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Estimating Time Loss Effects On Municipal Solid Waste Collection Using Haul Container System In Uyo Nigeria

Obot E. Essien[1], and J. C. Udo[2]

[1]*Department of Agricultural and Food Engineering, University of Uyo, Uyo, P.O. Box 1014, Uyo, Nigeria. Postal Code 52001.*

[2]*GIS Section, Department of Geography and Regional Studies, University of Uyo, Uyo, Nigeria.*

Abstract: - Time loss in time and motion study of the collection of municipal solid waste in Uyo metropolis was observed to affect the round-trip time, the solid waste generation rate and the collection efficiency of the haul container system of solid waste management, and hence needed information to drive control or reduction in the service. The result showed that its effects depended on the truck, route zone and operators skill in maneuvering the routes to reduce the dead ends and waste hours. Seven components of time losses with values ranging from 7 to 40 minutes per trip were measured, giving valuable total times loss per service truck per day as 2.0 hr for zones 2, 3 and 6, and 1.95hr for zone 4. The time loss for collection efficiency showed significant difference (P = 0.05) between zones and trucks, and varied as 19%, 20%, 7% and 30% for trucks 046, 053, 060 and 072 used in zones 03, 02, 04 and 06 respectively. Trucks for zones 05 and 01 were invalid. The available time was thus reduced. With average cycle time of 17.30 min to 24.21 min per trip, such loss time, in turn, reduced collection efficiency by 20 to 25% per truck thereby reducing the total trips and daily turnover. Recommendations include micro-routing principles, operators' motivation with team spirit and avoidance of observed start-up delays. Also route re-design of more dense zones and sparsely populated zones are recommended in order to bring trip time to near equality.

***Key words*: -** *Time allowance, time loss, solid waste collection, municipal solid waste, collection efficiency, round trip time, route zones.*

I. INTRODUCTION

Efficiency of municipal solid waste collection is a time function of cycle time and loss time in an operation day. In solid waste collection operation of conventional haul-container system, one loop round trips or cycle time comprises the time spent on/or appropriated for lifting of one container load of generated solid wastes at a container station to the disposal site and return with an empty or used container to the waste generation site (i.e. pick-up station), then moving to the next station to repeat the same time-based set of motion and spot actions (activities) [1, 2].

Therefore in a nominal working day of fixed work period, the number of travel loops or cycle times completed within the work period is predicated on the deficiency factor or time allowance that quantitatively reduces the proportion of a working day available for the maximum travel cycles attainable. Thus a certain number of cycles of solid wastes collection, transportation and disposal is only optimum when the deficiency factor tends to zero. When repetitive work cycles or sequence of repeated work phases of short to long duration are involved, useless time consumption are studied and eliminated [3, 4]. The optimization of productive collection hour by deficiency factor tending to zero is what the evaluation and standardization of repetitive job standard cycle time evaluated aims at [4]; and this is applicable to collection operation of Haul Container System (HCS) since the method is not changing but repeated.

The time available for optimal cycles when deficiency factor tends to zero is a full working day. But as the deficiency factor (or loss time) is not zero where work is executed, then the maximum total cycles of waste collection to disposal per working day is diminished by total time allowance, or is subject to the total available cycle time which is the work period less the total time allowance [5], i.e.

$$\boxed{\text{Total available cycle}} = \boxed{\text{Total work period}} - \boxed{\text{Total time allowances}} \quad (1)$$

Hence, efficiency of solid waste collection service, which is the total available cycle time per work period, and, as such, is a productivity coefficient, is factored by the time allowance (time loss) in a daily solid waste collection, transport and disposal activities cycles.
Hence, from Equation 1, time-based solid waste collection efficiency is

$$\boxed{\text{Optimal Efficiency}} = \boxed{1 - \frac{Total\ Time\ Allowance}{Total\ Work\ period}} \quad (2)$$

Time allowance comprises different deficiency occurrences involving machine worthiness, environmental factors causing travel interruptions and delays, and human operators' factors (skill, integrity, diligence, fitness). These are not fixed values, hence their combination imposes unpredictable effect on the availability of time for actual solid waste collection service, which affects adversely collection efficiency under conventional haul-container system (HCS) of solid waste management, or any travel management system for that matter.

