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MULTI-CRITERIA APPROACH TO SOLID WASTE MANAGEMENT IN YOLA METROPOLIS, ADAMAWA STATE

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ABSTRACT

The Adamawa State Environmental and Protection Agency is responsible for the evacuation of solid waste in Yola metropolis (Jimeta/Yola). At the time of this study the agency expends ₦50,000 daily for the evacuation of solid waste in the metropolis. However, the objective of total evacuation of the waste cannot be achieved with the present level of resources made available. The current level of resources can only evacuate waste in six zones. This study has shown that to evacuate all the waste, in the 12 zones of the metropolis per day an additional amount of ₦48, 000 is required.

KEYWORDS: solid waste evacuation, Yola metropolis, goal programming.

INTRODUCTION

Solid waste evacuation and disposal is an important aspect of environmental management that deals with the control of physical factors in the human environment that can affect development. It involves clearing and moving solid waste to disposal sites in different locations. It is a preventive intervention and a strategy for sustainable development (WHOEC, 1971).

The long presence of scattered heaps of waste along roadsides, near commercial centers of developing countries like Nigeria is a serious source of concern. Government (at all levels) in Nigeria has been fighting the problem of solid waste management over the years (George *et al*, 2000). Agencies were established in states under edict No. 6 of 1998, as mandated by section 24 of the Federal Environmental Protection Agency Decree No. 58 of 1988 (Adamawa State, 1998), following the little success recorded in some states of the federation. Winning the fight is still far from reality as most of our streets are still littered with heaps of solid wastes (Joseph *et al*, 2001). Adamawa State Environmental Protection Agency (ASEPA) is one of such agencies, responsible for solid waste evacuation and disposal in Yola metropolis.

The most common method of collecting solid waste in most of the urban centers in Nigeria, in which Yola metropolis is not an exception, is by constructing neighborhood, or community depots in different part of the city, where residents are expected to deposit their domestic wastes (Yahaya, 1997). These wastes are then conveyed to the disposal sites. There are three widely used systems of solid waste evacuation (ASEPA, 1998):

Side-Loader System – this requires residence to throw their rubbish in to a container near their houses. A truck with three or more crew drive from one house to another as some of the crew empty dustbins or throw rubbish back in to the rear of the truck.

Roll-on-Roll-off-Truck and Container System – this requires residences to carry their rubbish in to a big container located at particular place in the area (waste depots). The *Roll-on-Roll-off-Truck* carries the loaded container to the disposal site and unloads. The container is then returned to the depot.

Tipper and Front Loader System – in this case solid wastes that are dumped openly in the depots are loaded in to tippers by front loader. The tippers then take the wastes to the disposal site and offload.

The first two systems are mostly used in developed countries of Europe, USA and Asia (ASEPA, 1998). However, the system had been tried in some states in Nigeria (e.g. Cross River, Adamwa Ebonyi and the FCT).

Survey shows that little success was recorded, the equipments such as the containers provided were not properly put in to use by the residents, and most of the waste are dumped outside the containers. In most cases children are sent to deposit the waste (see Table 1). Investigation also revealed that most of the major machines/equipments are not functional (see Table 2). It was learned that the repair of these machines/equipments are costly and technical expert are not easily obtainable. The agency heavily relies on the third system.

Table1: Reasons for why solid waste is dumped outside the container in Yola Metropolis .

Reasons	No.of Respondents	Percentage of Respondents
Children are sent to deposit the waste	104	55.91
Lack of awareness on how to use the container	17	9.14
Lack of proper orientation on refuse disposal	46	24.73
Lack of adequate containers	19	10.22
Total	186	100

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Table2: **Status of Major Machines/Equipments for Solid Waste Evacuation in ASEPA.**

Machine/Equipment	No. of mach./ Equipment	Functional	Non-Functional
Front Loader	1	1	_
Tipper	8	3	5
Roll-on-Roll-off-Truck	5	1	4
Container	70	28	42
Side Loader	1	_	1

Attempt had been made by Joseph and Victor (2001) to estimate quantity of solid waste generated per day and per week in Yola metropolis. They also examined solid waste management strategy and suggested modification of the existing methods. They stated that transportation is critical factor, constitute, 80% of the total cost of the solid waste management, and suggested evaluation through cost optimization of the transportation of solid waste.

