

Research Article

Spatial Pattern of Dumpster' Distribution as a Solid Waste Collection Strategy in Enugu Metropolis.

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ABSTRACT: *The Enugu State Waste Management Authority (ESWAMA) introduced the use of dumpster as a solid waste collection strategy few years ago. The effectiveness of this strategy in addressing the solid waste collection problem is assessed in this study. Initially, nearby temporary refuse dumps were in existence at different locations in different residential neighborhoods but recently, the trend was improved upon by the introduction of dumpsters and mobile compactors with a view to providing solutions to the numerous environmental problems posed by the use of dumpsites. The goal is to evolve measures for efficient waste collection in Enugu metropolis. The study utilized the nearest neighbor statistical technique to identify the spatial pattern of dumpsters and to test hypothesis (1) which states that there is no significant random spatial pattern of dumpster's distribution in Enugu metropolis. The result with a record 2.10 Rn Index revealed that the pattern of s, dumpster location were unplanned, randomly and maximally spaced outside the convenient reach of the target residents thereby resulting to an increasing waste management ineffectiveness on the part of ESWAMA. The study determined 1,187 deficit numbers of dumpsters and recommends a total of 1,600 dumpsters, as the required number in order to attain the stipulated standard distance for effective operation of the system. A planned distribution pattern of dumpsters in the metropolis at Rn 0.8 was also recommended. The study also generated data for waste collection plan and suggests areas for further studies.*

I. INTRODUCTION

In Nigeria, like in other countries, rapid urbanization and population growth have brought about a proportional increase in the amount of waste generation. The inability to manage these wastes effectively in most urban centers with special reference to solid waste collection system (dumpster collection points) have become an issue of great concern given the huge sum of money spent in their procurement.

In Enugu State, The Enugu State Waste management Authority (ESWAMA) is a government agency established through Act No. 8 of 2004, edit 19 of Enugu State, Nigeria. It introduced the use of dumpsters as s solid waste collection strategy few years ago. One can now question the efficiency of this strategy in addressing the solid waste collection problem especially at the urban areas.

Presently there are hundreds of dumpsters spread all over to facilitate the collection of generated solid wastes; yet, mountainous heaps of solid wastes still deface most parts of Enugu metropolis. Waste collection is still a problem in the metropolis including all the residential areas. The major problem is the many drawbacks in the present waste collection arrangement. The issue of spatial pattern of distribution and allocation of dumpsters at inappropriate location, lack of separate dumpster for recyclable waste material, unsightliness of the collection points, pollution of the environment and the attendant's health implications as well as the issue of convenience of users are of great concern. In developed countries, the waste recycling system is no longer new as they are currently at the stage of advancing better ways of making waste recycling more sustainable. This system can therefore be replicated in Enugu metropolis.

However, the above listed problems are in one way or the other related to poor or a total lack of waste management planning in terms of allocation, random pattern of spatial distribution, and unplanned dumpster

location (distribution of solid waste collection points) by Enugu State Waste Management Authority (ESWAMA). The goal of this study is to assess the spatial pattern of dumpster distribution in Enugu metropolis with the view to evolve measures for efficient waste collection in Enugu metropolis. Two hypotheses were postulated in the study, first there is no significant random spatial pattern of dumpster distribution in Enugu metropolis. Secondly, the residents' perception on the use of dumpsters in waste administration and effectiveness do not significantly differ in the study area.

It is noted that a wide variety of solid waste collection system and equipment have been and can be used. The classification of solid waste collection system may be made on the basis of either the mode of operation, the equipment used, or the types of waste collected.

The collection system can be classified in different ways based on their mode of operation, types of equipment used, types/nature of wastes, etc. for instance, it is possible to distinguish between two types of container system, namely;

Hauled and Stationary.

Usually the former uses large containers in areas where there is high rate of generation and are more economical. However, since they are filled manually either low volume of utilization or misuse of the large container become common phenomena. The United Nations Center for Human settlement (Habitat) has classified the collection systems practiced particularly in developing countries under four heading:

- i. Communal Collection,
- ii. Block Collection,
- iii. Curbside Collection, and
- iv. Door-to-door Collection. [1]

Each of the four methods presented above have some advantages and disadvantages. Thus, for most economical and productive collection of solid wastes for different communities in urban areas, often the use of a combination of these methods is advisable.

