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EFFICIENCY OF THE SOLID WASTE MANAGEMENT AND DISPOSAL OF A SCHOOL CAMPUS

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Abstract

In response to the need for adept solid waste management, this study aimed to determine the efficiency of dustbins, and the transport of final disposal of waste stream through time and motion study. The study concluded the dustbin efficiency of 68.26% in keeping the generated solid waste of the campus into the available dustbins. Regarding collection efficiency, the data revealed poor collection efficiency due to the very time-consuming door-to-door collection. Efficient transfer of solid waste from the storage area to disposal area at the Eco Park was accomplished. A slow net speed of 6.79 kilometres per hour was recorded to collect and transport the wastes from the first station to the disposal site. The volume reduction efficiency varies from 54.30% in the wastes from food services to 70.85% from outdoors and hallways, with a mean value of 62.52%. This result implied that the school has met more than the national thrust of the Philippines of 25% reduction of solid waste at final disposal.

Keywords: Solid waste management, waste generation, time and motion study, school waste composition

1. INTRODUCTION

Solid waste management system necessarily requires an assessment to determine how far it achieved its objectives. One way of assessing solid waste management system is to have an outcome measure of its efficiency to determine whether or not the system is achieving the target goals and to give an alarm if it veers off the course.

One of the outcome measures in the determination of the efficiency of solid waste management system is to conduct the time and motion study. Time and motion study is a procedure for the solid waste collection and analysis of data on collection service in a systematic manner to help solid waste managers and practitioners to diagnose the shortcomings of the collection system and to determine options for improvement.

Time and motion study is helpful to determine the collection efficiency of the solid waste management system by considering how efficiently the crews use their time during collection. This finding would also give an idea of how efficient is the transfer of solid waste concerning speed and trip time during collection periods.

Collection efficiency is important in the solid waste management system to determine how well the collection crews are doing the collection. It would tell how effective the collection crews use their time while at the collection area. It would provide the net collection efficiency, gross collection efficiency, and overall collection effectiveness in the collection area.

Transfer efficiency is significant in providing the solid waste managers the knowledge on how the transfer of solid wastes is accomplished. It would give concrete basis whether the generated waste in a particular area needs transfer station or direct transport to final destination.

The efficiency of onsite storage is also one of the outcome measures because of aesthetic consideration, public health, and economics. Unsightly containers and even open ground storage are undesirable. The common public health concern is related primarily to the infestation of solid wastes with vermin and insects that may serve as a prospective source of disease. According to Tchobanoglous [1], aesthetic considerations are related to the production of odors and unsightly conditions. Most odors can be controlled through the use of containers with tight lids and the maintenance of reasonable collection frequency. Economics refers to the appropriate containers that are used to maximize storage.

The knowledge on volume reduction efficiency is another outcome measure in determining the percentage of the solid wastes that could be reused, recycled, and composted. Besides, solid wastes managers would have the accurate ideas on how to handle the component of wastes that have no economic value and due for final disposal. In effect, terminal disposal area is designed and estimated according to the volume of refuse in the waste stream.

2. MATERIALS AND METHODS

The study employed descriptive research design and was conducted in a 4-week period. The investigation used the "Data Format for a Time and Motion Study" in determining the collection and transfer efficiencies. Moreover, the "Tabulation Sheet" which recorded the number of dustbins and the amount of wastes in each source, was used in computing efficiencies of onsite storage and volume reduction.

2.1 Research Setting

A state-owned tertiary school of the Philippines, Misamis Oriental State College of Agriculture and Technology (MOSCAT) was the location of the study. It is a growing state school of the Philippines focusing agriculture, environment, and food technology typology courses. It is situated in the farming community of Claveria, Misamis Oriental– the southern part of the Philippines. It is approximately 603 meters above mean sea level.

2.2 Time and Motion Study

Below is an outlined procedure on how the time and motion study was administered.

