American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-02, Issue-12, pp-214-224
www.ajer.org

Research Paper **Open Access**

Prediction and Evaluation of Collection Efficiency Of Municipal Solid Wastes Collection In Uyo Metropolis.

Obot E. Essien[1], Obioma C. Nnawuihie[2], Joseph C. Udo[3]
[1,2]Department of Agricultural and Food Engineering,
[3]GIS unit, Department of Geography and Regional Planning
University of Uyo, Uyo PMB 1014, Uyo Nigeria.

Abstract:-The collection efficiency of haul-container system for municipal solid waste collection in Uyo metropolis was evaluated based on the variables of operating time, dispatch time and loss time. Data on those variables were measured on the time-study of routes zones in Uyo using continuous stopwatch timing, and were analyzed for mean, standard, deviation, covariance, ANOVA and correlations. Regression models of efficiency on operation and loss times components showed efficient and significant association (R^2 =1.000, p < 0.01), High values of collection efficiency showed variation with route zone as precise predictive tool. Nutcliffe coefficient of performancewas used to test the goodness of fit. The coefficient of performance or efficiency varied differently with root zones and operation times in the order of: Zone 6 (98%) > zone 4 (80%) > zone 2 (60%) > zone 4 (40%). The variation in efficiency was affected by distribution of waste receptacle in route zone designs and time loss factors. Route zone design and dispatch station location whichwill effect close equalization of cycle time (dump-trip time) are recommended.

Keywords:- *Time study, municipal solid waste collection, haul-container system, route zones, operation hours, efficiency*

I. INTRODUCTION

Solid waste management is the application of techniques that will ensure the orderly execution of the basic function of collection, transportation, processing and disposal of solid wastes (Masters, 1991; Sincero and Sincero, 2006). Horsfall *et al* (1998) described municipal solid wastes (MSW) collection as those activities of orderly gathering of solid wastes and hauling to where the collection vehicle is emptied. Those functions are rendered in the best principles of public health, economic, ergonomic, engineering conservation, neighborhood aesthetics and other environmental considerations that regard public attitudes (George, 1977). The intent is to keep the environment clean, devoid of nuances and diseases (Henry and Heinke, 2005) or to improve neighbourhood aesthetics and reduce public health risk (US EPA, 1999; Gwinnett country, 2012).

Different designs of collection operation are available in developed economies aimed to improve collection efficiency. The use of haul container system (HCS), with one hauler per zone collection mode as introduced to Uyo municipality based on the unsatisfactory performances of previous methods (backyard wastes dump/burning and stationary container on curbsides system). Backyard waste dumping was in place prior to the new status of Uyo as capital territory (1987). With the urban development, fallowed patches of land, which received litters of yard waste,vastly disappeared making it difficult to litter wastes in patches of bushes and built up areas of the metropolis. Also, the once-a-month sanitation day cleaning-up exercise cleared gutters and brought out heaps of garbage, yard trimmings and other solid wastes, but the tipper lorries used for collection could not remove all the heaps of generated wastes, sometimes, weeks after generation, even till another mass waste cleaning-up sanitation day came around. That meant, in some cases, the heaps of wastes were left uncollected for one month after their generation on sanitation day. These were washed by runoff back into the gutters or, where possible, were openly burnt on the curbsides. The problems were alluded to insufficient tippers Lorries released on the sanitation day for collection and disposal, and lack of adequate crew volunteers, since the collection crew and equipment were based on voluntary participation. Thus, after the sanitation day, the tippers, which turned up for the exercise, were withdrawn by their owners and the collection crew had no motivation to continue on voluntary service. Thus, the generated wastes remained sometimes till the return of the next sanitation day. Recyclables were sorted by scavengers (sorters) at the dumpsite. Also, during the collection of heaps of wastes by the tippers on sanitation day, the crew spent time sorting the recyclables from the mixed wastes at the curbside, which action delayed rapid mounting of containers and making it difficult to complete collection on one sanitation day.

Uyo did not witness planned and scientific solid waste management programme hither to (Uwem, 2005). Although research and information data on waste management were scanty, there was a significant increase in the volume and composition of wastes generated daily in Uyo, as well as other major towns in the state (Uwem, 2005). Therefore, the use of haul container system (HCS) on one hauler per zone basis was expected to offset the failures of the previous methods and produced an efficient, effective and cost-effective solid waste collection by private agency handling of solid waste collection and transportation to disposal (Gwinnettcounty.com, 2012; NSWMA, 2012). Gwinnett country choice of hauler preferred one solid waste hauler per zone on the claims that it increased collection efficiency, limited truck traffic in residential neighborhood and reduced noise pollution (Gwinnettcounty.com, 2012). Also, it has been observed that outsourcing of MSW collection to private management resulted in money-savings and efficiency maximization (NSWMA, 2012; World Bank, 2000; Gwinnettcounty.com, 2012).

Therefore the objectives of the study were:

1. to analyze the time component of daily operation of MSW collection activities and time loses on HCS daily collection of solid waste to disposal at dumpsite in Uyo.
2. to evaluate the daily collection efficiency of the one hauler truck per zone operation by HCS,
3. to make recommendations for sustainable efficient MSW collection in Uyo.