The variations in the local conditions caused by the problems of solid waste collection vary from community to community. So it might be impossible to lay down any hard-and-fast rules on the best plan or arrangement for solid waste collection services. Thus, the onus is on the waste manager/administrator to recognize and appreciate the local differences and then make selections of collection methods and equipment [2]

The multiple and diverse equipment and work force programs, mechanization of collection and operations, and labor efficiency and customer service levels, frequency of collection and location of containers, and the analysis of collection system; that is, the unit time required to perform each task are the major management concerns. The collection routes must be laid so that both workforce and equipment are used effectively. Moreover, a schedule for each collection route, on which the location and order of pick-up point to be serviced are found, should be prepared for use by the transportation dispatches and drivers [3]

1.1 Dumpster Location Standard

In advanced countries, dumpsters are placed along the fence-lines for easy access for waste collectors and managers but in developing nations like Nigeria, dumpster locations are usually unplanned hence, located randomly along the access roads thereby creating a number of traffic and environmental problems to the residents.

According to the Department of Public Works and Environmental Services, [4], the recommended maximum dumpster distance from residences is as given in the table 1. For residential areas, the maximum distance from the target is 150meters while that of commercial areas is measured at 250 meters.

1.2 Approximate Dumpster Dimensions

There are different types of dumpsters for refuse collection according to need and the size of population it is intended to serve with respect to the waste generation rate. These include:

Decentralized Dumpster/ Simple Dumpster (kerb-side storage facility) and Centralized Dumpsters. The standard dumpster dimensions are shown in the table below according to diameter in waste handles, height, width and depth characteristics.

1.3 Centralized Waste Storage Sites for High volume Generators

In Nigeria, [5] adopted the Nearest Neighbour Analysis (NNA) to examine the spatial distribution of dumpsters within Ilorin in their study of Solid Waste Generation and Availability of Dumpsters. They discovered that the proportion of available dumpsters for waste generation is high in the three residential areas. From the study survey, it was observed that the locations of dumpsters are accessible to their household, as only 30%, 25% and 35% respectively for the old residential area (Magaji Ngeria), new residential area (Oko-erin) and the government reservation areas respectively have it 100m to 200 meters away from their homes. While a large proportion of more than 65% in the ORA, NRA, and GRA have waste dumpsters at not easily accessible distance to their homes as far as between 300-700m.

The distribution is uneven and inadequate in the metropolis to cater for their needs. Thus, there is uneven distribution in the sitting or location of refuse dumps in Ilorin. The nearest neighbor analysis result reveals that the distribution of refuse dumps is random. The R_n factor of 1.02 was computed for the three areas and the relative disposition of different locations indicates absolute randomness of refuse dumps therefore, showing dispersal measures in the three areas.

However, areas like Ita Amodu, Pipeline road, Gaa Akanbi, Olorunshogo, Agbabiaka Lanjorin to mention just a few lacked the presence of these dumpsters due to narrow road which cannot accommodate the size of dumpsters [6].

They also observed that dumpster distribution have not been well planned and highlighted the need for more effective management in the area of equipment expansion and dedication to bring about job effectiveness. The study recommends that more efforts should be intensified to make the dumpsters accessible to the residents.

This study is therefore imperative since it will provide the necessary and basic information needed to effectively apply dumpster collection strategy as well as a platform for further waste collection researches. The demand for this study involves establishment of an optimal index for spatial pattern of dumpster distribution and sorting feasibility in view of waste recycling system of solid waste management in Enugu metropolis.