- Time Recording. Time upon arrival and departure from each point along the collection route was recorded. The 1st point was the garage exit, and the last point was the garage arrival. It was done using a stopwatch.
- Distance Recording. The distance between each point along the collection route was determined using the calibrated wheel trundle.
- Storage Bin Count. All storage bins emptied along the route were counted and classified according to size/capacity. The classifications are <10 liters, 10-30 liters, and > 30 liters.
- Mapping. With campus map, the points along the collection route were clearly marked. Each point was assigned a station number.
- Study Complete Work Shift. The study was done for the whole work shift, that is, it started the investigation when the vehicle left the garage and ended when the car returned to the garage. The procedure was repeated in a 4-week period.

2.3 Tabulation Sheet

- Storage Bin Count. Like in the time and motion, the number and capacity of dustbins in each station were recorded.
- Weighting of the Waste Stream. The wastes stream was collected from the four identified sources: food services; cottages and residence halls; hallways and outdoors; and classrooms and offices. Each bag of the collected wastes was properly labeled to identify the source. The weight of the waste stream in each source was recorded.
- Bulk Volume Determination. The bulk volume of waste from each identified source was determined using a calibrated wooden box. It was done before the segregation of waste component was made.
- Determination of the Volume Thrown to the Final Disposal Site. After segregation, the volume of wastes components due for disposal were determine calibrated wooden box.

The formulas that were used in the calculations are shown in Eqs 1-12 below.

Onsite Storage of Dustbins

$$Actual\ vol/dustbin = \frac{Ave.\ vol\ per\ source}{No.\ of\ dustbinsper\ source} \quad [1]$$

$$Dustbins\ Eff = \frac{No.\ of\ dustbin\ storing\ actual\ vol}{Total\ no.\ of\ dustbins} \quad [2]$$

Volume Reduction Efficiency

$$Vol\ Reduction\ Eff = \frac{bulk\ vol - vol\ thrown}{bulk\ vol} x100 \quad [3]$$

Net Collection Efficiency

$$Time/dustbin = \frac{Net\ collection\ time}{Total\ no.\ of\ dustbin} \quad [4]$$

$$Time\ per\ Unit\ Weight = \frac{Net\ collection\ time}{Net\ load} \quad [5]$$

$$Time/dustbin/person = \frac{(time/dustbin)}{(Total\ \#\ of\ crew)} \quad [6]$$

$$Time/unit\ wt/person = \frac{time\ per\ unit\ weight}{Total\ \#\ of\ crew} \quad [7]$$

Gross Collection Efficiency

$$Min/kg = \frac{Total\ time\ in\ the\ collection\ area}{Net\ load} \quad [8]$$

$$Min/kg/person = \frac{Total\ time\ in\ collection\ area}{Net\ load * total\ \#\ of\ crew} \quad [9]$$

Overall Collection Efficiency

$$Overall\ Collection\ Eff = \frac{Total\ time\ Consumed}{Net\ load} \quad [10]$$

Net Speed in the Collection Area

$$Net\ Speed = \frac{Total\ distance\ in\ collection\ area}{Net\ trip\ time\ from\ 1st\ stn\ to\ last\ stn} \quad [11]$$

Gross Speed in the Collection Area

$$Gross\ Speed = \frac{Total\ distance\ in\ the\ collection\ area}{Time\ from\ arrival\ @\ 1st\ stn.\ to\ depart\ at\ last\ stn} \quad [12]$$

3. RESULTS AND DISCUSSION

3.1 Dustbin Capacity

Table 1.Percentage Distribution of the Capacity of Dustbins Used in MOSCAT Campus

Type	Capacity, liter			Total	Percent Usage
	Large	Medium	Small		
	30	10-30	10		
Plastic Containers	3	38	50	91	64.08
Sacks	24	2	0	26	18.31
Metal	13	4	0	17	11.97

Containers					
Plastic Bags	4	1	0	5	3.52
Wood	1	1	0	2	1.41
Paper bags	0	1	0	1	0.70
TOTAL	45	47	50	142	100

Table 1 depicts the capacities of dustbins used in the campus. It was found out that 31.7% (45 pieces) of the dustbins has the capacity of more than 30 liters, 33.1% (47 pieces) has the capacity of 10-30 liters and 35.21% (50 pieces) has the capacity of fewer than 10 liters. The result manifested that the dustbins used are of variable sizes.