Prompt and proper management of this waste is an important facet of our environmental hygiene. Desirable as it is, however, the most obvious and perhaps most cogent of all social constraints on this issues is the cost, because solid waste evacuation is expensive and the agencies are always constrained by limited resource for the purpose. The objectives of the study among others are to determine:

- the amount of resource required to minimize waste in Yola metropolis .
- the level of evacuation that can be achieved for a given amount of resource in Yola metropolis.

Problem of solid waste evacuation is an optimization problem of limited resources utilization (Joseph *et al*, 2001). Volume of waste to be evacuated and resource meant for the evacuation are linearly correlated (Joseph *et al*, 2001). Most often, techniques used for such problem among others include: Linear Programming, Dynamic Programming, Integer Programming, Goal Programming (Taha, 1999).The result of the study is expected to guide Adamawa State environmental waste management Agency.

METHODOLOGY

The Director and other specialists in various departments of the agency were invited to represent the Agency. Face to face interview was conducted with these representatives to assess the status and number of major machines/equipments, used for solid waste evacuation (Table 2). The current methods of solid waste evacuation were also studied. Preliminary survey of the solid waste depots was carried out to ascertain their number and locations. There are one hundred and one (101) solid waste depots located in 12 zones of the metropolis.

There are also two disposal sides located at two opposite ends of the metropolis. Field survey was conducted during evacuations to estimate the volume of waste in the respective depots. *Input/ Output analysis* method was adopted (Vesilind *et al*, 1988). The population (community) was considered as primary generator. Waste depots were considered to be generation points of a particular population (community). Numbers of trucks ($11m^3$ trucks) of waste per week in the various depots were estimated with the assistance of the

