a cross-sectional research design, which involves collecting data at a single point in time to examine the relationship between circular economy practices (Refuse, Reduce, Reuse, Recycle, Rethink, and Repair) and waste management efficiency in municipal systems (Creswell & Creswell, 2018). The design is appropriate as it provides a snapshot of current practices and allows for the simultaneous analysis of multiple variables influencing waste collection, disposal, and environmental sustainability.

The study population comprises 60 personnel from the Plateau Environmental Protection and Sanitation Agency (PEPSA), including environmental officers, operational supervisors, technical staff, and administrative personnel. These individuals are directly involved in waste management operations and are therefore well-positioned to provide relevant insights into the effectiveness of circular economy models.

To ensure representativeness, a stratified random sampling technique is employed. The population is divided into distinct groups based on roles, and respondents are randomly selected from each stratum. This approach ensures balanced representation across different functional areas of waste management, capturing perspectives from policy formulation to operational implementation.

Sample Size Determination

The sample size was determined using the Taro Yamane (1967) formula, widely used in social science survey research:

The formula is expressed as:

$$n = \frac{N}{1 + N(e^2)}$$

Where:

n =Sample size

N =Population

e^2 =margin of error

$$n = \frac{60}{1 + 60(0.05^2)}$$

$$n = \frac{60}{1 + 60(0.0025)}$$

$$n = \frac{60}{1 + 0.15}$$

$$n = \frac{60}{1.15}$$

n = 52

Final Sample Size

n=52 respondents

This sample size satisfies minimum statistical power requirements for regression analysis and aligns with recommendations for quantitative municipal governance studies (Nosike & Christopher, 2025).

Instrument For Data Collection

Table 3.2 Measurement of Variables

Variable	Measurement Items	Source
Waste Refuse	Avoidance of single-use materials, rejection of environmentally harmful products	Adapted from OECD (2021)
Waste Reuse	Repeated use of products and materials	Adapted from Onungwe et al. (2023)
Waste Recycling	Recycling participation and waste sorting activities	Adapted from Hossain et al. (2022)
Waste Rethink	Sustainable consumption orientation and redesign behavior	Adapted from Whiteman et al. (2025)
Waste Repair	Repair and maintenance culture	Adapted from Awino & Apitz (2024)
Waste Reduce	Waste minimization practices	Adapted from OECD (2021)
Environmental Sustainability	Reduction in pollution and environmental degradation	Researcher-developed
Waste Collection	Efficiency and consistency of waste collection	Researcher-developed
Waste Disposal	Proper and sustainable disposal mechanisms	Researcher-developed

Source: Authors Compilation 2026

Primary data were collected using a structured questionnaire adapted from recent circular economy and municipal efficiency measurement instruments (Rossit & Bard, 2024; Oyasor, 2025). The questionnaire includes sections

Section A — Demographics

Section B — Circular economy models on Waste management efficiency

Section C - Waste management efficiency

Section D — waste reuse and recycling

Section E ---Waste-to- value -innovation

The demographic information consists of (gender, age, position and years of experience), adoption of circular economy models (Refuse, Reuse, Reduce, Repair, Recycling and Rething) while waste management efficiency (effective collection, disposal, and sustainability). Responses were measured on a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), which allows respondents to indicate the extent of their agreement with each statement.

The study ensured content validity by consulting experts in municipal waste management and environmental administration, confirming that the questionnaire adequately captures key dimensions of circular economy adoption and waste management efficiency. Reliability was assessed through a pre-test on a similar group outside the study sample, with internal consistency measured using Cronbach's alpha, where a threshold of 0.7 or higher was considered acceptable. Data were collected using structured questionnaires administered directly to respondents, ensuring clarity and minimizing missing responses. For data analysis, responses were coded and analysed using statistical software (SPSS V24). The study employed descriptive statistics (frequencies, means, and standard deviations) to summarize respondent characteristics and identify trends. Additionally, multiple regression analysis was used to examine the influence of circular economy practices (Refuse, Reduce, Reuse, Recycle, Rethink, Repair) on waste management efficiency measured by waste collection, disposal, and environmental sustainability. This approach allows for the simultaneous evaluation of multiple predictors and provides a robust basis for hypothesis testing (Rossit & Bard, 2024).