II. MATERIALS AND METHODS

2.1 *Measurement of time of activities and distance*

Time study (work measurement) was applied. Time study is the art of observing and recording the time required to do each detailed element of an industrial operation, where industrial (product or service) includes manual, mental and machining operations (Sharma, et al., 2004;Nuutinon 2013). In this case, service industry was involved with manual and mental and driving operations which combined to drive the time of operation to unforeseen efficiency. Measurements of times of activities and distances moved were involved. Time involved was both the on-the-job activity time and non-job-related (or off-route) times (called time allowance).

The continuous method of stop watch timing was used formeasurement of time components all time elements of the chequered activities of municipal solid waste (**MSW**) collection and transportation to disposal operations at MSW dumpsite, Uyo. These times were used to compute cycle time (t_{net}). For time measurement, the stop watch was set at zero at the dispatch and pressed on at the release of the truck (s). Travel distances were measured by reading off the counter of the odeometer on the dashboard of the hauler truck. Counter checking was made at the "start" and "stop" schedules of each activity.

2.2 *Sampling Duration*

Four route zones were randomly selected in the study area, Uyo metropolis, Nigeria(Fig 1)for the time study of HCS collection in 2010 which lasted for 2 months in the wet season including June and July and two months in the dry season including active period of December and January at 2 weeks per months. The temporal staggering was to meet seasonality and festive periods as well as the cost and logistic implications especially as agreed by the MSW management contract service agency. The respective hauler trucks attached to the routes zones were identified as 046 for zone 2, 053 for zone 3, 060 for zone 4 and 072 for zone 6.Time for each activity in the operations were added up and averaged for each time element for computation of net cycle time, t_{net}, and time loss.

2.3 *Evaluation of operation times*

Totalavailable cycle time is the net travel time for a trip (or a collection cycle) (Sincero and Sincero, 2006; Dr McCreanor, 2008); Net time per trip is given as:

$$t_{net} = m_1 + h_1 + s + u + h_2 + m_2 + dl \qquad (1)$$

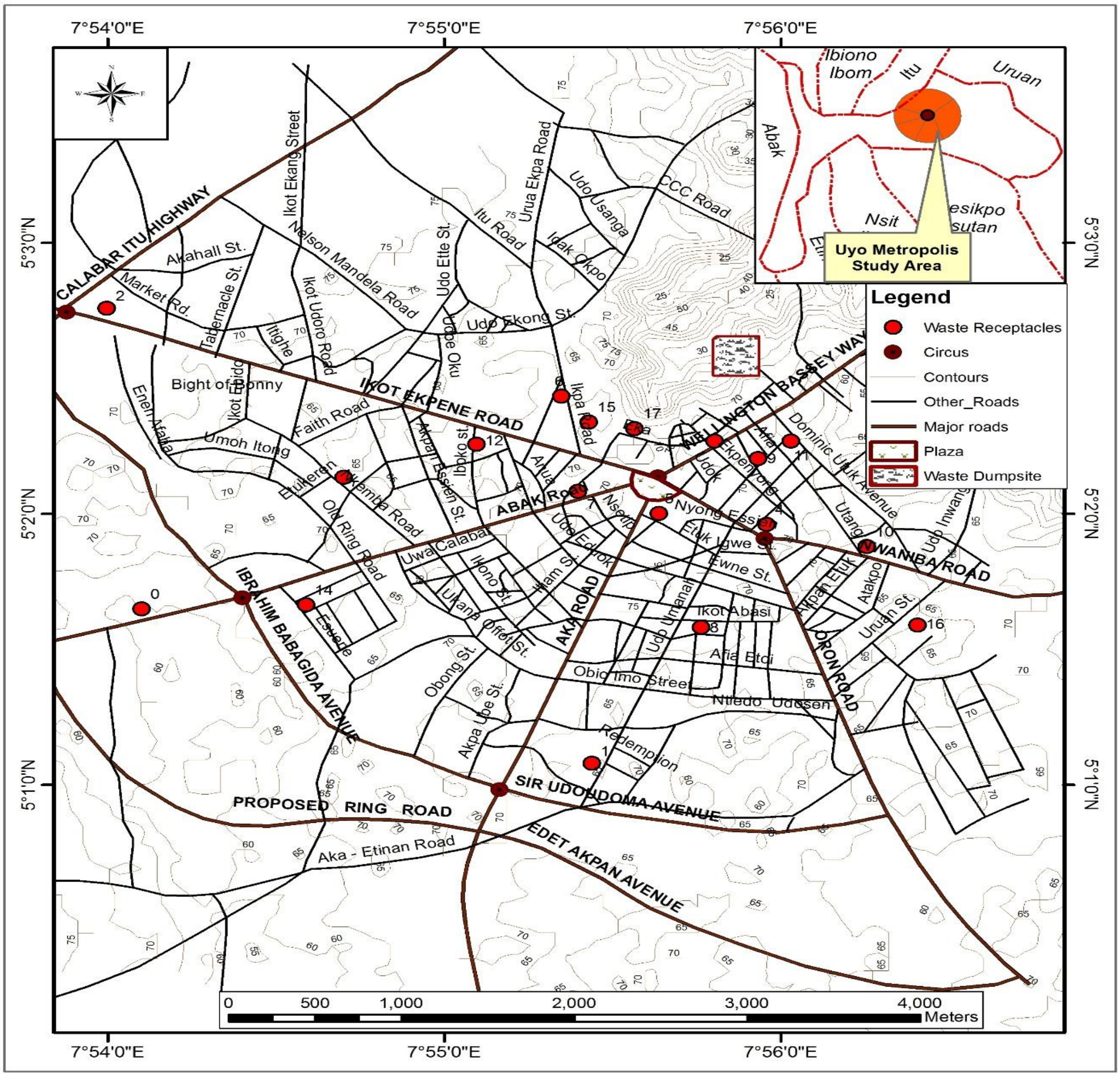


Figure 1: Showing municipal solid waste dumpsite and solid waste receptacle site in route zones in Uyo metropolis, Nigeria.

where m_1 is time taken to mount the used (or loaded) container into the collection truck at generation station; h_1 is the d time from the (container) station to disposal site with loaded containers, s is time taken to un-mount loaded truck at disposal site (mins), u is the time taken to mount empty truck at the disposal site, h_2 is time to drive back to the same container station with empty container, m_2 is the time taken to un-hitch the empty container at the same container before moving to the next station, and dl is the component time taken to move from the previous to the next container station, min. Total allowance,

T_L = total losstime $=\sum_{i=1}^{n}(time\ losses\ in\ trips)i$

Hence,

$$T_L = Dq + Bt + Dd + Hu + Dl + Ud + Dc \qquad (2)$$

where Dq is delay (queuing time) enroute the narrow lane to the dumpsite, min; Bt is extended break time by drivers to recover from mental/physical fatigue; Dd is dispatch delay caused by sudden truck break down; Hu is hold-up along the roads; Dl is extended lunch time break, Ud is unnecessary delay (e.g. for sorting or scooping of spilt waste) at collection stations; De is delay in evacuation; De is caused by insufficient trucks required to carry out round trip activities. Working period, H = total No of working hours per day; this is generally 8 hours per day. Operation hour = total available cycle hour, ho

ho = total work period /day – total time allowance

= total working hour/day – total timeloss

$$ho = H – (w + t_1 + t_2) \qquad (3)$$

where Total loss time Tι = $(w + t_1 + t_2)$, = w + t, where $t = t_1 + t_2$. (4)

*2.4**Evaluation of Efficiency***

HCS collection efficiency,

$$Ef = \frac{\underline{\text{total available cycle time per day}}}{\text{Total Work Period per day}} \qquad (5)$$

The stop watch measured the complete time for a cycle or trip, as wells as the loss of time (w) and the dispatch time (t). Thus,

$$ho = H – w – t. \qquad (6)$$

where,
Then, efficiency, $Ef = [ho/H] \times 100$, % (7)

$H = \sum^{i=n} t_{1i} - \sum^{n} t_{2i} - \sum w_i + ho$, hence, daily operating hour, ho is:

$$ho = H – (t_1 + t_2 + w) = H – t – w \qquad (8)$$

where
ho - operation time or total available cycle time
H - Working hours per day
t_1, t_2 = dispatch time from dispatch station to first container station (t_1), and time to return from last container station for the day back to dispatch station (t_2); $t = t_1 + t_2$ is overall dispatch time; w is loss time in the collection trips in a working day.

2.4.1 ***Precaution***: The following acts of caution were exercised:

1. the starting time at the dispatch station was the same for each day
2. fueling was served full tank at the dispatch stationbefore the start of the trips
3. checking on overall worthiness of each truck was made prior to releasing for theday's exercise
4. for less error in data, all members of team were briefed on rules or ethics and involvements before the survey started. How to measure time and distance using respective instruments were demonstrated.

2.5 Statistical Analysis

Descriptive statistics, covariance, reliability test, analysis of variance and test of significant differences were made with the use of SPSS software version 17: Correlation and regression analyses were used to modeled the relationship between operation time and efficiency.

III. RESULTS AND DISCUSSION

The results were obtained for cycle time of four trucks (truck 046, 053, 060 and 072) for five tripson week days and Saturday and are given in Table 1. Table 2contains values of collection efficiency and data of variables for computing efficiency of HCS pick-up truck.

3.1 Cycle time (tnet)

The data on elements forcomposing the net travel time, tnet (or cycle time) were averaged and summarized. Sample tnet for 5 trips are shown in Table 1 for Eighteen18 entries in 7 variables for the four trucks (046, 053, 060 and 072). The fastest truck was 072 with the least cycle time of 17.30 mins. The reason for this is not clear but cursory look at the area showed that the placement of receptacles were not deep into the largely community area because of the bad roads, as such solid waste burning went on at many roadside locations supposedly marked for waste containers but which stayed for days without being picked up. As such, fewer MSW were actually collected for disposal (175kg/km2 (Nnawuihe, 2006). The roads in this zone were largely not tarred compared to all other zones. Therefore, urban road development is needed in the communities making up this zone to improve collection.