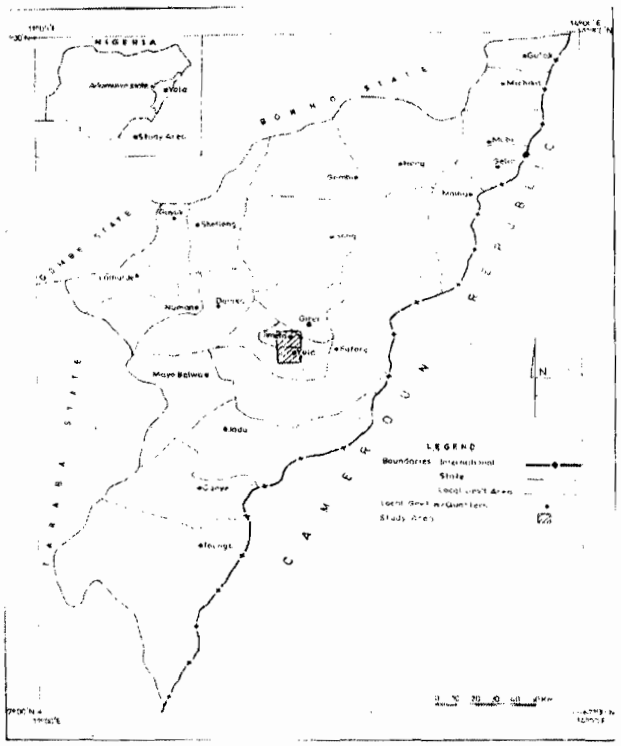

FIG 1.1 ADAMAWA STATE MAP SHOWING THE STUDY AREA,YOLA METROPOLIS (Jimeta/Yo

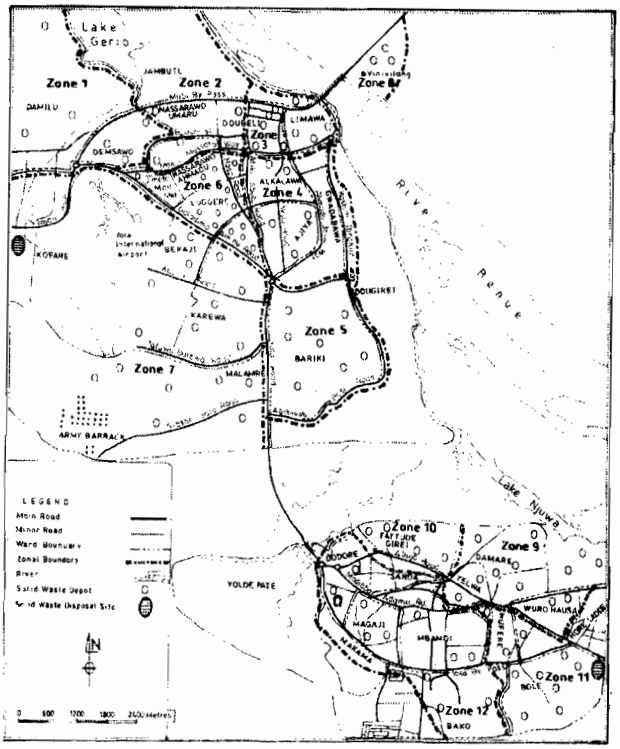

Fig 1.2 : Map of Yola Metropolis Showing the Zones, Solid Waste Depots and Disposal Sites.
(Source: Street Guide to Yola Jimeta)

agency's evacuation experts during weekly evacuation exercise (see Table 3). Table 4 shows the volume of solid waste per day in the respective zones. Some other important estimates also include:

- Volume of waste a tipper can move from one depot in a particular zone to disposal site per day (see Table 5)
- Number of tippers of waste a Front Load can load per day
- Number of laborers required raking the waste during evacuation.

Table 3: **volume of Solid Waste in the Waste Deports Per Week in Yola Metropolis.**

Zone	Area of the Town that Make up the Zone	Where the Deports are Sited	No.of Depots	Volume of wastePer Week (m^3)
1	Jambutu, Jambutu Housing Unit, Damilu And Damsawo	• Jambutu Stree •Jambutu Village • Damilu Ward	1 3 2	308 88 55
		Total	6	451
2	Nassarawo Fam and Doubeli	• Zaranda Street •Nassarawo Viewing Center • Bali Street •Midili Street	1 1 1 1	220 264 297 165
		Total	4	946
3	Romde,Va'atita, Yelwa And Anguwan Fana (Zango)	Mubi bye pass: •Kasuwan nono •Shinko junction •Dubeli junction •Opp. Vespa Mechanic •Goruba Uku •Dubeli bye-pass prim. Sch. •Kasuwan Shiyawa •Kasuwan dabbobi •Ebis Royal Resort	 1 1 1 1 1 1 1 1 1	 165 264 66 110 99 22 165 55 44
		Total	9	990
4	Alkalawa A,B & C, NEPA,Old Market, part Of old GRA and Jimeta Shoping complex.	• Grand view • Obasanjo Street • Kurmi Close • Sarti Street	1 2 1 1	132 110 132 11
		Total	5	385
5	State Secretariat, Commissioners Quarters, 80Unit, Clerk's Quarters, part ot old GRA	• Dwagere • Govt., House • Dep. Govern. House • F.C.E.	3 1 1 2	33 11 11 33
		Total	7	88
6	Nassarawo Madi, New Market, Lower & Upper Lugere, State Lowcost Housing.	• Bishop street • Hospital road • Gimba Road • Lugere • Hospital • Behind Hospital	3 2 1 1 5 1	451 88 22 198 165 44
		Total	13	968
7	Kofare, Airport, Bekaji, Malamre,police Barracks, Army Barracks Road.	Waziri street Catholic street Bekaji • Karewa • Karewa ext. • Malamre	3 1 5 3 1 3	110 231 209 22 33 264