Efficiency means getting more for less: picking more solid wastes or recyclables using fewer trucks, fewer people or less time [6]. The implication of loss time is that it would need extension of time (working day) to collect the nominal quantity of waste or attain the nominal cycles of waste collection than could be achieved without occurrence of loss time or when loss time is negligible. Such extension of working day in the circumstance of waste collection would be counter-purpose to implied collection efficiency and haul container system management, and should not be contemplated upon. Since the primary aim of HCS is ensuring efficient collection by removal of generated garbage and other solid wastes from the community or locality to ensure elimination of environmental contamination and protect environmental aesthetics and public health in a less-costly operation, the uncertainty of time loss might make the realization of their aim and efficiency elusive. Hence, the rising need to investigate and quantify these impacts of loss time in the present system of haul container solid waste management in the metropolis since no standard data is available for any such service evaluation and improvement in order to benefit the environmental sanitation and public health, and work standardization [4].

Therefore, the time study objectives were to:

1. Measure the time loss in solid waste collection of HCS in the urban collection metropolis and
2. Evaluate the time loss impact on collection service capacity and efficiency, and
3. Ascertain prospects of improvement.

II. MATERIALS AND METHODS

Work measurement techniques was used. It consists of careful time measurement of the task with a time measurement instrument for a comprehensive time loss study. The time study, according to good practice guidelines for productive studies comprised, in addition to good setting, experimental design, time data collection, data analysis and discussion [7, 8].

1.1 Experimental Design: Time Study area.

The study was done in Uyo metropolis, the urban area of Akwa Ibom State capital territory, Nigeria. The expanding urban-rural fringe are not comprehensively addressed presently. Four (4) route zones out of the six (6) presently operating were plied. The other two route zones had certain un-cleared handicaps. One truck was assigned to each route zone per day. The process was to take a truck on a route zone to a municipal waste generating station, load off the solid waste into a container and haul it to a dumpsite; empty and hitch back an empty container to the generator location before moving to the next station to repeat the same set of component activities in the collection process. Thus, the task involves a repetitive set of activities of short or long duration with time losses in between them. These are to be measured and effects evaluated. For commonness purpose, timings for the first five trips were measured and used for time loss analysis. From here, projection for the number of trips per day was made and used for efficiency analysis. The initial five trips timing was replicated for 5 days to minimize or eliminate human error of visual observation of instrument dial.

1.2 Time data collection

Time and motion data were captured with an electronic stop-watch using the continuous stop-watch reading method [5, 8]. In the continuous method, the stop watch was allowed to tick continuously and at the end of each element of operation (motion or activity) reading of the stop watch was made and recorded in a time study register. The time required for each particular element of the operation, the previous reading (i.e. before stepping into that activity) was subtracted from the next reading (i.e. reading at point of stepping out of that activity).

Set out rates

The set out capacity for each truck was the haul container heaped up or closed – cover volume, which was made up as follows;

Volume = length x width x height + ridged cover = $4.063m^3$

2.3 Evaluation of conventional HCS systems [8].

The round trip or cycle time for HCS collection of solid waste to disposal comprises the following in chronological order:

t_{pc} = time to pick up loaded or community bin of solid waste at first container Station

t_{h1} = time to haul loaded container from container station to disposal site

t_{ss} = time spent at disposal site (unloading waste container and re-attaching empty container)

t_{h2} = time spent returning empty container from disposal site back to some container station.

t_{uc} = time to un-mount empty container back at same container station

t_{dbl} = time to drive between container locations.

Therefore cycle or round trip time is

$$T_{cycle} = t_{pc} + t_{hi} + t_{ss} + t_{h2} + t_{uc} + t_{dbl} \quad (3)$$

III. EVALUATION OF TIME ALLOWANCE

The possible time losses encountered in a cycle of solid waste collection are as follows (IIE ANSI, 1982).

D_t = dispatch delay caused by sudden truck break down (maintenance factor time). This is incorporated in dispatch time, ti

D_b = extended break time by drivers to recover from fatigue (human factor time)

D_u = hold up along major (transit) roads (interruption time)

D_d = unnecessary delays (e.g. time for source sorting or scooping spilt waste at community bin station into the container haulage to disposal site. (This was very common).

D_v = delay in load evacuation, caused by insufficient trucks required to replace loaded container at disposal site

D_q = delay (or queuing time) enroute the narrow lane to dumpsite.

