Inventory Analysis of Solid Waste Generation and Distribution in Ibadan Using Zero Intercept Polynomial Regression Model

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ABSTRACT

Waste generation and disposal has today become a stern unruly in our dear country Nigeria and it has engrossed substantial curiosity among communities and government because of its multifaceted nature and associated economic, environmental and sociological glitches. This call for the need to understanding the rate and volume of waste generated is very imperative for environmental sustainability.
This paper centered on the inventory analysis of solid waste generation and distribution in Ibadan Metropolis. The data used for this study were collected from Oyo State Waste Management Agency (OYOWMA) and Zero Intercept Polynomial Regression Model was used to study the pattern of waste generated and distribution in Ibadan, Oyo state. Shapiro-Wilk and Kolmogorov-Smirnov test were applied to test Normality Assumption.

It is observed that the parameters in the model are statistically significant at 5% level of significance except for that of Abaeku. The adjusted R-Squared is 0.9854 indicates a high joint contribution of all the parameters to the response variable (Waste Generated).
The ANOVA table shows the appropriateness of the Regression model used for the data, as almost all the parameters are significant. Since the p-values for the models are less than 0.05, the residuals generated from the models are normally distributed.

Waste generated across Ibadan Metropolis increases yearly which was borne out of increase in population of people living in Ibadan. Also discovered that Ibadan North-East part of Oyo state contributes the largest percentage of waste generated across the city (about 75,000 metric tons yearly) with paper, plastic and food waste taking 52% of the whole waste generated.

Hence, there should be a policy to create ideas on how waste generated can be recycled in other to reduce the volume of waste generation as well as improving the economy with the recycling processes.

Keywords: *Waste, Population growth, waste composition, model*

INTRODUCTION

Nigeria, with its estimated population of over 180 million is prominent for solid waste generation and disposal glitches. The waste density oscillated from 280 to 370 kg/m3 and the per capital generation of municipal solid waste ranged from 0.44 to 0.66 Kg/capita/day (Ogwueleka 2009). Solid waste is generated at a rate yonder the ability of the city authorities to handgrip in order to sustain a sustainable urban environment. This has given rise to pitiable solid-waste management system that foretells thoughtful environmental catastrophe in most Nigeria towns and cities.

The residents of Ibadan and those of other Nigeria cities such as Lagos, Kano, and Enugu, dump refuse indiscriminately along the streets, roads, in open spaces, market places, frontages of residential buildings and drainage system. These result in an unsightly mountain of refuse that have become a common feature of Nigeria's urban landscape (Ogboi and Okosun, 2003). The level of environmental sanitation in the city of Ibadan is often well-thought-out as among the poorest in Nigeria. Almost every available open space is littered with garbage arising from numerous commercial activities. Waste generation and disposal has become a severe antisocial in Nigeria and it has engrossed considerable curiosity among communities and Government because of its complex nature and associated economic, environmental and sociological problems. Hence the need for understanding the rate and amount of waste generated is important for environmental sustainability.

Most researchers have written a lot on waste generation and waste management in Nigeria; however, they have not been able to analyze the volume of waste generated and distribution in Ibadan Metropolis. As there is rapid socio-economic development of Ibadan which pulls migrants from different parts of Nigeria and an increment in the population of the city, it is therefore imperative to stare into the inventory of waste generated.

Therefor this paper aim to analyze the generation and distribution of waste generated across Ibadan Metropolis with much emphasis on the determination of the amount of waste generated in Ibadan and also to compare the volume of waste across the four major dump sites in Ibadan and lastly to estimate the parameters of the regression model for the waste generated in Ibadan and to predict future waste that will be generated.

RELATED WORKS AND THEORIES

Oluwole Samuel Ojewole (2014) in his work Intra Urban Analysis of Domestic Solid waste Disposal methods in a Sub-Sahara African City, Multinomial Logistic Regression was used. The study established that most of the solid waste disposal methods utilized by residents in Lagos metropolis were not environmental friendly.