Further, Table 1 shows the kind of dustbins utilized in the school. More than one-half (64.08%) of the dustbins used plastics while 18.31% used sacks and 11.97% were metal containers.

The result reveals that most of the dustbins used in the campus are durable such as plastics, metal containers, and wood. The sum of the percentage of these durable dustbins is 77.46%; while, the remaining 22.54% comprised the non-durable one like sacks, paper bags, and plastic bags.

3.2 Onsite Storage Efficiency

Table 2 depicts the efficiency of dustbins used in each solid waste generation area. The average volume, in liters per dustbin, during one week storage period, is compared to the capacity of the dustbins used in the source. Dustbin with capacity that is greater than the actual volume per dustbin is considered most efficient.

3.2.1 Classrooms and Offices

The result shows that the average volume per dustbin of solid wastes from classrooms and offices is 3.67 liters per dustbins. There are 50 dustbins (51.55%) used in classrooms and offices having a capacity of fewer than 10 liters and considered less efficient. While 47 dustbins (48.45%), having a capacity of 10 liters or more, are considered most suitable. Hence, the on-site storage in classrooms and offices was 48.45% efficient.

Table 2. Efficiency of the Dustbins Used in each Source on the Onsite Storage of Solid Wastes

Source	Number of Dustbins and Capacity			Actual Volume /Dustbin	Dustbin Efficiency**
	3O L	10 – 30 L	10 L	liters/dustbin-wk	
Classrooms and Offices	12	35	50	3.70	48.45%
Food Services	8	6	0	10.53	57.14%
Outdoors and Hallways	10	2	0	20.68	83.33%
Residence Halls & Faculty and Staff Cottages	16	3	0	21.39	84.21%

However, most of the dustbins in classrooms and offices are plastics which have a capacity greater than 3 liters. It implies then that the efficiency would be higher than 48.45% and may reach to 100% if manual compaction would be employed in the 50 dustbins having a capacity of fewer than 10 liters.

3.2.2 Food Services

The result portrays that the average volume of solid wastes from food services was 10.50 liters per dustbin. There are six dustbins (equivalent to 42.86%) has the capacity of 10 to 30 liters while eight dustbins (equivalent to 57.14%) have the capacity of more than 30 liters. No dustbins found having the capacity below 10 liters. Hence, the storage efficiency of dustbins found in food services is 57.14% efficient.

However, 10.50 liters per dustbins of solid wastes is within the capacity of the six dustbins between 10 to 30 liters. It means that these dustbins could also hold the solid wastes of 10.50 liters. It implies that the storage efficiency would be greater than 57.14% and may reach to 100% if manual compaction would be employed to the six dustbins having the capacity of 10 to 30 liters.

3.2.3 Outdoors and Hallways

The result shows that the average volume of solid wastes from outdoors and hallways is 20.03 liters per dustbin. There are two dustbins (equivalent to 16.67%) only has the capacity of 10 to 30 liters while ten dustbins (equivalent to 83.33%) have the capacity of more than 30 liters. No dustbins found having the capacity below 10 liters. Hence, the storage efficiency of dustbins found in outdoors and hallways was 83.33% efficient.

However, 20.03 liters per dustbins of solid wastes was within the capacity of the two dustbins between 10 to 30 liters. It means that these dustbins could also hold the solid wastes of 20.03 liters. It implies that the storage efficiency would be greater than 83.33% and may reach to 100% if manual compaction would be employed to the two dustbins having the capacity of 10 to 30 liters.

3.2.4 Residence Halls and Cottages

The result shows that the average volume of solid wastes in residence halls and cottages is 21.47 liters per dustbin. Based on the type of dustbins used in this area, there are three dustbins (equivalent to15.79%) only having the capacity of 10 to 30 liters while 16 dustbins (equivalent to 84.21%) have the capacity of more than 30 liters. No dustbin has the capacity of fewer than 10 liters. Hence, the storage efficiency of dustbins found in residence halls and cottages is 84.21% efficient.