Unit of time was minutes. Then the loss times was

$$\text{Time Allowance} = D_b + D_d + D_l + D_q + D_u + D_v \quad (4)$$

2.4 Evaluation of efficiency

Collection efficiency (Ec) or service productivity (Cp) was computed as

Service productivity or productive hour Cp [5] is

$$Cp = \frac{\text{Total available cycle time, min/day}}{\text{Number of hours (or work period), hours}} \quad (5)$$

Total available time or round trip time was obtained from measurement and using equation (3)

Collection efficiency (Ec) is given as in equation (1) in terms of time allowance factor,

$$Ec = 1 - \frac{\text{Total time allowance}}{\text{Total work period}} \quad (1)$$

Total work period was 8 hours and total time allowance was obtained from measurement and using equation (4)

2.5 Evaluation of generation rate

$$\text{Generation rate} \quad K = \frac{\text{Collection load}}{\text{Total Available Time}} \quad (6)$$

Or in terms of loss time , (Tl),

$$K = \frac{\text{Daily waste collection load per truck}}{\text{Total work period} - \text{Time loss (Tl)}} \qquad (7)$$

When K >1, more trucks are needed.

Rate of solid waste collection and disposal (Qe).

Rate of municipal solid waste evacuation or collection and disposal by a collection truck per day was computed as

$$Qe = \frac{\text{Average weight of solid waste}}{\text{Average Cycle Time (tnet)}} \times \text{Number of trips} \qquad (8)$$

IV. RESULTS

The measured and computed values of cycle time and loss time were as tabulated below.

3.1 Travel (Cycle) Time

The component time-based activities were measured and their time values are as given in Table 1.

Table 1:Summary of cycle time per trip for HCS collection trucks

Truck	Day/Trip	1	2	3	4	5	Avg/Trip	Sd
46	Mon	24.6	21.2	24.6	18.8	24.3	22.7-	2.61
53		24.3	23.4	23.4	23.6	20.6	23.06	1.42
60		24.8	29.4	23	25.4	24.4	25.40	2.40
72		18	14.8	17.6	14.3	15.3	16.00	1.69
Ag/Trip/Truck		22.93	22.20	22.15	20.53	21.15	21.7	-
Sd		3.29	6.03	3.11	5.00	4.28	-	-
t								
46	Tue	29.4	24.3	29.4	13.1	21.2	23.48	6.78
53		29.4	24.3	29.4	13.1	21.2	23.48	6.78
60		29.4	23.4	23.3	27.1	17.5	24.14	4.52
72		19.3	16.3	17.2	16.4	15.4	16.92	1.48
Ag/Trip/Truck		26.88	22.08	24.83	17.43	18.83	22.01	-
Sd		5.05	3.87	5.84	6.63	2.87	-	-
t								
46	Wed	29.9	21.4	26.9	13.2	21.4	22.56	6.38
53		26.3	36.5	26.5	22.1	24.5	27.18	5.50
60		25.64	24.5	25	23.1	23.5	24.35	1.05
72		16.5	17.1	16.4	18.6	16.3	16.98	0.96
Ag/Trip/Truck		24.59	24.88	23.70	19.25	21.43	22.7	-
Sd		5.71	8.32	4.93	4.47	3.65	-	-
t								
46	Thur.	27.4	22.3	27.4	17.6	22.7	23.48	4.10
53		-	-	-	-	-	-	-
60		20.4	24.3	25.1	25.1	24.3	23.84	1.96
72		23.1	17.3	16.3	16	16.2	17.78	3.02
Ag/Trip/Truck		23.63	21.30	22.93	19.57	21.07	21.7	-
Sd		3.53	3.61	5.86	4.86	4.29	-	-
t								
46	Fri.	25.4	29.6	25.4	22.3	24.1	25.36	2.69
53		-	-	-	-	-	-	-
60		18.2	24.4	23.2	21.4	20.2	21.48	2.44
72		19.4	16	19.1	19.5	20.2	18.84	1.64
		21.00	23.33	22.57	21.07	21.50	21.9	-
		3.86	6.86	3.20	1.43	2.25	-	-
Ag/Trip/Truck		23.96	22.80	23.28	19.48	20.73	-	-
Sd		4.39	5.48	4.27	4.52	3.30	-	-
t								

Note: sd = standard deviation, t = t-statistics. Ag/Trip/Truck = average cycle time per trip per truck.