		• Army barrack Rd.	1	110
		Total	17	979
8	Vinikilang, part of Gerie	•Vinikilang	2	55
		•Bajabure Housing	1	22
		Total	3	77
9	Yola Town, Makama A	• Polo ground	1	55
		• Lamido Palace:		
		- Kofan bayin	1	33
		- Lamido House	1	55
		• UPBRDA	2	22
		• Wuro-Hausa	3	165
		• Damare (A&B)	2	99
		• Yelwa Ward	1	231
		• Lamido Road.	1	55
		TOTAL	12	715
10	Yola Tonw Makama B	• Abuja Road:		
		-Near L. Gabdo House	1	55
		-Opp.A.Garamba House	1	110
		- Kaigama House	1	77
		- Police Barrack	1	110
		Total	4	352
11	Yola Tonw, Tongo A	• Bamgel:		
		-Behind A. Joda house	1	22
		-Behind former VC's house		
		-Opp. CG.of custom house	1	11
		• Shagari L. Cost House		
		• Technical College Yola	1	22
			6	198
			1	22
		Total	10	275
12	Yola Town, Tongo B	• Mammayafai	1	22
		• ModibboAdama Way:		
		Opp. S. Ribado House	1	22
		Near A. Mustafa P. Sch.	1	11
		Near Wuro Chekke		
		Shopping Complex	1	44
		• Madaki Street	1	165
		• Sokoto Street	1	88
		• Ciroma Road	2	55
		• Etsu Street	1	22
		• Bako Ward	1	44
		• Ladan Street	1	22
		Total	11	495

Table 4: **Volume of Solid Waste Generated in the Respective Zones per Day.**

Zone i	Volume of solid waste In zone i Per week in m^3	Volume of solid waste in zone I per day (v_i) in m^3
1	451	64.43
2	946	135.14
3	990	141.43
4	385	55.00
5	88	12.57
6	968	138.29
7	979	139.86
8	77	11.00
9	715	102.14
10	352	50.29
11	275	39.29
12	495	70.71
Total	6721	960.15

Table 5: **Average Volume of Solid Waste Removed by Tipper. From Zone i to Disposal site j per day in Yola Metropolis.**

Zone I	Numan Bye Pass Road Disposal Site ($r_{i,1}$) in m^3	Mbamba, Yola Bye Pass Disposal Site ($r_{i,1}$) in m^3
	121	-
2	110	-
3	121	-
4	88	-
5	66	-
6	110	-
7	66	-
8	55	-
9	-	99
10	-	88
11	-	132
12	-	110

was also estimated, a Front Loader loads 30 tippers per day and a laborer is assigned for every $20m^3$ of waste for raking.

As mentioned earlier the agency pursued multiple objectives during the evacuation, these include; minimization of volume of waste in the zones and minimization of resources meant for evacuating the waste. These objectives are measured in different units, and *comparable importance* and/or *hierarchy of priority* were also attached to these objectives/goals.

In this study the primary objective is to minimize volume of waste in all the zones. While the secondary objective is to minimize the resources meant for evacuating the waste. The primary objective is comprised of the goals of waste volume evacuation from zones 1, 2, 3.....12. The secondary objective is comprised of major machines/equipments and amount of money set asides for evacuation of the waste.

Scoring model (David et *al*, 2005) was used in this study to determine the comparable importance/hierarchy of priority among the different objectives. This is because the agency considers the following criteria during the waste evacuation in the zones/deports:

- Proximity of the waste deports to public facilities (Viewing Centers, Market Place, etc)
- Proximity of waste deports to public infrastructures (Road sides, Water ways, etc) Community participation in some waste evacuating zones (some of the communities do contribute or actively participate)
- Densely/Sparsely populated area
- Accumulated waste volume in the zones/deports

The agency uses subjective assessment of priorities during evacuation, to weight these criteria, using the following five point's scale:

Importance	Weight
Very important	5
Some what important	4
Average importance	3
Some what unimportance	2
Very unimportant	1

Table 6: **priority weights assigned to the criteria.**

K	Criteria	Weight (g_k)
1	Proximity of waste deports to public facility (PPF)	5
2	Proximity of waste deports to public infrastructure(PPI)	4
3	Evacuating zones with communal involvement(EZCI)	3
4	Densely populated area (DPA)	4
5	Sparsely populated area (SPA)	2
6	Volume of waste in the zone (VWZ)	3

The evacuations of the waste in the zones are then rated in terms of how well it satisfies each criterion (see Table7), using the following five point scale:

Level of satisfaction	Rating
• Very high	5
• High	4
• Average	3
• Low	2
• Very low	1

Table 7: **Rating for Each Decision Criterion and Evacuation of the Waste in the Zones.**

	Evacuation of Waste in Zone i											
Criterion (k)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
PPF	1	3	2	5	1	5	1	2	1	1	2	3
PPI	2	4	5	4	3	4	3	3	2	2	3	2
EZCI	1	2	2	3	3	3	2	1	3	3	1	1
DPA	2	4	4	4	1	5	1	4	2	2	3	4
SPA	3	2	1	1	4	1	4	2	4	3	1	1
VWZ	3	4	5	4	2	4	2	3	2	1	3	3

m_{ki} = the rating for criterion k and decision of waste evacuation in zone i.