3.2 *HCS Collection Efficiency*

***3.2.1 Time components affecting efficiency*:** Time components affecting efficiency are captured in the function (3) comprising dispatch times ($t_1 + t_2 = t$), non- job- related or off- routes loss w, and operating hour, ho.

Operation hour or total available cycle time (Sharma et al., 2004) varied amongst trucks or route zones, although not significantly being 6.06hr for truck 046 (route zone 2), 5.96hr for 053 in zone 3, 6.58hrsfor 060 in zone 4 and 5.21hrs for 072 in zone 6. Truck 072 (prowling the widest area,zone 6 (2.25ha))recorded the lowest mean daily operation hours (ho) of(5.21hrs) while truck 060, which covered one of the two smallest zones (1.0ha) but with greatest waste load capacity (1699kg) (Nnawuihe, 2006), recorded the highest mean daily operation hour (6.58hrs) followed by truck 046 with ho = 6.06hrs.

Figure 2 shows the component mean time distribution pie charts with mean time distribution in percentages. Dispatch time occupied between 5 and 6% of the time with 046 having 6%, and 053, 060 and 072 individually having 5%. The loss time varied significantly (P = 0.05) between the zones or truck operations, being 19% for 046, 20% for 053, 7% for 060 and 30% for 072. This is very reasonable account especially as truck 072 in the widest zone had the highest loss time. The operation time (ho) distribution in daily solid waste collection operation also had a significant variation or difference (P= 0.05) with 046 having 75% of the working hour of the day, 055 with 75%, 060 with 88% and 072 with 65% (the smallest)(Figures 1 and 2)

3.3 HCS Collection Efficiency, Ef

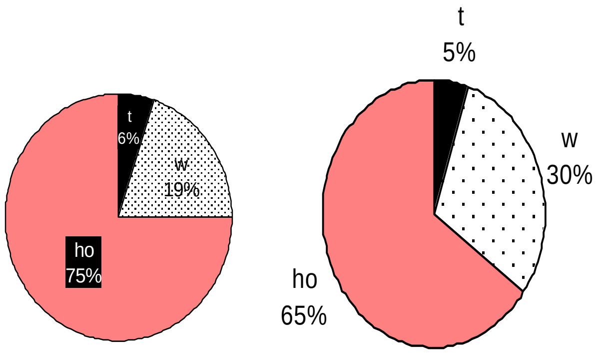
The collection efficiency of the Haul container system of municipal solid waste management was related to total available cycle time or operation hour ho as in (7**).** The computed values of efficiency are shown in Table 3 while Figure 3 shows, in composite charts and comparatively, the efficiency and deficiency of route zone solid wastes collection by HCS pick-up trucks.

Daily collection efficiency varied significantly with, travel time components, hence with total available cycle time (**ho**), loss time (**w**) and total dispatch time (**t**); as well as with route zone. For truck 046 (route zone 2), average daily Ef was 79%; while it was 75% for truck 053 (route 3), 82% for truck 060 (route 4) and 65% for truck 072 (route 6) (Table 2). The hierarchy of efficiency was in the order: truck 060 > 046 > 053 > 072, and showed truck 060 to be the most efficient collector having the highest efficiency (82%). Truck 072 also had the lowest average efficiency as well as the lowest $\mathbf{t_{net}}$ and **ho**. Collection efficiency varied with daily cycle time in the order: 072 < 053 < 046 < 060 (Table 2), which is the same sequence as efficiency. However, variation of efficiency with loss time (w) and dispatch time **(t)** did not follow the above observed pattern, hence regression analysis was used to understand their relationships. The variation of efficiency with total daily t_{net} time showed significant difference between the values for five week days (Mondays, Tuesday, Wednesday, Thursdays and Fridays), although a definite pattern was not observed, except that for some route zones and trucks like 060, 053 and 072 loss time and total loss time were highest on Tuesdays while for 046, in particular, highest loss times and total loss time were sustained on Mondays. These significant differences or variations made it necessary to use multiple regression analysis to understand their relational effect on HCS MSW collection efficiency.

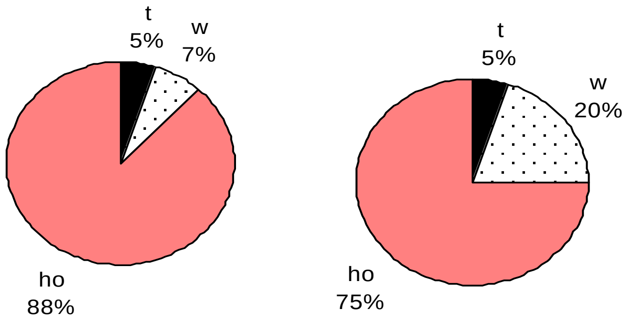
Table 1: Cycle time for individual trips, t_{net} from travel time Componentsand total net time for solid waste collection