3.2 Time losses

The following time losses (Time allowance) per day were recorded for Truck 060 in zone 4 and other trucks in solid waste collection using symbols in equation 4, they are:

Table 2: Time losses during HCS Municipal Solid Waste Collection to Disposal at Uyo Metropolis

Time loss1(w)	Values, (min),	(hr)
T_L for Truck 060:		
U_d	10	0.167
H_u	25	0.417
D_t	7	0.117
D_l	40	0.667
B_t	20	0.333
D_2	2	0.033
D_e	20	0.333
Total for Truck 060 (T_L)	117	1.95 hr
Daily 5 trips avg.		1.50 hr
T_L for Truck 053, zone 3		2.0 hr
T_L for Truck 046, zone 2		2.0 hr
T_L for Truck 072, zone 6		2.0 hr

NB: T_L is sum of component time losses (equation (4)).

3.3 The loss effect on collection efficiency.

The efficiency is affected by the total time loss given as

$$T_{loss} = T_L + T_t \qquad (9)$$

Where T_L is in equation 4 (time loss in operation), and T_t is dispatch time considered time loss because it also reduces day's operation or start up time outside collection to disposal activities [1].

Time loss varied significantly (P = 0.05) between the zones and truck operations, being 19% for truck 046, 20% for 053, 7% for 060 and 30% for truck 072. The lowest time loss for truck 072 is in line with the truck being the fastest evacuator of solid waste with mean cycle time of 17.75min.

Table 3: Average cycle time, theoretical and actual number of daily trips, Ae

Truck	Average T_{net}	Theoretical N_t	Actual N_t	Production hour	Production efficiency, %
046	24	20	15	-	75
053	25	20	16	-	80
060	24	20	15	-	75
072	17	28	21	-	75

V. DISCUSSION

4.1 Analysis of t_{net} data shows the following

For the cycle time (or t_{net}), the t_{net} values between daily trips time for trips 1 to 5 showed no significant difference (@ P < 0.05) between the trips (trips 1 to 5) on each day for each truck. That means that the t_{net} for each trips was specific to the truck, hence no significant variability per truck travel time. This suggests that the operators are conversant with their zonal routes layout, to reduce unchecked time at obstructions in the usual routes they plied in individual zones, and can create confidence in selecting zonal routes mean t_{net} as standard cycle times for the zonal routes.

Thus, the standard cycle times for zonal routes were as shown in Table 1.

The variability of the cycle times between trucks within each day was also checked. The sum of squares of t_{net} between 4 trucks and within each day, as given by ANOVA, was grossly less than the sum of squares within the t_{net} of each day; hence no significant difference in t_{net} (at P = 0.05) except on Tuesday that the difference was significant at P = 0.1. The 4th trip on Tuesday was the smallest t_{net} compared to other days, and might have contributed to the significant variance within days.

However for all groups, i.e. between all trucks and within all days' $t_{net,}$ the between trucks sum of squares was one-sixth the sum of squares for within groups or mean square for between trucks was 3.241 times of mean square for within group, hence making the variance significant at P = 0.05. That means the overall t_{net} had significant standard deviations within its values for the number of trips, days and trucks, or the mean t_{net} values for each truck for all days were significantly (P = 0.05) different from each other. Thus, in the overall truck performance, operator's skill, route size and loss time significantly affected individual truck's cycle time.

4.2 Cycle Time, Time Loss and Available Time

The cycle times in Table 1 are average sum of the component activity times in the circuitous road haulage of containerized MSW from generation point (container location) to disposal site and return. The cycle time for truck 072 was the least (Table 2) although its zonal area was 2.25 km2 and 1.125 times the size of zone 03 for truck 046, and 2.25 times the size of zone 02 for truck 053 and zone 4 for truck 060. It could mean that, in overall, that truck 072 was very frugal with time or very fast. This may be a coupled effect of the operator's skill, machine worthiness, operator's knowledge and the use of route for easy maneuverability, and perhaps a strategy of firstly evacuating the many containers at close proximity to the disposal site, freer routes at the start of collection when operator is fresher and clear-headed, and ending up with few distant containers in the mid-morning or early afternoon day when service routes are less busy [10, 11]. If that strategy is worthwhile then it can be so researched and then routes re-design undertaken to equalize zonal cycle times as much as possible. Cycle time seemed to vary with the collection vehicle trip number and day of operation. The intent satisfies the rule of micro-routing that collection from heavily travelled streets should not be carried out during rush hours; also collection should start as close to the garage or motor pool as possible taking into account heavily travelled and one-way streets where it is best to start near the upstream end of the street working down it through the looping process [10] 11]. The intent is to minimize driving time on the collection route through minimizing the dead head distance [10, 11].