Hoornweg et al., (2012) estimated current global generation of solid waste to be 1.3 billion tons per day and projected the generation to increase to approximately 2.2 tons per day by 2025. The study projected per capita generation to increase from the current 1.2 kg per person per day to 1.42 kg per person per day in the next fifteen years. The study stated that solid waste generation rates are influenced by level of economic development, degree of industrialization, communities' habits and local climate.

Rahji, M.A and Oloruntobi, (2009) Determinants of households' willingness-to-pay for private solid waste management services in Ibadan, Nigeria. Multinomial logit model and Tobit model were used and they came up with findings that charging methods affected the choice of waste charging and the willingness to pay (WTP) amount.

Zero Waste

Zero waste encompasses more than eliminating waste through recycling and reuse; it focuses on restructuring production and distribution systems to reduce waste C.Y. Young et al., (2010). An important consideration of the zero waste philosophy is that it is more of a goal, or ideal rather than a hard target. Even if it is not possible to completely eliminate waste due to physical constraints or prohibitive costs, zero waste provides guiding principles for continually working towards eliminating wastes

Cradle-to-Cradle / Cradle-to-Grave

Cradle-to-grave (C2G) is a term used to describe the linear, one-way flow of materials from raw resources into waste that requires disposal. Cradle-to-cradle (C2C) focuses on designing industrial systems so that materials flow in closed loop cycles; meaning that waste is minimized, and waste products can be recycled and reused. C2C focuses on going beyond simply dealing with issues by addressing problems at the source and by re-defining problems (McDonough et al., 2003).
There are three key tenets to C2C: waste equals food, make use of solar income, and celebrate diversity (McDonough et al., 2003).

METHODOLOGY

Source of data

The data used for this study was collected from secondary source. These data include the following: the volume of solid-waste generation in Ibadan, the characteristics of solid waste in Ibadan and the population. The data was sourced from Oyo State Waste Management Agency (OYOWMA).

Exploratory Data Analysis

In other to display the distribution of waste generated across Ibadan Metropolis, we made use of histogram, multiple bar charts and scatter plots

$$\bar{X} = \frac{\sum_i^n X_i}{n}$$

The sample variance S^2, is defined as

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}(X_i - \bar{X})^2$$

$$\textbf{Skewness} = \frac{1}{(n-1)S^3}\sum_{i=1}^{n}(X-\bar{X})^3$$

Regression Model Used

In this paper, we model the expected value of y as an nth degree polynomial, giving the polynomial regression model:

$$y = \beta_0 + \beta_1 x + \beta_1 x^2 + \beta_1 x^3 + \ldots + \beta_n x^n + \epsilon$$

These models are conveniently linear in the process of estimation. Therefore, the least square analysis, the computational and inferential problems of the polynomial regression can be addressed as using the techniques of multiple linear regression models.

The least squares estimates of the parameters in the model can be expressed in matrix form

$\hat{\beta} = (X^T X)^{-1}(X^T Y)$

With respect to the data,

Since $r_{ij}^{(k)} \subset R^+$ which is fixed under the deterministic condition, then