Trucks/Day	Trip1	Trip 2	Trip 3	Trip 4	Trip 5	Hr
046						
M	24.60	21.20	24.30	18.80	24.3	1.20
T	29.35	24.25	20.25	13.10	21.2	1.20
W	26.09	22.35	21.30	13.15	21.13	1.45
T	27.38	22.27	18.57	12.58	22.70	1.49
F	25.35	19.57	23.38	22.32	24.1	1.31
S	24.54	19.30	18.11	14.50	15.52	1.32
072						
M	18.0	14.80	17.60	14.33	15.32	1.19
T	19.29	16.32	17.21	16.38	15.35	1.26
W	16.50	17.08	16.35	18.55	16.33	1.29

T	23.10	17.32	16.33	16.00	16.22	1.30
F	19.37	16.02	19.08	19.53	20.15	1.34
S	21.70	17.38	14.12	1618		1.10
060						
M	24.80	29.80	23.02	25.02	25.37	2.70
T	25.47	23.37	23.33	27.13	17.5	1.57
W	25.37	24.50	26.43	23.90	23.48	2.03
T	20.40	24.33	24.15	25.80	24.25	15.8
F	18.15	24.43	23.22	21.40	20.17	1.48
053						
M	24.33	23.28	28.35	22.60	20.58	1.22
T	24.02	21.28	23.38	23.60	20.48	1.53
W	26.25	36.50	26.45	22.08	24.47	2.16



Truck 046: route zone 2 **Truck 072: route zone 6**



Truck 060: route zone 4 **Truck 053: route zone 3**

Figure 2: Percentage mean time distribution in HCS solid waste collection inrespective route zones for pickup trucks 046, 072, 062 and 053.

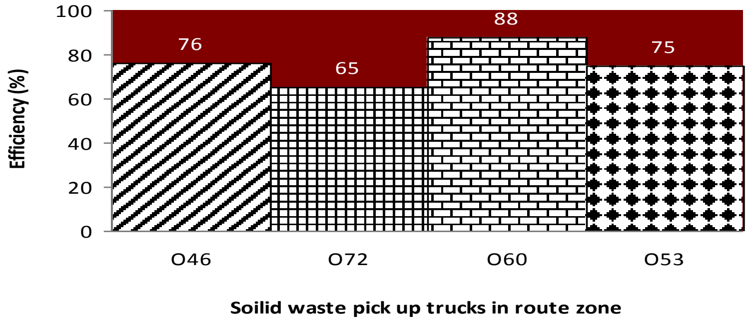


Figure 3: Comparative efficiency(shaded area) and deficiency (brown area)of waste collection in route zones by HCS pick up trucks

Table 2: Dispatch time, non job activity time, total time loss, operation time and collection efficiency in HCS MSW collection in route zones, Uyo

Truck/day	Dispatch time, T, Hr	Loss time W, Hr	Total loss time Tι, Hr	Operation Time Ho, Hr	Efficiency Ef%
060					
M	0.483	1.683	1.866	6.32	**79**
T	0.350	1.819	2.169	5.83	**73**
W	0.350	0.660	1.010	6.99	**87**
T	0.383	0.870	1.253	6.75	**84**
F	0.350	0.660	1.010	6.99	**87**
Avg	**0.380**	**0.570**	**0.950**	**0.58**	82
053					
M	0.517	1.222	1.74	6.26	**78**
T	0.350	1.683	2.03	5.97	**75**
W	0.217	1.633	1.85	6.15	**77**
Avg	**0.360**	**1.513**	**2.04**	**5.96**	77
046					
M	0.508	2.747	3.255	6.06	**76**
T	0.425	0.887	1.312	6.69	**84**
W	0.410	0.973	1.433	6.57	**82**
T	0.483	1.775	2.175	5.83	**73**
F	0.450	1.063	1.513	6.49	**81**
Avg	**0.455**	**1.489**	**1.938**	**606**	79
072					
M	0.383	2.433	2.816	5.184	**65**
T	0.450	2.732	3.820	4.818	**60**
W	0.482	2.101	2.583	5.417	**68**
T	0.332	2.849	3.181	4.819	**60**
F	0.316	1.899	2.215	5.785	**72**
Avg	0.393	2.403	2.923	5.21	65

NB: Total loss time = t + w

3.4 Regression Analysis

Using the data for total loss time **(w)**,dispatch time (**t**), and total available cycle time **(ho)**, (Table 2), multiple variables regression equations were modeled for collection efficiency as a function of (**t, w, ho**). The coefficients of the general multiple regressional equations are tabulated in Table 3 for trucks 046, 053, 060 and 072. The general form of regression equations for collection efficiencies under travel times of trucks 046, 053, 060 and 072 in their respective zones were obtained by substituting the coefficients into the general regression model of collection efficiency. Thus, the general regression equation for collection operation by each truck using average of values was:

046; Ef = 3.297 T + 4.992W + 17.339ho – 3.5,279, $R^2 = 1$, $p <0.05$ (8)
053; Ef = 0.583T + 0.583W + 10.680ho + 11.442, $R^2 = 1$, $p < 0.001$ (9)
060; Ef = 2.176T + 1.062W + 13.130ho – 4.720, R^2=1.000, $p < 0.01$ (10)
072; Ef = 2.547T + 0.2547 W + 12.670ho – 1.941, R^2=.9988 (11)

Table 3: Regression model coefficients for efficiency-time relationship, coefficient ofdetermination (R^2); ANOVA and significant differences