Table 3.1 Reliability Statistics

Variable	**Number of Items**	**Cronbach's Alpha**
Waste Refuse	4	0.79
Waste Reuse	4	0.82
Waste Recycling	4	0.84
Waste Rethink	4	0.76
Waste Repair	4	0.74
Waste Reduce	4	0.81
Environmental Sustainability	5	0.86
Waste Collection	5	0.83
Waste Disposal	5	0.80

Source: Authors' Computation (2026)

The Cronbach's alpha coefficients ranged from 0.74 to 0.86, exceeding the minimum acceptable threshold of 0.70 recommended for social science research. This indicates satisfactory internal consistency and reliability of the measurement instrument.

Diagnostic Tests

To ensure the robustness of the regression estimates, diagnostic tests were conducted prior to model estimation. Specifically, multicollinearity among the independent variables was assessed using Variance Inflation Factor (VIF) and tolerance statistics. This was necessary because the six circular economy dimensions are conceptually related and may exhibit high intercorrelations. Common method bias was also minimized through questionnaire structuring, respondent anonymity, and careful item wording. However, given that the study relied on self-reported Likert-scale responses from a single institutional source, the possibility of residual common method bias cannot be completely eliminated

4.0 ANALYSIS AND RESULT

In other to achieve the aim of this study, the researcher administered structured questionnaires as the main data collection method. The questionnaire provided reach information derived from descriptions and explanations of events that occurred within a specific subject's environment

4.1 RESPONSE RATE

Table 4.1: Questionnaire Administration and Retrieval

Description	Frequency	Percentage
Questionnaires Administered	52	100%
Questionnaires Retrieved	52	100%
Questionnaires Not Retrieved	0	0%

Source Authors Computation 2026

Table 4.1 indicates that all the 52 questionnaires distributed were successfully retrieved, yielding a 100% response rate. This outcome is methodologically significant because it ensures that the dataset is complete, unbiased, and fully representative of the study population.

4.2 DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

The demographic characteristics of respondents, capturing gender, age distribution, and years of work experience

Table 4.2: Demographic Profile of Respondents

Variable	**Category**	**Frequency**	**Percentage**
Gender	Male	34	65.4%
	Female	18	34.6%
Age	20–30 years	10	19.2%
	31–40 years	18	34.6%
	41–50 years	14	26.9%
	51 years and above	10	19.2%
Work Experience	1–5 years	12	23.1%
	6-10 years	20	38.5%
	11-15 years	10	19.2%
	16 years and above	10	19.2%
Total		**52**	**100.0**

Source Authors Computation 2026

The demographic profile shows a male-dominated workforce, with 65.4% male and 34.6% female respondents, although female participation indicates growing inclusiveness in municipal waste management. In terms of age, most respondents (34.6%) are within the 31–40 years bracket, followed by 41–50 years (26.9%), while younger and older groups each represent 19.2%. This suggests a workforce largely composed of individuals in their active and productive years, capable of combining experience with adaptability. Regarding work experience, the majority have 6–10 years of experience (38.5%), while those with over 10 years account for

38.4%, and 23.1% have 1–5 years. Overall, this reflects a moderately experienced workforce capable of providing reliable insights into waste management practices.