II. STUDY AREA

Enugu lies approximately on latitude $06^{\circ} 21' 0''$ N and $06^{\circ} 30' 0''$ and longitude $07^{\circ} 26' 0''$ E and $07^{\circ} 37' 0''$ E of Enugu State of Nigeria. It has an estimated land area of about 72.8 square kilometers. Enugu has a total Land area of about 12,831 kilometer and is the state capital of Enugu State of Nigeria. Residential land-use account for the highest land use comprising about 54.3% of total urban area in Enugu. Enugu has about twenty (20) distinct neighborhoods that may be broadly categorize as low, medium and high-density areas. It is pertinent to note the housing types are typical of density areas. For example, tenements building dominate and are characterized of high-density areas such as Ogui New Layout, Obiagu neighborhoods, while block of flats are prevalent in New Heaven and Achara Layout, a medium density area. In the low-density area, bungalows and duplexes are common. Due to the influences of spread effects, mixed densities exist. Planned and unplanned areas sprang alongside Enugu metropolis as a result of high demand in residential accommodations. That is to say that the urban residential space in Enugu metropolis is not necessary a continuous zone but an arbitrarily defined circumscribing area of about sixteen neighborhoods and some intervening open spaces. Many informal business sectors grow alongside with the residential units as noticed in areas like Kenyetta-Edozie street axis, Agbani-Ziks Avenue Road, Ogui Road, Obiagu Road, Abakpa Road, Emene Road, Chime Avenue, e.t.c. rapid urbanization has increased the population of the city. By 1953, the city's population stood about 63,000, this later increase to about 138,500 by 1963. The 1991 census figures put the population at about 482,977. The population figures for Enugu urban in 2006 stands as 722,664 [7]

2.1 Legal Framework for Environmental Management in Enugu

Enugu state Government in attempt to effectively manage the environment of the state, has set up a legislative framework to help address the problem of indiscriminate waste disposal in Enugu urban. The Federal Environmental Protection Agency (FEPA) law of 1992 is the main guide from which state legislation derives. There is a development control guide on environmental Impact Assessment of some developing projects, in the state; this provided by the Enugu State Waste Management Authority edict of 2004 as the legislative guide for the management of the environment of the State [8]

III METHODS AND PROCEDURES

Survey research design was used in the study. Both primary and secondary data were employed in the work. Interview technique was used to obtain data from a number of stakeholder groups in the study. The questionnaire method was used to obtain information on the socio-economic characteristics of the respondents,

the operations and satisfaction levels of the various dumpster users in Enugu metropolis. In determining the sample size of the research, a survey on the spatial pattern of dumpster's distribution in the selected neighborhoods in Enugu metropolis was determined. Enugu metropolis was chosen for the study because of the inefficient and pronounced solid waste collection strategy in Enugu. The sample size for this research was determined through application of [9]. A sample of four hundred (400) was obtained. In order to obtain valid data for analysis, dumpster distances were translated into electric pole distance between each other to enable non-professionals in this field to provide accurate data to this end. However, the distances were transferred to the equivalents (meter distances) required for this research as shown below:

- 3-4 poles=150-200 meters
- 5-7 poles=250-300 meters
- 8-9 poles=350-400 meters
- 10 poles and above=450 meters and above,

The statistical tool that was employed in this study was the Nearest Neighbor Analysis

3.1 Nearest Neighbor Analysis

The distribution of point-specific urban facilities like dumpsters, petrol service stations, hospital etc can be measured mathematically using the nearest neighbor analytical method. The formula is given as

$$R_n = 2 \sqrt{n/A} \quad (1)$$

Where:

R_n = the nearest neighbor index, A = the size of the area concerned = the mean distance between facilities (Taken as an average of the distance between nearest neighbors)

n = the number of facilities (Dumpsters)

The R_n values ranges from zero (when there is no distribution at all) to 2.15 (when facilities have a maximum spacing). A purely random distribution has an index of 1.0. Values above 1.0 indicate a tendency towards spacing and those below 1.0 indicate clustering [10]

$R_n=0$: The distribution is clustered

$R_n=1$: The distribution is random

$R_n=2$: The distribution maximally spaced

In urban analysis, the application of the R_n statistics is usually to find out the extent to which a given distribution departs from randomness and also to explain the distribution of the facilities tending to either clustering or dispersion.

If the R_n is less than 1, then it means that the average neighbor distance between the facilities are shorter than the values for a random arrangement. When the distances are short, it implies that the facilities are closer to each

other in random distribution and there will be degree for clustering, until a completely clustered pattern is reached at an R_n value of zero.

On the other hand, if the R_n value is more the 1.0, then the observed average distance will be greater than expected under a random distribution.