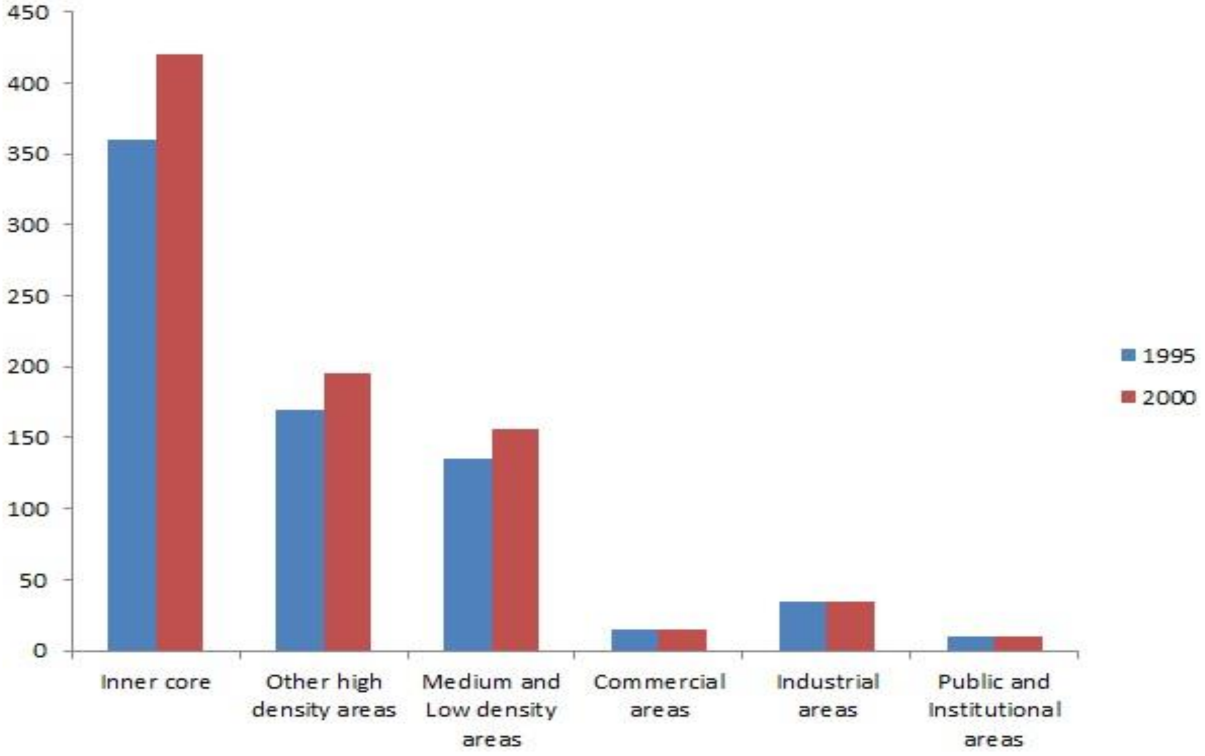
$Y(k) = r(k)Y(t)$

With

$$r^{(k)} = \left[Y^{(t)T}Y^{(t)}\right]^{-1}\left[Y^{(t)T}Y^{(k)}\right]$$

Where $Y^{(k)}$ is a vector of $Y_{ij}^{(k)}$ and $Y^{(t)}$ is a vector of $Y_{ij}^{(t)}$