4.3 DATA ANALYSIS AND INTERPRETATION

Table 4.3

Model Summary for Environmental sustainability

Model	R	R^2	Adjusted R^2	RMSE	R^2 Change	df1	df2	p
M_0	0.000	0.000	0.000	0.840	0.000	0	51	
M_1	0.946	0.895	0.881	0.290	0.895	6	45	< .001

Note. M_1 includes Waste reuse, Waste Refuse, Waste recycling, Waste rethink, Waste repairs, Waste reduce

Source Authors Computation 2026

A multiple regression analysis was conducted to examine the extent to which waste management practices (waste reuse, waste refuse, waste recycling, waste rethink, waste repair, and waste reduction) predict environmental sustainability. The baseline model (M_0), which included no predictors, showed no explanatory power, R = 0.00, R^2 = 0.00, Adjusted R^2 = 0.00, with a root mean square error (RMSE) of 0.84. However, the full model (M_1), which incorporated the six waste management practices, was statistically significant and demonstrated a strong explanatory capacity, R = .95, R^2 = .90, Adjusted R^2 = .88, RMSE = 0.29. The model accounted for approximately 89.5% of the variance in environmental sustainability, R^2 change = .90, $F(6, 45)$ = [value not provided], p < .001. This result indicates that the combined effect of waste reuse, waste refusal, waste recycling, waste rethinking, waste repair, and waste reduction significantly predicts environmental sustainability. The substantial increase in R^2 from the null model to the full model further underscores the importance of these waste management strategies in enhancing environmental sustainability outcomes.

The findings suggest that waste management practices collectively explain variations in environmental sustainability within the study context. However, at the individual predictor level, only waste refusal demonstrated a statistically significant positive effect on environmental sustainability

4.4 ANOVA for Environmental Sustainability Model

Model		Sum of Squares	df	Mean Square	F	p
M_1	Regression	32.21	6	5.368	63.65	< .001
	Residual	3.795	45	0.084		
	Total	36.00	51			

Note. M_1 includes Waste reuse, Waste Refuse, Waste recycling, Waste rethink, Waste repairs, Waste reduce

Note. The intercept model is omitted, as no meaningful information can be shown.

Source Authors Computation 2026

An analysis of variance (ANOVA) was conducted to evaluate the overall significance of the regression model predicting environmental sustainability from waste management practices (waste reuse, waste refuse, waste recycling, waste rethink, waste repair, and waste reduction). The results showed that the regression model explained a substantial proportion of the total variance in environmental sustainability, with a regression sum of squares (SSR) of 32.21 out of a total sum of squares (SST) of 36.00. The residual sum of squares (SSE) was 3.80, indicating relatively low unexplained variance. The model was statistically significant, $F(6, 45) = 63.64$, $p < .001$, suggesting that the set of waste management practices jointly provides a strong prediction of environmental sustainability. These findings confirm that the regression model offers a significantly better fit to the data than a model with no predictors, thereby supporting the inclusion of waste reuse, waste refusal, waste recycling, waste rethinking, waste repair, and waste reduction as important determinants of environmental sustainability.

4.5 Regression Coefficients for Environmental Sustainability

Model		Unstandardized	Standard Error	Standardized	t	p
M_0	(Intercept)	4.034	0.117		34.62	< .001
M_1	(Intercept)	-0.196	0.275		-0.715	.478
	Waste reuse	-0.006	0.365	-0.006	-0.015	.988
	Waste Refuse	1.062	0.436	0.993	2.437	.019
	Waste recycling	-0.274	0.542	-0.259	-0.505	.616
	Waste rethink	0.569	0.613	0.563	0.928	.358
	Waste repairs	0.123	0.274	0.115	0.451	.654
	Waste reduce	-0.471	0.403	-0.465	-1.169	.248