V. DISCUSSION AND FINDING

4.1 Dumpster Location Distance from Households.

In order to obtain valid data from analysis, dumpster distance were translated into electric pole distance to enable non professional in this field give accurate data to this end. However, the distances and equivalent to the requirement for this research are as shown below:

3-4 poles=150-200 meters

5-7 poles=250-300 meters

8-9 poles=350-400 meters

10 poles and above=450 meters and above

The study shows that 152 respondent representing 38% admitted that dumpster distance from households is between 8-9 poles (350-400 meters), 126 respondents representing 31% accepted 5-7 poles (250-300 meters), 95 respondents which is 24% observed that dumpsters are spread between the range of 10 and above poles (450 meters and above) while 27 respondents making up 10% responded that the distance range between 3-4 poles (150-200 meters). It can be observed that distances vary according to neighborhoods.

Table 1: Estimate of dumpster location from household in poles (40m=1pole)

S/N	Distance(Poles)	Trans-Ekulu	Achara-Layout	Abakpa	Obiagu	Ogui	Asata	Total	%
1	3-4	-	-	26	3	1	-	30	10%
2	5-7	-	3	87	3	1	39	133	31%
3	8-9	21	-	51	1	73	-	146	38%
4	10& above	-	88	-	3	-	-	91	24%
	TOTAL	21	91	164	10	75	39	400	100

Table 1 above shows that dumpsters are spread within very long distance from households. This could be attributed to the proliferating illegal refuse dumpsites in the city.

4.2 Estimated distance between dumpsters.

Table 2 shows that 152 respondents representing 38% admitted that the nearest neighbour distance range between 8-9 poles (350-400 meters), 126 respondents representing 31% accepted 5-7 poles (250-300 meters), 95 respondents which is 24% observed that nearest neighbour distance is between the range of 10 and above (450 meters and above) while 27 respondents making up 10% responded that the distance between neighbours

range between 3-4 poles (150-200 meters). It can be observed that nearest neighbour distance vary according to neighborhoods.

Table 2: Estimated Distance between Dumpsters (in poles) by Residents

S/N	Distance(in poles)	Trans-Ekulu	Achara-Layout	Abakpa	Obiagu	Ogui	Asata	Total	%
1	3-4	-	-	26	3	1	-	30	10%
2	5-7	-	3	87	3	1	39	133	31%
3	8-9	21	-	51	1	73	-	146	38%
4	10 & above	-	88	-	3	-	-	91	24%
	TOTAL	21	91	164	10	75	39	400	100

Table 2 above shows that dumpsters are spread within very long distance between one another. The nearest neighbor distances are on the high side. This factor could also be traced to the reason for the present proliferation of illegal refuse dumpsites in the city

4.3. Nearest Neighbour Analysis (NNA).

Data on the location and number of dumpsters in different neighborhoods and densities were collected. The average distance were observed and recorded accordingly for each neighborhood. The area density of Enugu city which was estimated at 72.8km² from [11] was used to calculate the Rn index for all the neighborhoods. Refer to table 3 below.

Table 3: Coverage Area for different Local Government Area in Enugu metropolis.

S/N	L.G.A	DENSITY
1	Enugu South	67km ²
2	Enugu North	106km ²
3	Enugu East	383km ²
4	TOTAL	Σd=556km ²

Source: from [11]

From (1) above, the average distance between dumpsters (i.e. Nearest Neighbor Distance) in each neighborhood were added together to get the total sum, which is 5,800 meters (5.8km²) while the total number of dumpsters is 413 in the study area.

A purely random distribution with an index of 1.0 value, which is above 1.0 indicate a tendency towards spacing and those below 1.0 indicate clustering [10]

It follows that $R_n=0$ shows that the distribution is clustered, then $R_n=1$ shows that the distribution is random, and $R_n=2.15$ shows that the distribution is maximally space. By implication, when the R_n is less than 1, it means that the average neighbour distances between the facilities are shorter than the values for a random arrangement. When the distances are short, it implies that the facilities are closer to each other than in a random distribution and there will be some degrees of clustering, until a completely clustered pattern is reached at an R_n value of zero. On the other hand, if the R_n value is more than 1.0, then the observed average distance will be greater than expected under a random distribution.