Result of findings



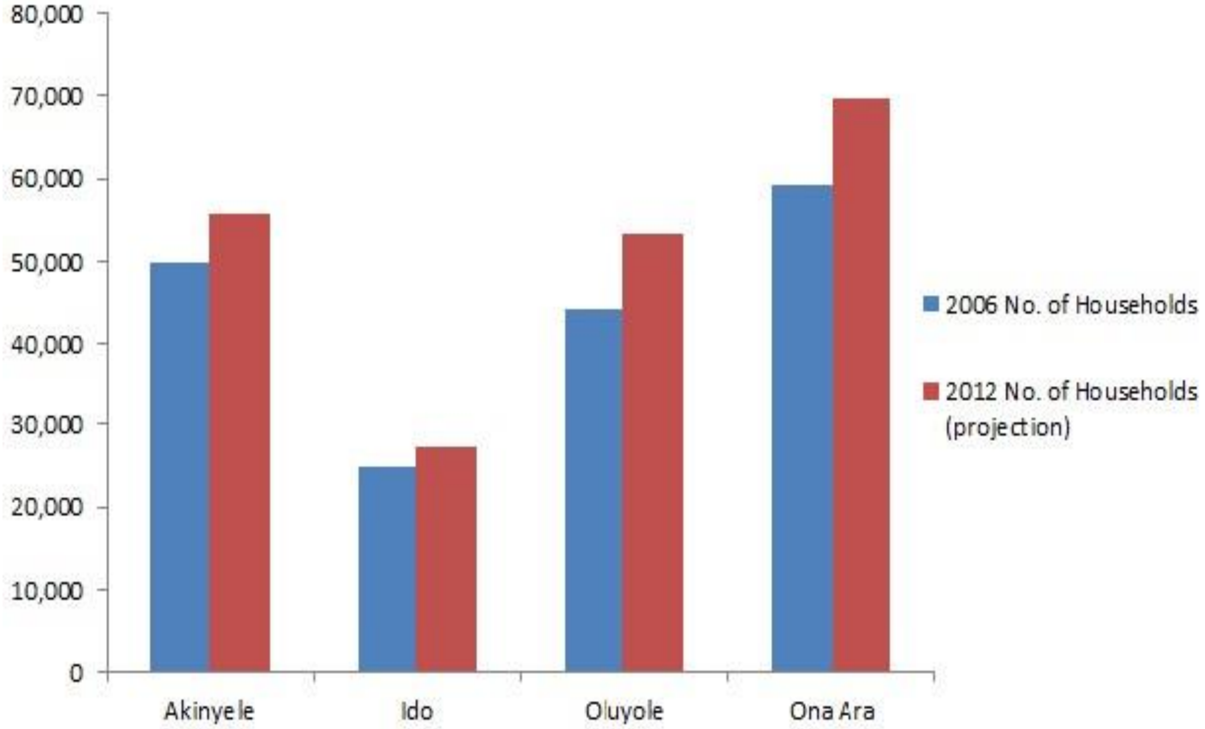


Figure 1: Bar Charts Showing Data on Estimated Waste Generated in Ibadan.