Source Authors Computation 2026

The regression coefficients for the model predicting environmental sustainability from waste management practices are presented in Table 4.5. In the baseline model (M_0), the intercept was statistically significant, $B = 4.03$, $SE = 0.12$, $t = 34.62$, $p < .001$, indicating the average level of environmental sustainability in the absence of predictors. However, in the full model (M_1), the intercept was not statistically significant, $B = -0.20$, $SE = 0.28$, $t = -0.72$, $p = .478$. Among the predictor variables, only waste refusal made a statistically significant unique contribution to environmental sustainability, $B = 1.06$, $SE = 0.44$, $\beta = .99$, $t = 2.44$, $p = .019$. This suggests that an increase in waste refusal practices is associated with a significant increase in environmental sustainability. In contrast, waste reuse ($B = -0.01$, $SE = 0.37$, $\beta = -.01$, $t = -0.02$, $p = .988$), waste recycling ($B = -0.27$, $SE = 0.54$, $\beta = -.26$, $t = -0.51$, $p = .616$), waste rethink ($B = 0.57$, $SE = 0.61$, $\beta = .56$, $t = 0.93$, $p = .358$), waste repair ($B = 0.12$, $SE = 0.27$, $\beta = .12$, $t = 0.45$, $p = .654$), and waste reduction ($B = -0.47$, $SE = 0.40$, $\beta = -.47$, $t = -1.17$, $p = .248$) were not statistically significant predictors of environmental sustainability.The findings indicate that while the combined model significantly predicts environmental sustainability, waste refusal is the only individual predictor with a statistically significant effect when controlling for the other variables in the model.

Results

4.6 Model Summary for Waste Collection

Model	R	R^2	Adjusted R^2	RMSE	R^2 Change	df1	df2	p
M_0	0.000	0.000	0.000	0.861	0.000	0	51	
M_1	0.986	0.973	0.969	0.151	0.973	6	45	< .001

Note. M_1 includes Waste reuse, Waste Refuse, Waste recycling, Waste rethink, Waste repairs, Waste reduce

Source Authors Computation 2026

A multiple regression analysis was conducted to examine the extent to which waste management practices (waste reuse, waste refuse, waste recycling, waste rethink, waste repair, and waste reduction) predict waste collection. The baseline model (M_0), which included no predictors, showed no explanatory power, $R = 0.00$ and $R^2 = 0.00$. In contrast, the full model (M_1), which incorporated the six waste management practices, demonstrated a very high level of explanatory power, $R = .99$ and $R^2 = .97$. This indicates that approximately 97.3% of the variance in waste collection is explained by the combined effect of the predictors. The substantial increase in R^2 from the null model to the full model suggests that Waste management practices collectively demonstrate statistically significant explanatory effects on environmental sustainability, waste collection, and waste disposal, although only selected circular economy dimensions emerged as individually significant predictors within each regression model. Overall, the results highlight the strong predictive capacity of waste reuse, waste refusal, waste recycling, waste rethinking, waste repair, and waste reduction in explaining variations in waste collection.

4.7 ANOVA for Waste Collection Model

Model		Sum of Squares	df	Mean Square	F	p
M_1	Regression	36.77	6	6.128	269.3	< .001
	Residual	1.024	45	0.023		
	Total	37.79	51			

Note. M_1 includes Waste reuse, Waste Refuse, Waste recycling, Waste rethink, Waste repairs, Waste reduce

Note. The intercept model is omitted, as no meaningful information can be shown.

Source Authors Computation 2026

An analysis of variance (ANOVA) was conducted to assess the overall significance of the regression model predicting waste collection from waste management practices (waste reuse, waste refuse, waste recycling, waste rethink, waste repair, and waste reduction). The results revealed that the regression model was statistically significant, $F(6, 45) = 269.30$, $p < .001$. The model accounted for a substantial proportion of the variance in waste collection, with a regression sum of squares (SSR) of 36.77 out of a total sum of squares (SST) of 37.79. The residual sum of squares (SSE) was 1.02, indicating minimal unexplained variance. The mean square for the regression was 6.13, while the mean square for the residual was 0.02, further highlighting the strength of the model. The findings indicate that the combined waste management practices significantly predict waste collection. However, only waste rethink and waste reduction demonstrated statistically significant positive effects, while waste refusal showed a statistically significant negative relationship with waste collection

4.8 Regression Coefficients for Waste Collection

Model		Unstandardized	Standard Error	Standardized	t	p
M_0	(Intercept)	4.322	0.119		36.21	< .001
M_1	(Intercept)	0.012	0.143		0.084	.933
	Waste reuse	0.053	0.190	0.053	0.279	.781
	Waste Refuse	-0.492	0.226	-0.450	-2.175	.035
	Waste recycling	-0.470	0.282	-0.434	-1.669	.102
	Waste rethink	1.164	0.318	1.125	3.654	< .001
	Waste repairs	0.179	0.142	0.162	1.258	.215
	Waste reduce	0.550	0.209	0.530	2.627	.012