However, apart from truck 072, there was no significant difference (P =0.05) between them. The variation of overall average round trip (cycle time) per day was not significantly different (P = 0.05) from the average trip cycle per truck for each day (Table 1) but varied as follows:

For Monday: average trip cycle time per day =

Average trip cycle time per truck	=	(21.75 mins)
For Tuesday	=	22.01 mins; (22 mins)
For Wednesday	=	22.76mins (23 mins)
For Thursday	=	21.70 mins (22 mins)
For Friday	=	21.89 mins (22 mins)

Thus, the cycle time for solid waste collection trip varied with the day of operation and the operation truck.

The mean cycle time (t_{net}) for each was computed as:

$$\text{Average } t_{net} = (\sum \text{mean daily } t_{net}) / n_d$$

where n_d is number of days.

Using data in Table 1, the mean cycle time (Avg t_{net}) for the trucks varied as follows:

For 046, Avg t_{net}	=	23.52 mins
For 053, Avg t_{net}	=	24.57 mins
For 060, Avg t_{net}	=	23.84 mins
For 072, Avg t_{net}	=	17.30 mins

Number of cycle trips per day

The theoretical maximum number of collection trips per day is

Theoretical N_t = working hours/t_{net}

For an 8-hour working period

Theoretical N_t = 8 hour x 60 mins/$t_{net. us.}$
Using the t_{net} values above (in Table 1), theoretical N_t for the trucks were as in Table 3) as follows:

For 046, it was 20 $\simeq$ 20
For 053, it was 19.5 $\simeq$ 20
For 060, it was 20 $\simeq$ 20
For 072, it was 27.7 $\simeq$ 28

3 trucks (046, 060 and 053) had about the same N_t. However, the difference between mean cycle time for 072 and each or all the others was significant. The order of magnitude for overall average cycle time (t_{net}) was (Table 1): 053 (24.21 mins) > 046 (23.50 mins) > (23.84mins) > 072 (17.30 mins).

Above results show that, when rounded up t_{net} for 046, 053 and 060 would be the same as 24 min (Table 1), and t_{net} for 072 would be 0.75 x t_{net} of each of the other 3 truck i.e. t_{net} (072) $\simeq$ 75% t_{net} (046) or (053) or (060).

Time loss, T_L cut across all route zones and trucks' operation time. On the average T_L was of the order of magnitude as in Table 2, which was T_L (053) = T_L (046) = T_L (072) = 2.0 hr > T_L (060) = 1.95 T_L. Using T_L (060) for example, Dl(extended lunch break for operator adjustment to fatigue was the highest time loss of 0.667 hrs. The order of component losses (w) were: $D_l > H_u > B_t = D_e > U_d > D_t > D_q$. This suggests more special package of incentive and counseling of the operator, who was the main causal agent for De time loss [6].

The ratio of total T_L to total cycle times T for each service truck in a day was:

$$\text{T – T Ratio} = (\text{Time loss/cycle daily time}) = \frac{\text{Total time loss, } T_L}{\text{Number of trips x tnet}}$$

This shows that there is inherent time loss of time allowance in all cycle times for MSW collection to disposal either operator mental and physical fitness or machine worthiness of and environment both of them [5].

For truck 046, T – T ratio was 10%
For truck 053, T – T ratio was 10%
For truck 060, T – T ratio was 9.85%
For truck 072, T – T ratio was 7%

4.3 Time loss and total available time actual cycle time per truck and actual no. of trips per day
Time allowance + normal time = standard time []. Therefore time allowance or time loss affect the available time.
Thus, available time = standard time –time allowance
For truck 046 total available time is 8.0 – 2.0 = 6.0 hr, giving total number of trips per day as:
For truck 046 N_t is 15
For truck 053 N_t is 16.118 is 16
For truck 060 N_t is 15.233 is 15
For truck 0.72 N_t is 20.81 or 21

4.4 Collection Efficiency
Efficiency was considered in two aspects both resulting from effect of time.
As productive hour (Banga et al 2004), efficiency, by definition, is

$$E_f = \frac{Actual\ N_t}{Theoretical\ N_t}$$

Using the theoretical and actual N_t (Table 3), Efficiency was computed as follows: for 046, E_f = 15/20 or 75%; for 060, 072, E_f = 75%; while for 052, E_f = 80%. By order of magnitude, efficiency for truck 052 (80%) > 046 = 060 = 072.

Thus, the efficiency reduction by the effect of loss time varied between 20 and 25% per truck.