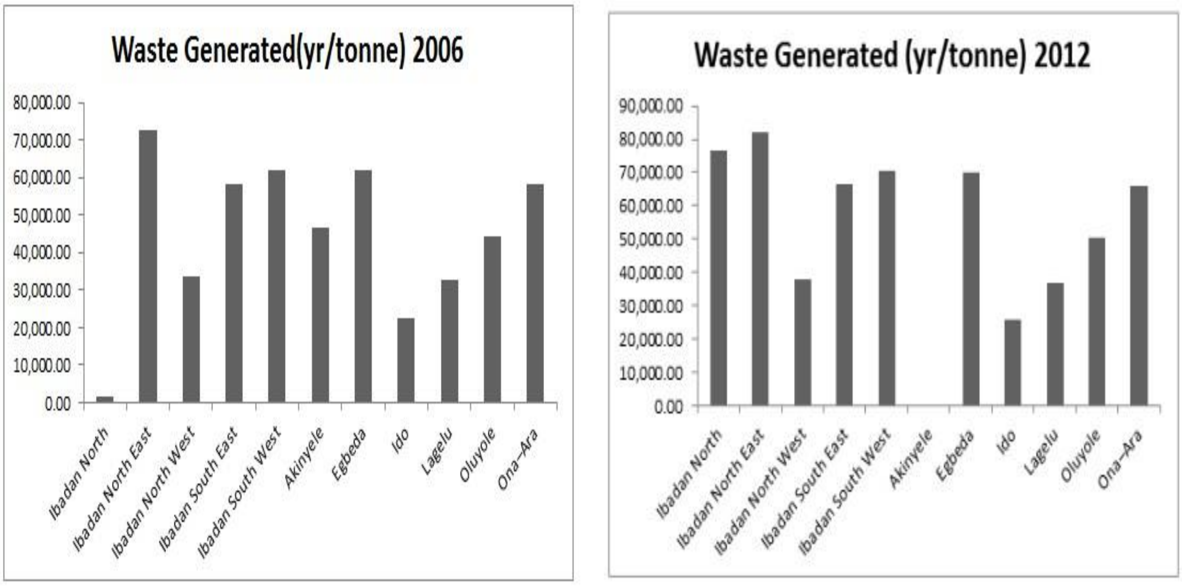


Figure 2: Bar Plots Showing Waste Generated in Years 2006 and 2012

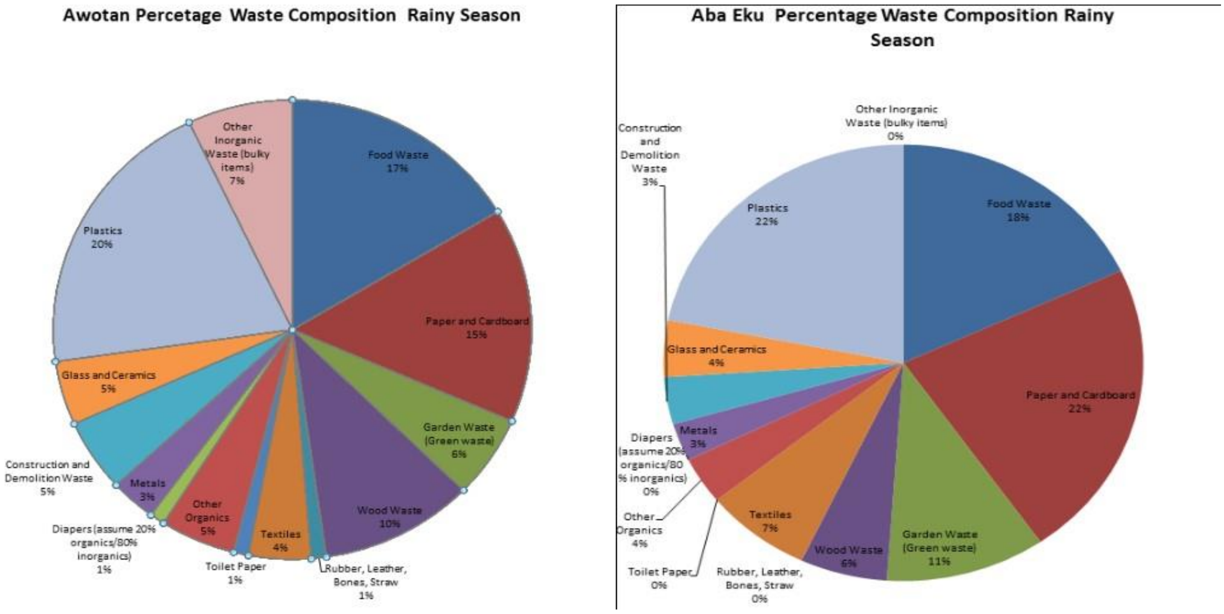


Figure 3: Pie Charts Showing Percentage Waste Composition across Different Locations

Table 3: Multiple Bar Chart Showing Average Weight of Waste Composition

Composition		**Average Weight %**	
	Awotan	**Lapite**	**Aba-Eku**
Vegetable Matter	72	67	72

Putrescible	0	0	0
Paper	12	13	12
Textile	4	2	4
Metals	2	4	5
Plastics	2	3	4
Total	**92**	**89**	**97**