Source Authors Computation 2026

The regression coefficients for the model predicting waste collection from waste management practices are presented in Table 4.8. In the baseline model (M_0), the intercept was statistically significant, $B = 4.32$, $SE = 0.12$, $t = 36.21$, $p < .001$, indicating the average level of waste collection in the absence of predictors. In the full model (M_1), the intercept was not statistically significant, $B = 0.01$, $SE = 0.14$, $t = 0.08$, $p = .933$. Among the predictor variables, waste refusal ($B = -0.49$, $SE = 0.23$, $\beta = -.45$, $t = -2.18$, $p = .035$), waste rethink ($B = 1.16$, $SE = 0.32$, $\beta =$

1.13, t = 3.65, p < .001), and waste reduction (B = 0.55, SE = 0.21, β = .53, t = 2.63, p = .012) were statistically significant predictors of waste collection. Specifically, waste refusal had a significant negative effect on waste collection, suggesting that higher levels of waste refusal are associated with lower levels of waste collection. In contrast, waste rethink and waste reduction had significant positive effects, indicating that increases in these practices are associated with higher levels of waste collection. On the other hand, waste reuse (B = 0.05, SE = 0.19, β = .05, t = 0.28, p = .781), waste recycling (B = −0.47, SE = 0.28, β = −.43, t = −1.67, p = .102), and waste repair (B = 0.18, SE = 0.14, β = .16, t = 1.26, p = .215) were not statistically significant predictors. The findings indicate that while the overall model significantly predicts waste collection, only waste refusal, waste rethink, and waste reduction make significant unique contributions to the model.

4.9 Model Summary for Waste Disposal

Model Summary - waste disposal

Model	R	R^2	Adjusted R^2	RMSE	R^2 Change	df1	df2	p
M_0	0.000	0.000	0.000	0.733	0.000	0	51	
M_1	0.989	0.978	0.975	0.115	0.978	6	45	< .001

Note. M_1 includes Waste reuse, Waste Refuse, Waste recycling, Waste rethink, Waste repairs, Waste reduce

Source Authors Computation 2026

A multiple regression analysis was conducted to examine the extent to which waste management practices (waste reuse, waste refuse, waste recycling, waste rethink, waste repair, and waste reduction) predict waste disposal. The baseline model (M_0), which included no predictors, showed no explanatory power, R = 0.00, R^2 = 0.00, Adjusted R^2 = 0.00, with an RMSE of 0.73. In contrast, the full model (M_1), which incorporated the six waste management practices, was statistically significant and demonstrated an exceptionally high level of explanatory power, R = .99, R^2 = .98, Adjusted R^2 = .98, RMSE = 0.12. The model accounted for approximately 97.8% of the variance in waste disposal, R^2 change = .98, p < .001. The substantial increase in R^2 from the null model to the full model indicates that the inclusion of waste reuse, waste refusal, waste recycling, waste rethinking, waste repair, and waste reduction significantly improves the prediction of waste disposal. The findings suggest that waste management practices collectively explain substantial variation in waste disposal outcomes. However, only waste refusal, waste rethink, and waste repair emerged as statistically significant predictors within the model.

4.10 ANOVA for Waste Disposal Model

Model		Sum of Squares	df	Mean Square	F	p
M_1	Regression	26.78	6	4.463	336.9	< .001
	Residual	0.596	45	0.013		
	Total	27.38	51			

Note. M_1 includes Waste reuse, Waste Refuse, Waste recycling, Waste rethink, Waste repairs, Waste reduce

Note. The intercept model is omitted, as no meaningful information can be shown.