Haulage truck	Model predictor and parameters	Unstandardized	Coefficients	t- statistics	Sig	Remarks
046	Constant	35.279	39.300	-898	Ns	**P = 05**
	T	-3.297	13.489	-244	Ns	**P =005**
	W	4.992	6.178	-808	Ns	**P = 05**
	Ho	17.339	5.574	3.111	Ns	**P = 05**
	R^2	1.000				
	Adj R^2	0.999				
	f-ratio	1416.940			.05	**P = .05**
053	Constant	11.442	.000			
	T	-583	.000		.000	
	W	(excluded)				
	Ho	10.680	.000			**P < 001**
	R^2	1.000				

	Adj R^2					
	f-ratio					**P < .001**
060	Constant	-4.720	.000	-7.016E+ 05	Ns	
	T	-2.176	.000	-8.056E+05	Ns	
	W	1.062	9.745E07	1.90E + 06	Ns	
	Ho	13.130	.000	1.313E+07	Ns	
	R^2	1.000				
	Adj R^2	1.000				
	f-ratio					**P<.001**
072	Constant	-1.941	2.233	-869	Ns	**P=.05**
	T	2.547	2.096	1.215	Ns	**P = 05**
	W				.000	**P< 001**
	Ho	12.670	0.367	34.478	.001	**P < 0.001**
	R^2	998				
	Adj R^2	977				
	f-ratio	**611.581**			**.01**	**p < 0.01**

Ns = not significant

Using ANOVA and f-ratio, the following effects of the groups of variables on efficiency were tested. For truck 046, the differences between the groups of variables (**t, w, ho**) were significant effect on efficiency at p= .05, and R^2 = 100%, adjusted R^2 = 99.99%, in which case the variance between the variables completely explained any difference in efficiency. For truck 053, the variables (**t, w, ho**) had very significant effect on efficiency at $p < 0.001$. For truck 060, the variables highly influenced the efficiency ($p < 0.001$) and the within- sample error was not significant such that the association between the predictors and efficiency was completely (100%) explained by any variances between variables (thus, R^2 = 100%, Adjusted R^2 = 0). For truck 072, the differences between the groups (**t, w, ho**) were very significant ($p < 0.01$) and they explained the 99.8% effect on efficiency (R^2 = 99.8% adj R^2 = 99.9%). The 02% unexplained coefficient was an significant error variance in ho (p <.001). In general, the efficiency was completely dependent on the three independent variables (R^2 = 99.9- 100%). Also there was a perfect correlation between the predictors (variables) and the efficiency (r = 0.999 -1.000).

3.5 *Predicted Efficiency, Ep*

The predicted efficiency Ep was obtained by substituting the daily average time elements (**t, w, ho**) (Table 4) into the respective general regression model of HCS collection efficiency (Equations8, 9, 11). Predicted daily collection efficiency (Ep) are presented in Table 4

Table 4: Predicted daily collection efficiencies from regression model for route zone truck operation.

Predicted Efficiency				
Day/Truck	**046**	**053**	**060**	072
Mon.	82	79	80	**65**
Tue.	84	76	74	**61**
Wed.	82	78	88	**68**
Thu.	73		85	**61**
Fri.	81		888	**73**
Avg	**76**	**77**	**82**	**66**

3.5.1 Overall Collection Efficiency:The data for each predictor time element from all zones (**t, w, ho**) were merged into one list for each time element and regressed on Ep using into SPSS version 17 software windows, to obtain the all zones predictive model for overall (or all-zones collection) efficiency, (E_Z) was obtained as:

$E_Z = 0.127t + 0.273w + 12.721ho – 1.881$, R^2 = 99.9% (12)

and adj. R^2 = 0.999 also, which indicated a very perfect relationship, and Se = 0.28523. The low Se indicated that the use of all-zones time variables for predictive efficiency model offered better time-based overall predictive collection efficiency than using singular zonal predictors (time element). ANOVA and F-ratio of 5870.796 indicated significant differences ($p<0.01$) with the between-variables being greater than the within-variables, which also means that the variance between the three groups of variables affected the efficiency prediction more than the within - variable variance (Ofo, 2000). No significant differences existed in the predictors (P = .05), except Ho at $P < 0.01$, and Cv = 5%. The all-zones predicted efficiency was 76%.

3.6 Validation

The validity of the predictive models of collection efficiency was tested using parametric test on the field computed (Ef) and predicted (Ep) efficiencies for each truck or zone. The following parameters were used for the tests:

1. Nash Sutcliffe coefficient (Nash and Sutcliffe, 1970 also called coefficient of performance efficiency, COE is

$$COE = 1 - \frac{\sum_{i=1}^{n}(Oi - Pi)^2}{\sum_{i=1}^{n}(Oi - Om)^2} \qquad (13)$$

2. Average error of Bias, AEB

$$AEB = 100 \text{ x } [1/n\sum^{n}_{i=1} (P_i - O_i)^2]^{1/2} / [O_m] \qquad (14)$$

3 Coefficient of residual mass, CRM

$$CRM = \frac{\sum_{i=1}^{n} Oi - \sum_{i=n}^{n} Pi}{\sum_{i=1}^{n} Oi} \qquad (15)$$

where O_i, O_m, P_i are respectively the measured, mean, and predicted data, and n is the number of data from i =1 to i = n. In addition, coefficient of variation (**Cv**), and root mean squared error (RMSE) were used to analyzed variances or mean differences between field measured **(Ef**) and predicted (**Ep**) efficiency.