However, 21.47 liters per dustbins of solid wastes is within the capacity of the three dustbins between 10 to 30 liters. It means that these dustbins could also hold the solid wastes of 21.47 liters. It implies that the storage efficiency would be greater than 84.21% and may reach to 100% if manual compaction would be employed to the three dustbins having a capacity of 10 to 30 liters.

3.3 Collection Efficiency

The campus collected its solid waste from all sources once a week. Collection crew practiced the room-to-room collection during the collection period in most offices and classrooms which made the collection a very time-consuming activity. The door-to-door collection was also observed in the cottages whose residents did not practice the curb service. Curb service requires homeowners to be responsible for placing the containers to be emptied at the curb on collection day and for returning the containers to their storage location until the next collection.

Table 3 depicts a summary of the result of the time and motion study of the solid waste management program of MOSCAT. This summary gives the efficiency of the existing solid waste management of the campus during collection and transfer of the solid wastes. Collection efficiency is classified into net collection efficiency, gross collection efficiency, and overall collection efficiency.

Table 3. Summary of the Result of the Time and Motion Study

Parameter		Ave
a.	Total number of dustbins	142
b.	Net collection time, min	126.10
c.	Net load, kg	198.51
d.	Net collection efficiency	
	* sec/dustbin (b/a)	53.28
	* min/kg (b/c)	0.64
	* sec/dustbin-person	27.61
	* min/kg-person (Note: 2 crew members (1 driver + collector)	0.33
e.	Total time in the collection area, min (from arrival at 1* station to departure to last station)	147.77
f.	Gross Collection Efficiency	
	* min/kg (e/c)	0.77
	* min/kg/person	0.39
g	Total time consumed, min (from garage departure to garage arrival)	170.51
h.	Over-all collection efficiency, min/kg (g/c)	0.89
i.	Mean weight of waste in the dustbin, kg/dustbin (c/a)	1.40
j.	Total number of stations	16.00
k.	Number of dustbin per stations (a/j)	8.56
l.	Total distance in the collection area, km (from 1*station to last station)	2.373
m.	Net trip time from the 1* station to last station, min	21.67
n.	Total trip time from arrival at the first station to departure from the last station, min	147.77

o.	Mean distance between two stations, m {l/(j-1)}	158.21
p.	Mean trip time between two stations, min {m/(j-1)}	1.44
q.	Net speed in the collection area, km/hr (l/m)	6.79
r.	Gross speed in the collection area, km/hr (l/n)	0.97

3.3.1 Net Collection Efficiency

Net collection efficiency determines how efficiently the collection is done from the time the vehicle arrives at the station until the time the vehicle departs the same station.

The results show that the net collection period is 126.10 minutes (or equivalent to 73.96% of the total time of 170.51minutes). It manifested a poor net collection efficiency of almost one minute (53.28 seconds) to empty one dustbin and to load the wastes into the collection vehicle when compared to the collection efficiency determined by WHO. Based the result of the study of WHO [2], the time needed to empty one dustbin was less than 20 seconds as follows: small open files – 10 seconds, half sized drum – 11.7 seconds, sacks – 12.5 seconds, plastic bins – 10.3 seconds, plastic bags – 8.5 seconds, sacks – 12.5 seconds and small plastic containers of 6.7 seconds. The study indicated that more than 60% of the dustbins used in the school were plastic containers. It indicates that net collection efficiency is nearer to the plastic container collection efficiency of 6.7 seconds per dustbin. The difference of 46.58 seconds was spent in the room-to-room (classroom) and door-to-door (cottages & residence halls) collection of the crews.

The result would then indicate that other collection efficiency, where time is one of the variables, would lead to a reduced efficiency. It includes the time needed to collect one kilogram of the waste of 0.66 minutes (40 seconds). It means that the net collection efficiency regarding the length of time needed to obtain a unit mass of waste is poor having the efficiency of 0.66 min/kg.

Furthermore, the result indicates that 27.61 sec/dustbin-person is the net collection efficiency regarding the length of time needed to empty one dustbin when one crew is doing the work alone.