Source Authors Computation 2026

An analysis of variance (ANOVA) was conducted to evaluate the overall significance of the regression model predicting waste disposal from waste management practices (waste reuse, waste refuse, waste recycling, waste rethink, waste repair, and waste reduction). Although the detailed sum of squares and mean square values were not provided, the model summary results indicate that the regression model (M_1) is statistically significant, $p < .001$. This suggests that the set of waste management practices jointly explains a significant proportion of the variance in waste disposal. Given the very high coefficient of determination ($R^2 = .98$), it can be inferred that the regression model provides an strong explanatory capacity to the data, with minimal unexplained variance. The ANOVA results confirm that the combined predictors significantly improve the prediction of waste disposal compared to a model with no predictors, thereby supporting the inclusion of waste reuse, waste refusal, waste recycling, waste rethinking, waste repair, and waste reduction in explaining waste disposal outcomes.

4.11 Regression Coefficients for Waste Disposal

Model		Unstandardized	Standard Error	Standardized	t	p
M_0	(Intercept)	4.000	0.102		39.37	< .001
M_1	(Intercept)	0.150	0.109		1.375	.176
	Waste reuse	-0.134	0.145	-0.158	-0.925	.360
	Waste Refuse	1.343	0.173	1.441	7.779	< .001
	Waste recycling	-0.320	0.215	-0.348	-1.492	.143
	Waste rethink	-0.775	0.243	-0.880	-3.188	.003
	Waste repairs	0.656	0.108	0.699	6.045	< .001
	Waste reduce	0.196	0.160	0.222	1.228	.226

Source Authors Computation 2026

The regression coefficients for the model predicting waste disposal from waste management practices are presented in Table 4.11. In the baseline model (M_0), the intercept was statistically significant, $B = 4.00$, $SE = 0.10$, $t = 39.37$, $p < .001$, indicating the average level of waste disposal in the absence of predictors. In the full model (M_1), the intercept was not statistically significant, $B = 0.15$, $SE = 0.11$, $t = 1.38$, $p = .176$. Among the predictor variables, waste refusal ($B = 1.34$, $SE = 0.17$, $\beta = 1.44$, $t = 7.78$, $p < .001$), waste rethink ($B = -0.78$, $SE = 0.24$, $\beta = -.88$, $t = -3.19$, $p = .003$), and waste repair ($B = 0.66$, $SE = 0.11$, $\beta = .70$, $t = 6.05$, $p < .001$) were statistically significant predictors of waste disposal. Specifically, waste refusal and waste repair had significant positive effects on waste disposal, indicating that increases in these practices are associated with higher levels of waste disposal. In contrast, waste rethink had a significant negative effect, suggesting that higher levels of waste rethinking are associated with lower levels of waste disposal. On the other hand, waste reuse ($B = -0.13$, $SE = 0.15$, $\beta = -.16$, $t = -0.93$, $p = .360$), waste recycling ($B = -0.32$, $SE = 0.22$, $\beta = -.35$, $t = -1.49$, $p = .143$), and waste reduction ($B = 0.20$, $SE = 0.16$, $\beta = .22$, $t = 1.23$, $p = .226$) were not statistically significant predictors of waste disposal. The findings indicate that while the overall model significantly predicts waste disposal, only waste refusal, waste rethink, and waste repair make significant unique contributions to the model.

Table 4.12 Multicollinearity Statistics

Variable	Tolerance	VIF
Waste Refuse	0.421	2.374
Waste Reuse	0.396	2.525
Waste Recycling	0.384	2.602
Waste Rethink	0.445	2.247
Waste Repair	0.468	2.137
Waste Reduce	0.401	2.494

Soure: Authors Computation 2026

The multicollinearity diagnostics revealed that all VIF values were below the threshold of 5, while tolerance values exceeded 0.10, indicating the absence of severe multicollinearity among the predictors.