The values Ep were plotted against those of **Ef** and their (goodness of fit) varied with the truck and route zone. The graphs are showed in Figures 4 a, b, c and d for truck 046, 053, 060 and 072; and Figure 5 for overall zone (or all-zones) average collection efficiencies. The profiles of Ep and Ef showed perfect goodness of fit hence the model coefficient of performance was very efficient and reliable for efficient prediction of effect of travel time or operation times on collection efficiency of haul container system collection of municipal solid waste in Uyo metropolis. The statistic of efficiency model characteristics are shown in Table 5.

Table 5: The characteristics of goodness of fit of the efficiency curves.

Statistics	046	053	060	072
RMSE	2.622	0.78	2.41	**2.09**
AEB	1.17	0.78	2.02	**0.56**
CRM	- 0.015	-0.012	- 0.013	**- 0.01**
CV, %	3.5	1.0	2.9	**1.0**
COE, %	**60**	**40**	**80**	**98**

The goodness of fit shows the time-based efficiencies for trucks 060 and 072 to be very superior, to all others, that fortruck046 was good, while it was just fair for truck 053. The performance of truck 053 would need more data to improve its predictive model.

IV. CONCLUSION

The operation and loss times and efficiencies of the haul-container system collection and disposal of the municipal solid wastes in the challenging route zones in Uyo metropolis wereinvestigatedusing the strategy of one pick-up truck per route zone under private agencyconsultancy management. The time study utilized the continuous method of stop watch timing for the sample field survey for timing of all the job-based activities and the non-job-related time losses for four trucksin four zones (2, 3, 4, and 6).

The one-haulage-truck-per-route-zone MSW collection strategy worked successfully and efficiently;the collection efficiency ranged from 65% for truck 072 (zone 6),77% for truck 053 (zone 3),79% for truck 046 (zone 2) to 82% for truck 060(zone 4),in Uyo metropolis. The overall Net travel time, time varied (withzone)in the order: zone 3 (24.21) > zone6 (23.83) > zone 2 (23.50) > zone 4 (17.30mins). ANOVA showed very significant difference ($p < 0.001$)in w and ho for truck 072 and in t for truck 053. The collection efficiency ranged from 65% for truck 072 zone 6, 77% for truck 053, zone 3, 79% for truck 046, zone 2 to 82% for truck 060, zone 4; and showed perfect association very high goodness of fit with predicted efficiencies obtained from regression equations.

The goodness of fit indicated efficient prediction of MSW collection for truck 072 (98%), 060 (80%) and 046 (60%).however its prediction for truck 053 was imprecise (40%) and more data are required to enrich analysis in future. Also, receptacles distribution and paved roads are needed for better collection efficiency. The overall collection efficiency of 76% is very good performance.

Fig. 4 (a): Observed and predicted efficiencies for truck 060 in route zone 4

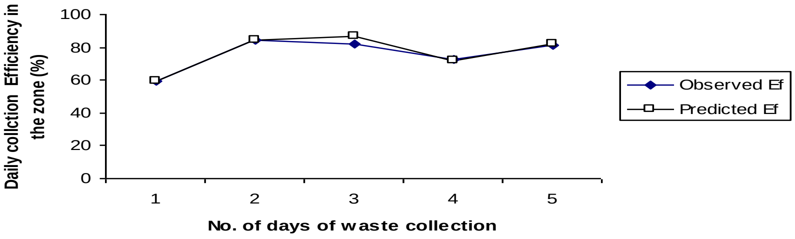


Fig. 4 (b): Observed and predicted efficiencies for truck 046 in route zone 2

Fig. 4 (c): Observed and predicted efficiencies for truck 072 in route zone 6

Fig. 4 (d): Observed and predicted efficiencies for truck 053 in route zone 3

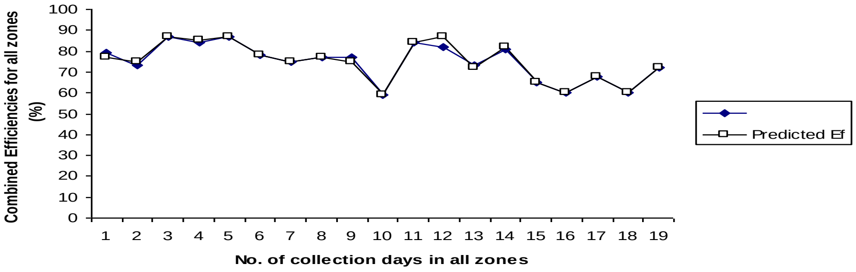


Fig. 5: Combinedobserved and predicted efficiencies for all zone

REFERENCES

[1]. Banga T. R., Agarwal N. K. and Sharma S. C. 2004. *Industrial engineering and management science*. Khanna Publishers, New Delhi 110006, pp 49-80.