4.5 Daily Generation (Collection)

The total weight of collected load was the sum of the weight of load for each trip for each truck for the whole day. The daily generation rate was estimated as the total collected waste at the generation stations in the zone. The results are as recorded in Table 4.

Table 4. Rate of daily collection (or generated) solid waste load in Uyo metropolis

Trip	Haulage truck			
	046	**053**	**060**	**072**
1	400.00	400.0	400.0	400.0
2	450.0	450.0	450.0	450.0
3	200.0	200.0	300.0	200.0
4	200.0	200.0	200.0	200.0
5	150.0	200.0	200.0	150.0
Total, kg/day	1400.0	1450.0	1600.0	1400.0
Area, km^2	2.0	1.0	1.0	2.3
Waste Collection or generation rate kg/hr	175.00	181.3	200.0	175.0
Collection or generation density $kg/km^2/day$	700.00	1450.0	1600.0	622.1
Avg. collection per trip, kg/trip	280	290	320	280

* 1 day was 8 nominal operation hours.

The rate of generated solid waste was obtained as the rate of solid waste collection per day where nominal day was 8 nominal operation hours.

From the Table (Table 4), the highest solid waste collection rate, hence the highest solid waste generation with a collection area of only 1.0 km^2, resulted also in the solid waste highest generation density of 1600.00kg/km^2.

The least rate was 175 kg/day by truck 072 from the widest collection area (2.23km^2) in zone 6. This gave the least density of 622.1 kg/km^2. Actually, 046 also had the least generation rate 175 kg/day from the next larger area (2.0 km^2), giving the next lower collection or generation density of 700kg/km^2.

The set out rate or waste load per trip varied between 280 and 320 kg/trip, coming from truck 060 in one of the smallest area. This is so because the trucks were the same, the container capacity was the same, and the number of trip was the same.

Table 5. Effect of time loss on daily collection rate

Truck	Zone	Nominal collection rate, kg/day	Loss time w, hr.	Unexpected collection rate kg/day	Percentage difference (%)
046	2	175.0	2.0	233.3	33.3
053	3	181.3	2.0	242.0	33.5
060	4	200.0	1.5	213.3	7.0
072	6	175.0	2.0	233.3	33.3
Av. Per truck/day		182.8		230.5	26.2

Therefore, the difference was likely attributable to the packing and how full the containers were, and the level of decomposition of the bottom content. If the waste at the bottom has started decomposing in the waiting days before collection day, then it will lose moisture and so lose weight.

Also, it could be seen in the table (Table 5) that collection rate for 060 truck was the highest (200 kg/day) amongst the trucks set-out loads except 053 which was similar and as such had the next high collection rate (185 kg/day). For the smallest collection area to produce the highest collection rate and load/trip, it means the area (Zone 4) is a high solid waste generation zone in the metropolis; followed by zone 3 with truck 053. The larger areas 2.0 and 2.25 kg/m^2 produced lower generation rate of solid waste with the same lowest collection rate (175 kg/day) and load/trip (280kg/trip).

Effect of time loss on solid waste collection rate

The generation or collection rate was affected by loss time. Table 5 shows generation rate by between 7.0% and 33.5% of the nominal collection rate. The difference was significant at P = .05. The impact was greatest at 33.5% on truck 053 in zone 3 with area of 1.0 km^2, and the percentage difference was least (7.0%) for truck 060 in Zone 4. The loss time seemed to have extended the period for extra wastes to be thrown into the container thereby increasing the set out rate. Also the loss time reduced effective operation hours, thereby minimizing the daily operation hours.

VI. CONCLUSION AND RECOMMENDATIONS

Time losses components were identified and measured using continuous and snapback electronic stopwatches in the solid waste collection cycle in Uyo metropolis. Time loss affected the short duration round trip time. Four route zones at one haulage truck per zone were used in time and motion study of municipal solid waste collection with haul container system, and the data were statistically analyzed using SPSS version 17.

Time loss effect was observed on the short cycle time, time allowance, daily generation rate and daily truck collection efficiency; it depended on truck or operator's skill, route zonal area and density of community bins as well as on the collection week day – as affected by both load generation, and traffic density on collection routes.

The seven (7) components of time losses, including delays and extra time on lunch break and recuperation from fatigue constituted variable total loss on collection trip, reducing time allowance, efficiency which significantly varied with truck zone and day of operation and daily generation load.

Recommendations include measurement of cycle time for future new collection systems, reduction of startup loss of time by adequate garage preparation; route zone re-design for round-trip equality, and training of operators on skills of route management.

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