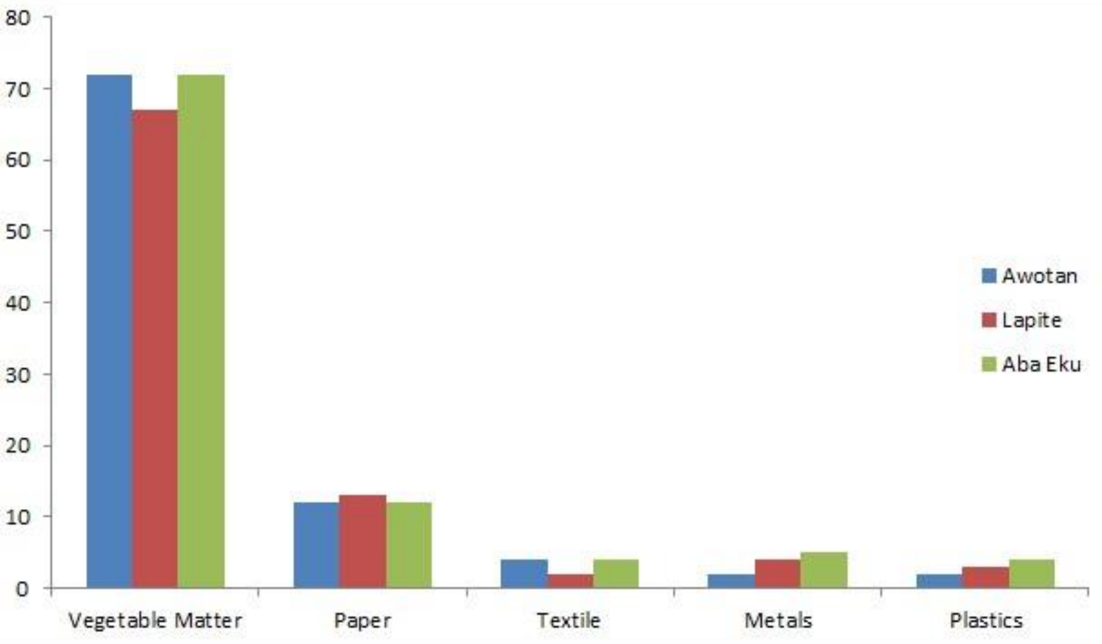


Figure 4: A Multiple Bar Chart Showing Average Waste Composition Across Different Locations

Estimation of Parameters

Table 2: A table showing the estimates of the parameters for the Regression models

Parameter	Estimate	Std	t value	P-value
Intercept	21709.7580	8838.4573	2.456	0.018153 *
Abaeku	0.4286	0.6791	0.631	0.531322
Ajakanga	0.2742	0.3648	0.752	0.0145***