[2]. Cointreau S., Gopalan, P. and Coad, A. 2000. *Private Sector participation in municipal Solid waste management* toolkit. Guidance pack, World Bank Group. worldbank.org/INTURBANDEVELOPMENT/Resources/3336387-1249073752263/6354451-1244073991564/aiel

[3]. Environmental Research and Education Foundation, 2001. *Size of the United States Solid Waste Industry*. R.W. Beck and Chartwell Information Publishers.

[4]. Gwinnet county com. 2012. *Frequently Asked Questions*, Gwinnett County, GA.

[5]. mht.gcsolid@gwinettcounty.com.; GwinnettcountyGAFrequently Asked Questions.mht..

[6]. Henry J. G. and Heinke G. W. 2005. *Environmental Science and Engineering*, 2nd Ed.,

[7]. Prentice Hall of India , New Delhi 110001, 778p.

[8]. Horsfall, M. Jnr. and Spiff, A. I. 1998. *Principle of Environmental Studies in Physical, Chemical and Biological Emphasis*. Metro Prints Ltd, Port Harcourt, Nigeria

[9]. McCreanor, Dr. 2008. Lesson 6. *Solid waste collection.* Available at the http://faculty.mercer.edu/McCreanor-pt/eve420/les Accessed 2/2/2010

[10]. Mehdian, M. H. and Fallichard, J. 1995. Validation of the SUBSTOR Model for Simulating Soil Water Contents. *Transaction of the American Society of Agricultural Engineers*. 38: 513-520

[11]. Morristown to Outsource Garbage Pickup Services, 2011. *Morristown Patch*, February 2011.

[12]. http://morristown.patch.com/aiticles/morristown-to-outsource-garbage-pickup-services.

[13]. National Solid Wastes Management Association (NSWMA), 2012. *Privatization: Saving money, maximizingefficiency and achieving other benefits in solid waste collection, disposal, recycling*. National Association of Solid Waste Management. 4p. www.environmentalistseveryday.org/privatization.

[14]. Nnawuihe O. C. 2006. *Evaluation of haul container system of solid waste disposal in Uyometropolis*.B.Sc.project, Faculty of Engineering, University of Uyo, Uyo.Ofo, J. E. 2001. *Research Methods and Statistics in Education and Social Sciences* .Joja Educational Research and Publisher Ltd, Lagos, Nigeria, 311p

[15]. SWANA. 1997, Integrated municipal solid waste management: six case studies of system cost and energy use. *Summary Report*. Solid Waste Association of Northern America (SWANA), GR-G 2700

[16]. US EPA .1999$_{a..}$*Collection Efficiency: Strategies for success*. US Environmental Protection Agency. No. EPA530-K-99007. www.epa.gov/osw/nonhaz/municipal/landfill/coll-eff/k 99007.pdf

[17]. US EPA. 1999$_{b..}$ *Getting more for less: improving collection efficiency*. US Environmental Protection Agency. No. EPA 530-R-99-038. www.epa.gov/osw/nonhaz/municipal/land fill/coll-eff/r99038.pdf

[18]. US EPA, 2011. Municipal Solid Waste in the United States: 2010 *Facts and Figures*, Office of Solid Waste, US EPA, Washington D.C.

[19]. http://www.epa.gov/epawaste/nonhaz/municipal/msw 99.htm.

[20]. World Bank, 2000. Private Sector participation in municipal solid waste management toolkit, World Bank. http://rru.worldbank.org/Toolkits/SolidWasteManagement.

[21]. World Bank Group, 2000. *Urban solid waste management. Promote micro - enterprise as part of poverty reductionstrategy*. World Bank Group. http://web.worldbank.org/WEBSITE/EXTERNAL/TOPICS/EXTURBANDEVELOMENT/EXT

[22]. World Bank Group - what a waste: Global review of solid waste management. Urban *Development Series-Knowledge Papers*. http://siteresources.Worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/chapt4.pdf

[23]. Worldbank.org/In turbandevelopment/Resourbes/3336387-1249073752263163544 51-1244073991564/Aiello.pdf

[24]. NSWMA and WASTEC. 2011. Privatization of trash collection, disposal and recycling. The Environmental Industry Association (EIA). The Environmentalist Every day.

[25]. www.environmentalistseveryday.org/publications-solid-waste-industry-research/index.php

BIOGRAPHICAL NOTES

1. Dr.O. E. Essien received his B. Sc. (Agricultural Engineering) in 1978 and Ph.D. (Agricultural Engineering) in 2004 from University of Ibadan. He is anAssoc. Professor in the Department of Agricultural and Food Engineering, University of Uyo. He is a fellow of Nigerian Institution of Agricultural Engineers (NIAE). He has many publications in the area of Environmental water quality, soil and water conservation Engineering, amongst others. He designed and supervised the research study and wrote the article.
2. O. C. Nnawuihe is Agricultural Engineer, University of Uyo, Uyo. He carried out data collection along with others in the field.
3. Dr. J. C. Udo is a specialist in GIS and lectures in the Department of Geography and Regional Planning, University of Uyo. He produced the GIS map for this study.