ω_i = Score (priority weight) placed on evacuation of waste on zone i.

$$\omega_i = \sum_{k=1}^{6} g_k m_{ki}$$

These values give us the required subjective priority weights; use to prioritize the goals of the primary objective during evacuation, (see Table 8).

Table 8: **Priority weights place on evacuation of waste in the zones**

Zone i	1	2	3	4	5	6	7	8	9	10	11	12
Weight (ω_i)	39	68	69	80	44	84	41	54	44	39	48	53

Weighted/preemptive multi-criteria decision, Goal programming (Davis *et al,* 1986) was then used to formulate the problem. The formulation assumes that major machines/equipment (tipper, front loader) and laborer are readily available, can be hired and or contributed by individual or organization during the evacuation. Solution to the model was then obtained, using excel best linear programming module, *The Management Scientist version 6.0* software package (David *et al,* 2005).

The Problem

$$\text{minimize } z = p_1\left(\sum_{i=1}^{12} \omega_i s_i\right) + p_2\left(d_2 + d_4 + d_6 + d_8\right)$$

subject to: $x_{i1} + s_i = v_i$, for i = 1,2,...,8

$$x_{i2} + s_i = v_i, \text{ for i} = 9,10,...,12$$

$$\sum_{i=1}^{8} \frac{x_{i1}}{r_{i1}} + \sum_{i=9}^{12} \frac{x_{i2}}{r_{i2}} + d_1 - d_2 = T$$

$$\frac{1}{\alpha}\left(\sum_{i=1}^{8} x_{i1} + \sum_{i=9}^{12} x_{i2}\right) + d_3 - d_4 = L$$

$$\frac{1}{\beta}\left(\sum_{i=1}^{8} x_{i1} + \sum_{i=9}^{12} x_{i2}\right) + d_5 - d_6 = F$$

$$c_1 d_2 + c_2 d_4 + c_3 d_6 + d_7 - d_8 = N$$

$$x_{i1}, x_{i2}, s_i \geq 0, \text{ i} = 1, 2, ...,12$$

$$d_1, d_2, d_3, d_4, d_5, d_6, d_7, d_8 \geq 0$$

Where;

$x_{i,1}$ = volume of waste removed from zone *i* to disposal site 1

$x_{i,2}$ = volume of waste removed from zone *i* to disposal site 2

s_i = remaining volume of waste in zone *i*

v_i = total volume of waste in zone *i*

p_1 = priority attaché to the primary objective

p_2 = priority attaché to the secondary objective

ω_i = comparable importance (weight) attaché to the goals of primary objective

T = number of tippers available during evacuation of the waste

L = number of laborers available during evacuation of the waste

F = number of front loaders available during evacuation of the waste

$r_{i,1}$ = average volume of waste a tipper can remove from zone *i* to disposal site 1

$r_{i,2}$ = average volume of waste a tipper can remove from zone *i* to disposal site 2

α = Average volume of waste a laborer is assigned for raking

β = Average volume of waste a front loader loads per day

c_1 = cost of hiring a tipper per day

c_2 = cost of hiring a laborer per day

c_3 = cost of hiring affront loader per day

d_1 = number of tippers in excess (idle)

d_2 = additional number of tippers required during evacuation

d_3 = number of laborers in excess (idle)

d_4 = additional number of laborers required during the evacuation

d_5 = number of front loader in excess (idle)

d_6 = additional number of front loader required during evacuation

d_7 = amount of money in excess

d_8 = amount of money required to achieved desired level of evacuation

At the time of this study the agency had three tippers (T), one front loader (F), eight laborers(L) and total amount of ₦50,000.00 (N) was set aside for the evacuation of the waste. Front loader is hired at rate of ₦10, 000.00 per day and laborer is hired at rate of ₦1000.00 per day (official working hours). Solution to the model is as follows:

Table9: Management Scientist Solution to the Primary Goals (P_1) of the problem
Optimal solution:
Objective function = 0.0000

variable	value
$X_{1,1}$	64.4300
$X_{2,1}$	135.1400
$X_{3,1}$	141.4300
$X_{4,1}$	55.0000
$X_{5,1}$	12.5700
$X_{6,1}$	138.2900
$X_{7,1}$	139.8900
$X_{8,1}$	11.0000
$X_{9,2}$	102.1400
$X_{10,2}$	50.2900
$X_{11,2}$	39.2900
$X_{12,2}$	70.7100
s_1	0.0000
s_2	0.0000
s_3	0.0000
s_4	0.0000
s_5	0.0000
s_6	0.0000
s_7	0.0000
s_8	0.0000
s_9	0.0000
s_{10}	0.0000
s_{11}	0.0000
s_{12}	0.0000
d_1	0.0000
d_2	6.8740
d_3	0.0000
d_4	16.0045
d_5	0.0000
d_6	1.1124
d_7	0.0000
d_8	48093.4300

Table10: Management Scientist Solution to the Secondary Goals (P_2) of the problem
Optimal solution:
Objective function = 48117.42091

Variable	value
$X_{1,1}$	64.4300
$X_{2,1}$	135.1400
$X_{3,1}$	141.4300
$X_{4,1}$	0.0000
$X_{5,1}$	0.0000
$X_{6,1}$	138.2900
$X_{7,1}$	0.0000
$X_{8,1}$	0.0000
$X_{9,2}$	102.1400
$X_{10,2}$	17.5290
$X_{11,2}$	39.2900
$X_{12,2}$	70.7100
s_1	0.0000
s_2	0.0000
s_3	0.0000
s_4	55.0000
s_5	12.5700
s_6	0.0000
s_7	139.8900
s_8	11.0000
s_9	0.0000
s_{10}	32.7610
s_{11}	0.0000
s_{12}	0.0000
d_1	0.0000
d_2	3.35600
d_3	0.0000
d_4	9.7240
d_5	0.0000
d_6	0.5597
d_7	0.0000
d_8	0.0000

INTERPRETATION AND DISCUSSION OF RESULT

Table 9 shows the management scientist solution to weighted/preemptive goal programming for the primary goals problem (i.e dropping the secondary goals in the objective function). It shows that all the primary goals were achieved this is so because all the values of $s_i = 0$, for i = 1,2,...,12, that is no volume of waste is left in the zones. This is also confirmed by the objective function value (0.0000), with d_2 = 6.874, d_4 = 16.004, d_6 = 1.1124 and d_8 = 48093.4300 showing that the secondary goals should be exceeded by ₦48, 093.43 which is required for additional 7 tippers, 1 front loader and 16 laborers to be hired.

Solution to the secondary goals problem was obtained when we modified the primary goals problem by introducing the condition that all the primary goals should be satisfied. The optimal solution to secondary goals problem is shown in Table 10. We see that the objective function value is 48,117.42, which indicates that the secondary goal can not be achieved, at the same time satisfying the primary goals.

If the priority of the agency is on level of evacuation to be achieved for the given amount of resource, Table 11 shows that additional 3 tippers, 1 front loader and 10 laborers should be hired from the N50, 000.00. All the waste in zone 1, 2, 3, 6, 9,11and 12 would be completely evacuated with 17.53m^3 in zone 10. Nothing would be removed from zone 4, 5, 7 and 8.

CONCLUSION

With the amount of N50, 000.00, 3 tippers, 1 front load and 8 laborers for evacuation of waste per day in Yola metropolis, the primary objective of evacuating the waste in all the zones cannot be achieved. However the results had shown that only zones 1, 2, and 3,6,9,11,12 can be completely evacuated with 17.53m^3 in zone 10. Alternatively to achieve the evacuation of all the waste in all the zones, it showed that an additional amount of N48, 093.43, is required to hire 7 tippers, 1 front loader, and 16 laborers.

If the agency is not satisfied with these results, a different set of weight/priority should be assigned to the goals/objectives. The agency must keep in mind that in any situation involving multiple goals at different priority levels; rarely will all the goals be achieved with existing resources.

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