Lapite	2.6419	0.6308	4.188	0.000137 ***
Awotan	-0.8027	0.9759	-0.823	0.00415**

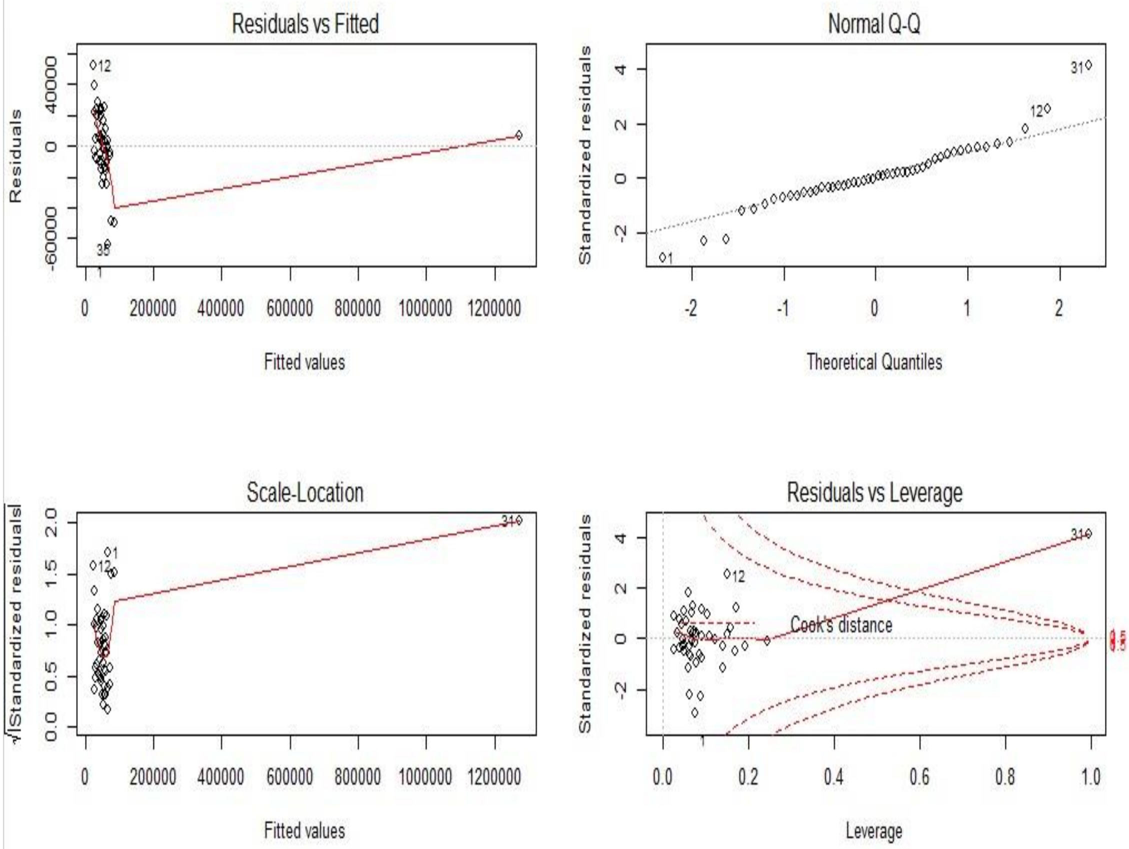
Interpretation: It is observed that the parameters in the model are statistically significant at 5% level of significance except for that of Abaeku. The adjusted R-Squared = 0.9854 indicates a high joint contribution of all the parameters to the response variable (Waste Generated)