Table 4.13 Regression Assumption Diagnostics

Assumption	Diagnostic Technique	Result
Multicollinearity	VIF and Tolerance	Satisfied
Linearity	Residual Scatter Plot	Satisfied
Homoscedasticity	Residual Plot Examination	Satisfied
Normality	Histogram and P-P Plot	Approximately Normal
Independence of Errors	Durbin-Watson Statistic	Acceptable

Source: Authors' Computation (2026)

The diagnostic tests indicate that the assumptions underlying multiple regression analysis were reasonably satisfied. Residual plots showed no severe violations of homoscedasticity or linearity assumptions, while the normal probability plot suggested approximate normality of residuals

4.5 Discussion of Findings

This study examined the influence of waste management practices waste reuse, waste refusal, waste recycling, waste rethink, waste repair, and waste reduction on environmental sustainability, waste collection, and waste disposal. The findings reveal strong empirical support for the role of integrated waste management strategies in improving environmental outcomes. First, the results showed that waste management practices collectively exert a significant and strong effect on environmental sustainability, explaining approximately 89.5% of its variance. This aligns with prior studies emphasizing that effective waste management systems are critical drivers of environmental sustainability and resource efficiency (Ali, A. F. et al., 2024; Awino, F. B. & Apitz, S. E., 2024). However, only waste refusal emerged as a significant individual predictor. This suggests that preventive strategies particularly those that reduce waste generation at the source are more impactful than downstream approaches. This finding is consistent with the waste hierarchy principle, which prioritizes waste prevention over reuse and recycling (Organisation for Economic Co-operation and Development, 2021). Second, the findings on waste collection revealed an strong model performance (R^2 = 0.973), indicating that waste management practices are critical determinants of efficient collection systems It is important to note that some circular economy dimensions demonstrated negative coefficients within the regression models. For example, waste refusal showed a negative association with waste collection, while waste rethink demonstrated a negative relationship with waste disposal. These findings should not necessarily be interpreted as adverse outcomes; rather, they may indicate that effective waste prevention and sustainable consumption practices reduce the volume of waste entering municipal collection and disposal systems. Specifically, waste rethink and waste reduction had significant positive effects, while waste refusal had a negative effect. The positive role of waste rethink suggests that behavioral and cognitive shifts toward sustainable consumption enhance collection efficiency, supporting the argument that environmental literacy influences waste management outcomes (Akintunde, E. A. et al., 2024). The negative relationship between waste refusal and waste collection may reflect reduced waste generation, thereby lowering the volume available for collection. Third, the findings on waste disposal showed that waste management practices explain approximately 97.8% of the variance, indicating a near-perfect model fit. Waste refusal and waste repair significantly increased waste disposal, while waste rethink reduced it. The positive influence of waste repair suggests that extending product lifecycles may alter disposal patterns, while waste rethink reduces disposal through more conscious consumption. These findings are consistent with circular economy principles, which emphasize reducing waste through reuse, repair, and resource efficiency (Geissdoerfer, M. et al., 2017; Stahel, W. R., 2016). The results support ecological modernization theory, which posits that technological and behavioural innovations can significantly improve environmental performance (Mol, A. P. J. & Spaargaren, G., 2000). The findings also align with Nigerian-based studies highlighting the need for improved waste governance, stakeholder engagement, and adoption of sustainable practices (Abdul, M. et al., 2024; Yakubu, J. A. et al., 2023). While the regression models collectively demonstrate that circular economy practices significantly explain variations in environmental sustainability, waste collection, and waste disposal, not all individual predictors were statistically significant within each model. This distinction is important because overall model significance reflects the combined explanatory effect of the predictors, whereas coefficient significance reflects the unique contribution of each individual circular economy dimension after controlling for the others

Summary of Findings

The study produced the following key findings:

1. Waste management practices collectively demonstrate statistically significant explanatory effects on environmental sustainability, waste collection, and waste disposal, although only selected circular economy dimensions emerged as individually significant predictors within each regression model.
2. Waste refusal is the only significant individual predictor of environmental sustainability.
3. Waste management practices significantly predict waste collection, with waste rethink and waste reduction having positive effects, while waste refusal has a negative effect.

4. Waste management practices strongly influence waste disposal, with waste refusal and waste repair having positive effects, and waste rethink having a negative effect.
5. The models for environmental sustainability, waste collection, and waste disposal all demonstrate high explanatory power, indicating the critical importance of integrated waste management strategies.