At $R_n (>1.0)$ significance index, the (H_0) hypothesis will be rejected while at $R_n (<1.0)$ significance index, the (H_0) hypotheses will be accepted after the computation of R_n model.

4.4. Computation of nearest neighbor analysis

The hypothesis was validated using the data from tables 2 and 3.

$$= 5800/413=14.0$$

$$R_n = 2 \times 14 \sqrt{413/72,800m} \quad \{R_n=2.10\}$$

Since the R_n index is 2.10, the null hypothesis is hereby rejected. In essence, there is a significant random spatial pattern of dumpster distribution in Enugu metropolis. The nearest locations are unplanned, randomly and maximally distributed in the neighborhoods hence the locations are far from the households (target residents) as well as from one dumpster location to another.

4.5.Total number Of Dumpsters in Enugu Metropolis and the Spatial Pattern of Distribution.

The total number of dumpsters in Enugu metropolis from ESWAMA records is four hundred and thirteen (413). The average distance from households to dumpster locations are made explicit by table (3) for various neighborhoods. Against the standard distance of 100-150 meters of residential area (Refer to table 1), the existing distance for residential densities in the city ranges from between 5-7 and 10 and above poles which is equivalent to 250-450 meters and above. This goes to establish the fact that the dumpster locations are widely spread between one another on the other hand from the target users (households). The spatial pattern of distribution was determined using the nearest neighbour analysis. Results revealed that the distribution index for the city is 2.10 which indicate a high degree of randomness in the spatial distribution of dumpsters. Hypothesis (1) addressed this question squarely.

The R_n index of 2.10 indicates that the dumpsters are maximally spaced hence in disagreement with the recommended standard of 150m and 250m for residential and commercial areas respectively. In other words, the collection system is unplanned hence highly disorganized, disconnected and poorly situated. This implies longer distance for residents in a bid to dispose of the accumulated household waste. There exists

indiscriminate dumping of refuse, uncollected refuse, heaps of solid waste in every part of the city, unplanned distribution pattern, poor facility (dumpster) management and other problems.

The negative effects associated with this trend are innumerable since residents are motivated to travel such long distance in order to dispose of their solid waste for collection. The problems associated with the existing pattern of dumpster distribution can be better explained and appreciated through plates.

V. CONCLUSION

The study has been able to establish that the spatial distribution of dumpsters in Enugu metropolis is unplanned, random and maximally spaced, hence, the system is ineffective. One can deduce that there exists a significant impact of these gaps on deficient and sustainable waste management by ESWAMA as well as the living environment. Although the system is currently ineffective, it has contributed immensely to the recent improvement in waste collection. The study has shown that the challenging issue of solid waste management in Enugu metropolis is actionable hence; government attention is highly needed to improve on the existing structures in order to close the identified gaps, strengthen the system by making it efficient as well as sustainable.

VI. RECOMMENDATIONS

Based on this study, the following recommendations apply:

The state government should create a state database on waste and also support local authorities to undertake regular research to generate data on the situations within their jurisdictions. This will facilitate waste planning and management.

ESWAMA should adopt a distribution pattern at $R_n 0.8$ which will ensure a balance in dumpster accessibility to all neighborhoods and residents. They should also increase their facilities; based on this study, a total of one thousand, one hundred and eighty-seven (1,187) dumpsters are needed in addition to the existing ones (413). This will help to make locations (drop-off points) accessible to households in all neighborhoods.

Route Optimization Using Gis/Gps Model for Transportation of waste will be helpful in terms of proximity to the clusters of the dumpsters. Each cluster is allocated to a vehicle for dumpster collection. The clusters are formed in such a way that the time of the total working hours is sufficient to cover the allotted cluster. With the help of optimal path the total time required will be calculated and displayed. The user then selects any cluster he wishes to work with. Different options of optimum paths can be found and each vehicle is allotted the cluster of dumpsters to collect waste.

There should be public education on environmental sanitations through avenues like the media, schools, churches/mosques and curriculum, while institutions of higher learning should be encouraged to introduce programmes on environmental management, including courses on waste management, to train qualified personnel for the sector.

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