Table 4: A table showing the Analysis of Variance for the models

Sources of Variation	Df	Sum Sq	Mean Sq	P-Value
Abaeku	1	6.8020e+09	6.8020e+09	0.0006714 ***
Ajakanga	1	1.4538e+12	1.4538e+12	2.2e-16 ***
Lapite	1	9.1665e+09	9.1665e+09	0.0001104 ***
Awotan	1	3.4231e+08	3.4231e+08	0.4152895

Interpretation: The ANOVA table above shows the appropriateness of the Regression model used for the data, as almost all the parameters are significant.

Residual Analysis. Residual plots for the Regression Model



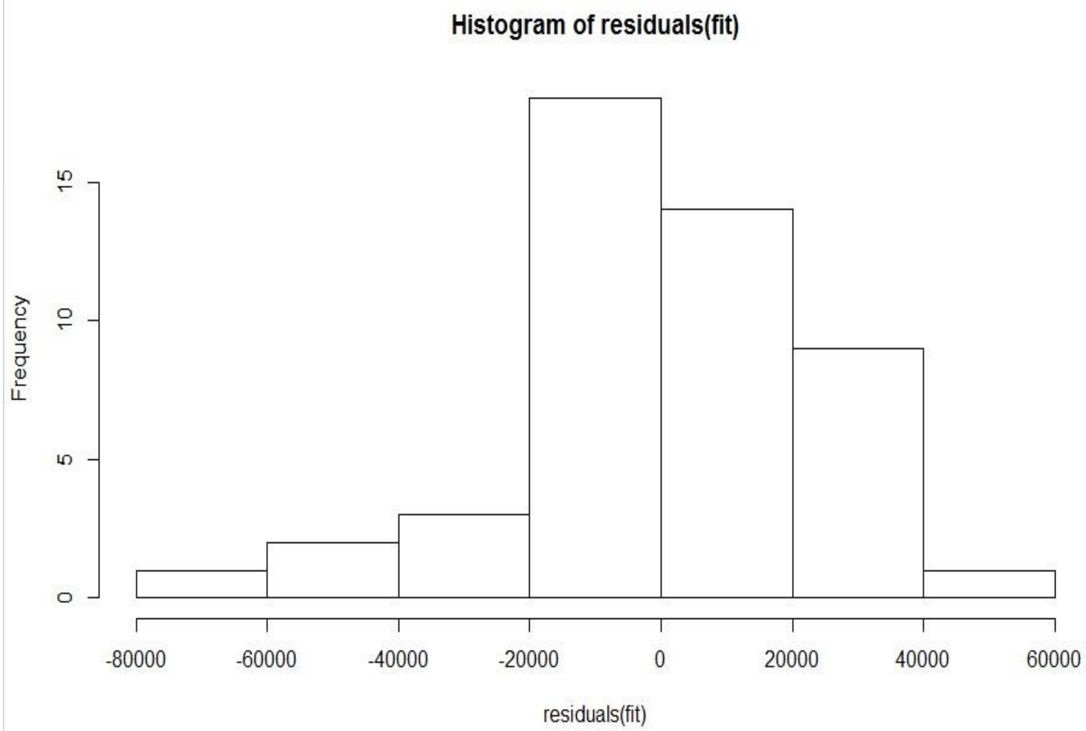


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Figure 5: Residual Plots for the Model

The histogram as well as the QQ Plots suggests that almost all the models generated residuals that are normally distributed.

Tests for Normality

Kolmogorov-Smirnov test

The hypothesis to be tested

H_o: The residuals are normally distributed.
H_1: The residuals are not normally distributed. α =0.05
Table 5: Table of summary for K-S test for normality

Model	D_n	P-value
	0.89583	2.2e-16

If the p-value is greater than the significant level (0.05), the null hypothesis will be rejected and if otherwise, we accept the null hypothesis.

Since the p-values for the models are less than 0.05 which is the chosen alpha, there is no evidence to reject the null hypothesis; therefore, the residuals generated from the models are normally distributed.

Shapiro-Wilk test for normality

The hypothesis to be tested

H_o: The residuals are normally distributed. H_1: The residuals are not normally distributed. α = 0.05

Table 6: Table of summary for Shapiro-Wilk test for normality

Model	W	P-value
	0.9861	0.0601

Decision rule:

If the p-value is greater than the significant level, we accept the null hypothesis and if otherwise, we reject.

Since all p-value for the model is greater than 0.05 which is the chosen alpha, we conclude that the residuals generated from the models are normally distributed.

Summary of findings

Waste generated across Ibadan Metropolis increases year by year which is as a result of increase in population of people living in Ibadan.

From the descriptive statistics as well as the EDA, it was observed that most of the wastes generated in Ibadan are from the North-East part of the state. This may be due to the population of people within the area as well as the access road along Iwo-Road.

The composition of waste generated ranges from plastics (22%), paper and cardboard (22%) and food waste (18%).The polynomial regression model was used to study the pattern of waste generated in Ibadan Oyo state. It is observed that the parameters in the model are statistically significant at 5% level of significance except for that of Abaeku which means the generated waste from this location has no significant effect on the total waste generated in Oyo state.

The generated residuals from the regression model are normally distributed. This was confirmed by the results gotten from Shapiro-Wilk and Kolmogorov-Smirnov tests carried out of the residuals.

Conclusion

The total waste generated from the urban areas of Ibadan is far greater than those generated from the rural areas. It was also discovered that Ibadan North-East part of Oyo state contributes the largest percentage of waste generated across the state (about 75,000 metric tonne yearly) with paper, plastic and food waste taking 52% of the whole waste generated.
However, in Lapite, Awotan and Aba-Eku which are considered as rural areas of Ibadan, 72% of the average composition of waste generated was vegetable matter

Recommendation

Strategies and policies as well as community participation are needed for the source reduction in waste generation as it is known that if wastes generated are not properly managed, it is detrimental to the health of the citizens
There should be a policy to create ideas on how waste generated can be recycled in other to reduce the volume of waste generation as well as improving the economy with the recycling processes.

Data on waste generated across all dumpsites in Oyo state should be properly kept for analysis purpose.

Citizens are also advised not to dump waste in any drainage as we know that this can block the free flow of water and as a result, cause flooding.

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