The poor net collection efficiency is mainly due to the time-consuming collection along the route. It indicates that the school lacks the facility like transfer storage bins where the wastes would be transported to minimize collection of each dustbin inside the classrooms. Moreover, time management of the collection crew was also one factor that affected the collection efficiency. It was observed that the school waste collection team sometimes swept wastes not stored in the dustbin. Supposedly, the collection team has no responsibility for the wastes not found inside the trash cans.

3.3.2 Gross Collection Efficiency

Gross collection efficiency determines how efficient the collection during the total time in the collection area. Total time in the collection area is the period when the vehicle arrives at the first station up to departure from the last station. This time includes collection time and traveling time in the collection area. Due to poor collection time, gross collection efficiency consequently led to an adverse result.

The result shows that the gross collection efficiency regarding the length of time needed to collect and load the solid waste in the total collection area is 0.77 minutes (46.2 seconds) per kilograms. It is 0.11 minutes (6.2 seconds) greater compared to the net collection efficiency of 0.66 min/kg.

This study establishes a fact that each collection crew requires a time 0.39 minutes (23.1 seconds) to accumulate a kilogram of waste. The value of 0.30 min/kg-person is a gross efficiency of the collection in term of time per unit mass per collection crew.

The result of the gross collection efficiency is also poor considering that the net collection efficiency is poor. This efficiency is significantly affected by the time- consuming room-to-room and door-to-door collection of solid wastes.

3.3.3 Overall Collection Efficiency

Overall collection efficiency determines how efficient the collection is done. The basis is the total time consumed when the vehicle departs the garage until it returns to the garage after collection.

The result indicates that the overall collection efficiency is 0.89 minutes (53.4 seconds) per kilogram of solid waste collected. It is poor due to the very time-consuming collection inside classrooms and offices.

3.3.4 Vehicle Collection Efficiency

The collection vehicle efficiency determines how efficiently the collection vehicle is being used. The result would tell on whether the vehicle is loaded to capacity or overloaded and at risk of being damaged.

The vehicle used for the collection of waste was the Pick Up type Land Rover with Trailer hitch on it at the drawbar. The trailer has assembled compartments. The overall dimension of the trailer is 1.54m x 2.42m x 0.84m leading to a trailer capacity of 3.131 cubic meters. Moreover, there were five compartments of the trailer: four compartments have the capacity of 0.52 cubic meters, and one compartment had the capacity of 1.03 cubic meters.

As it has been known of the result of the simultaneous study on solid waste audit, the average bulk volume of the solid waste collected per week is 1.158 m3. Extreme values are 1.61875 m3 and 0.9125 m3. Even at extreme high bulk volume generation of wastes, the bulk volume was still smaller compared to the capacity of the trailer. Hence, the collection vehicle was efficiently used since it was still under loaded even after the total bulk of solid wastes were loaded. At an average, the trailer is 270.34% efficient. The efficiency may vary from 193.20% during highest bulk volume to 343.12% during lowest bulk volume of solid wastes. It implies that even collection of solid wastes was only done once a week the collection vehicle was still very efficient in collecting the solid wastes.

3.4 Transfer Efficiency

3.4.1 Net Trip Time

Table 3 reflected an average net trip time of 21.67 minutes (as shown in letter m of Table 3), an average duration when the collection vehicle was running on the collection route from the first station to the last station. It implies that only minimal net trip time was spent (21.67 min) in collecting solid wastes from the different stations when compared to the average total time spent of 170.51 minutes (as shown in letter g of Table 3) from the garage departure to start collecting solid wastes up to the garage arrival after all wastes were collected and dumped at the Eco Park. Hence, transfer efficiency is good with less net trip time.

3.4.2 Net Speed in the Collection Area

The basis for determining the net speed in the collection area was the total distance and net trip time when the collection vehicle was in motion from the first station to the last station. It excluded the loading time when the vehicle stopped at various collection stations.

Table 3 indicates that the net speed of the vehicle in the collection area was 6.79 kilometers per hour (as shown in letter q of Table 3). It implies that the collection vehicle was at the minimum speed while it was in the collection area. This finding is mainly because collection area was within the school premises and thus, safety was always being observed to refrain from a vehicular accident.