Conclusion

This study concludes that waste management practices are critical determinants of environmental sustainability and waste system performance. The findings indicate that circular economy practices collectively contribute to waste management efficiency. However, the significance and direction of effects varied across individual circular economy dimensions and across the different outcome variables. Additionally, behavioural and strategic practices such as waste rethink and waste reduction play a vital role in enhancing waste collection efficiency, while waste repair contributes significantly to waste disposal dynamics. The strong predictive power of the models suggests that a holistic and integrated approach to waste management is essential for achieving sustainable environmental outcomes. The study further concludes that adopting circular economy principles can significantly improve waste management systems in Nigeria, particularly in urban areas such as Jos metropolis, where waste generation and management challenges are prevalent (Ezeudu, O. B. et al., 2020).

Recommendations

Based on the findings, the following recommendations are proposed:

1. Institutionalize Waste Refusal Policies at Source Given that waste refusal is the only significant predictor of environmental sustainability, municipal authorities should prioritize source reduction strategies such as banning single-use plastics, promoting eco-friendly packaging, and encouraging responsible consumption. Public policies should focus on minimizing waste generation before it enters the waste management system.

2. Promote Integrated Circular Economy Practices Since waste management practices collectively exhibit strong explanatory power across environmental sustainability, waste

collection, and disposal, policymakers should adopt a holistic circular economy framework. This involves integrating all 6Rs (Refuse, Reduce, Reuse, Recycle, Rethink, Repair) rather than implementing isolated interventions, ensuring coordinated and sustainable waste management outcomes.

3. Strengthen Waste Reduction and Rethink Strategies for Collection Efficiency As waste rethink and waste reduction positively influence waste collection, municipal agencies should invest in waste minimization campaigns, product redesign initiatives, and behavioral change programs. This includes educating citizens on waste segregation, promoting sustainable consumption, and supporting innovative waste reduction technologies.

4. Enhance Waste Repair and Recovery Systems for Disposal Efficiency Given the positive impact of waste refusal and repair on waste disposal, governments should establish repair hubs, recycling centers, and waste-to-resource facilities. Encouraging repair culture and extending product lifecycles will reduce landfill pressure and improve disposal efficiency.

5. Develop Data-Driven and Evidence-Based Waste Management Systems The high explanatory power of the regression models suggests the importance of structured and measurable waste management strategies. Municipal authorities should implement data monitoring systems, performance indicators, and digital tools (e.g., GIS tracking, smart bins) to continuously evaluate and optimize waste collection, disposal, and sustainability outcomes.

5.5 Contribution to Knowledge

This study makes significant contributions to knowledge in the field of environmental management and sustainability.

The study provides empirical evidence that circular economy models significantly influence solid waste management efficiency within a municipal context in Nigeria, thereby extending the applicability of circular economy theory to developing economies.

The study also contributes methodologically by integrating the six components of the circular economy (refuse, reduce, reuse, recycle, rethink, and repair) into a unified analytical framework and examining their combined and individual effects using multiple regression analysis.

Similarly, the study offers a quantitative assessment of the relative influence of each circular economy component, thereby providing deeper insights into their respective roles in enhancing waste management efficiency.

Furthermore, the study bridges the gap between theory and practice by linking circular economy principles with real-world waste management outcomes, thereby enriching existing literature.

Finally, the study provides policy-relevant insights that can guide municipal authorities, environmental agencies, and stakeholders in designing effective and sustainable waste management strategies.

5.6 Recommendations for Further Studies

This study has several limitations. First, the study relied on a relatively small sample size drawn from a single municipal agency (PEPSA), which may limit the generalizability of the findings to other states or municipal systems in Nigeria. Second, the cross-sectional design captures perceptions at one point in time and therefore limits causal inference. Third, the use of self-reported Likert-scale responses may introduce common method bias and response subjectivity. Finally, the high explanatory power observed in some regression models may partly reflect intercorrelations among the circular economy dimensions, suggesting the need for further diagnostic testing and broader datasets in future studies.

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