3.4.3 Gross Speed in the Collection Area

Gross speed was determined through the total distance in the collection area and the total trip time consumed from arrival at the first station to departure from the last station. Total trip time included the loading time and the net trip time in the said stations.
Table 3 establishes a fact that the average gross speed of the collection vehicle in the collection area was 0.97 kilometers per hour (as shown in letter r of Table 3). The low gross speed is mainly because the total trip time was almost two and a half hours (147.77 min). About 85.34 %

(126.10 min) of the total trip time was the average net collection time or the time spent in loading the solid wastes while the remaining 14.66% (21.67min) was net trip time or the time spent in moving from station to the succeeding station. It implies that there is an inefficiency of maximizing the time in the collection area, especially in loading the solid wastes, which leads to low gross speed. The crew spent time in the room-to-room collection of solid wastes which made the net collection time very high.

3.5 Volume Reduction Efficiency

Table 4 depicts the volume reduction efficiency of the solid wastes that reached the Eco Park. The overall volume reduction efficiency of all the solid wastes that reached the Eco Park is 62.52%. This outcome was because the remaining 37.48% (0.434 cubic meters) per week of the solid wastes generated from the four sources were thrown away. This volume being thrown was collected by the solid waste collector of the Local Government Unit of Claveria, and it was disposed at the controlled dumpsites at Rizal, Claveria, Misamis Oriental.

Table 4. Volume Reduction Efficiency of Solid Waste from each Source

SOURCE	Ave Bulk Vol. (a)	Ave Volume Thrown (b)	Volume Reduction Efficiency* (a-b)/a*100%
	m^3/week	m^3/week	
Classrooms and Offices	0.358	0.123	65.64%
Food Services	0.146	0.059	59.59%
Outdoors/ Hallways	0.247	0.072	70.85%
Residence Halls and Faculty & Staff Cottages	0.407	0.186	54.30%
Summary	1.158	0.434	62.52%

The compositions of the wastes that were thrown are soft plastics, hazardous wastes, special wastes and other components that could not be composted, recycled nor be used again. This result implies that, after segregation was accomplished, about 62.52 percent of the wastes that reached the Eco Park were potential for reuse, recycle or compost every week.

The volume reduction efficiency from the four sources ranges from 54.30%-70.85%. Waste stream from hallways and outdoors was found to have the highest reduction efficiency of 70.85%. It implies that the total waste stream from this source had been reduced to almost 71% which can be processed further for recycling, reusing, and composting purposes. The remaining 29% of wastes from hallways and outdoors was due for final disposal. While the wastes stream from residence halls and cottages had the lowest volume reduction efficiency of 54.30%. This result indicates that about almost one-half (45.7%) of the wastes from this source had been finally disposed and the remaining one-half (54.30%) was further segregated into recyclables, reusable and compostable materials. Waste streams from classrooms and offices have a volume reduction efficiency of 65.64% while 59.59% in food services. The result implies that, from the four sources, more than 50% of the wastes collected could either be reused, recycled or composted to maximize their beneficial use.

4. CONCLUSIONS

Based on the investigation's outcome of the solid waste management of the school campus, the following conclusions were drawn:

- Most of the dustbins used in the school were made up of durable materials such as plastics, metals, and wood. Concerning onsite storage efficiency, the SWM of the campus was found to have a mean score of 68.28% efficiency in storing solid wastes in the dustbins.
- Regarding collection efficiency, the result revealed reduced collection efficiency due to a time-consuming collection (room-to-room collection) at the collection route. However, the vehicle was found efficient in handling the total waste streams of the campus even having a once-a-week collection frequency. Regarding transfer efficiency, the result stressed out an efficient transfer of solid wastes due to minimal trip time during collection.
- The result of the study revealed a volume reduction efficiency of 62.52% which is found to be greater compared to the national thrust of 25% volume reduction efficiency. The 62.52% were the materials that include recyclable, reusable and compostable materials.

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