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Logistics of Solid Waste Management in FUTO

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Abstract: This study evaluates the logistics performance of solid waste management in FUTO by examining the strength of correlation existing between collection frequency, waste volume collected per day and waste tonnage per trip. The prescriptive model developed from the regression is $Y = 0.555 + 0.037X_1 + 0.018X_2 - 0.034X_3 + 0.006511$ from the secondary data collected from the Office for University Development. The results showed a strong positive correlation between waste volumes collected per day, waste tonnage per trip with logistics performance. While an inverse correlation existed between logistics performance and collection frequency. Conclusively Campus-wide solid waste management can be design with this model for optimal logistical performance.

INTRODUCTION

The environmental consequence of waste has become an issue of growing concern globally. Concerted efforts are mobilized to manage waste and thus reduce its environmental impact. According to The World Bank[1] study, wastes create serious health, safety and environmental consequences. Poorly managed waste serves as a breeding ground for disease vectors, contributes to global climate change through methane generation and can even promote communal violence. Thus it becomes necessary for waste to be managed properly and disposed in the most acceptable manner so as to ameliorate its effect on humans, plants, animals and the environment. Though advance in technology has shown significant strides in minimization of pollutant generation and reuse or disposal of wastes yet its menace still subsists.

Solid waste is defined as any useless, unwanted or discarded material[2]. Also, the Waste Act adds that 'all items weather solid or liquid other than water management resulting from any form of human or business activity, unsuitable in place or time where it arises constitutes waste[3]. The World bank reports that 2.01 billion tonnes of solid waste was generated in 2016 which amounts to 0.74 kg/person/day and annual waste generation is expected to increase by 70% to 3.40 billion tones in 2050[1]. FUTO community with an increasing population of staff, students and businesses alike contributes to the growing indiscriminate habit of dumping of solid wastes in undesignated areas around lecture halls, halls of residence and business places situated around the campus.

Such indiscriminate dumping of wastes according to Pukkalanun *et al*.[4] leads to the generation of leachates which results when rainfall wash off these wastes into nearby water bodies thus resulting in pollution and other environmental risks. Since, waste collection/removal in FUTO is far less than generation it is common sight to see over filled bins and improper or wrong disposal of waste, research geared towards adequate collection and management of solid waste in FUTO becomes imperative.

Although, the current administration of the university has innovated novel collection strategy aimed at managing waste, this giant stride is met with waste logistics concerns that limits or reduces the intended efficiency and effectiveness of the scheme which before now was lacking in the university community.

Logistics management of wastes is a veritable tool for improving the collection of any kind of waste generated in FUTO. Traditional definition of logistics as defined by the Council of Logistic Management in USA states that: Logistics management is that part of supply chain management that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origination and the point of consumption in order to meet customer's requirements. Relevant aspects of logistics management akin to waste management includes transport management, material handling, logistics network design, inventory management, supply and demand tracking of waste. This paper seeks to improve waste management in FUTO through the proposition of integration of logistics management and qualitative analysis of waste streams and possible solutions to improve the process by; creating a logistic and reverse logistics proposals that manages waste disposal sites in FUTO comprising waste sorting, transporting, storage and recycling or reuse of treated waste for the possible provision of secondary raw materials or bio friendly landfill.

Literature review

Waste chain: Dima *et al*.[5] opines that traditional waste chain is a supply chain with opposite direction of material flow to the basic supply chain. Four elemental constituents of the waste chain are defined; first is the 'waste generator' (students, staff, visitors and businesses around the campus) who uses a product up to the point in time it becomes unusable, the second is the 'collector'; saddled with organizing waste collection and subsequent transport to the next chain. Third is the 'segregator' supposedly dealing waste segregation and further processing (reuse or recycling). The last link is the 'disposer' as shown in Fig. 1. Sadly in FUTO the first two elemental links are active but the last two links are copiously absent.

Waste logistics model: Models are systems, objects or idea representation other than reality. They aid planning and decision making with a basic assumption that the model's options and decision criteria have been identified. Methods and tools employed in waste models includes; risk and environmental impact

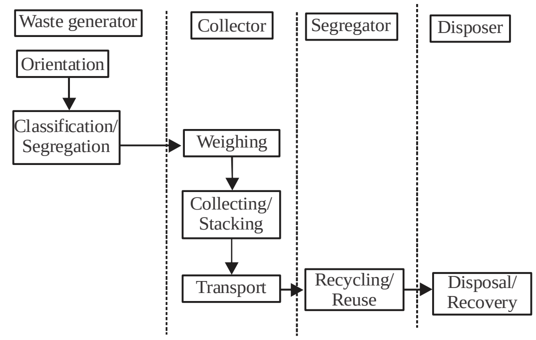

Fig. 1: Elemental aspects of waste management logistics system for FUTO; Authors Design in 2020

assessment, cost benefit and life cycle analysis and multi-criteria decision. As Zapounidis and Doumpos[6] notes the tool choice is a function of the decision makers decision.

Morrissey and Brown points that models are either based on cost benefit analysis, life cycle analysis or multi-criteria techniques.

Cost Benefit Analysis (CBA) Models: CBA Models aims at maximization of economic efficiency at the expense of social and environmental consideration. The only decision criteria improved on is cost and according to Carbone, etc., it not a suitable decision aid. CBA models appraise environmental and social effects and impacts in absolute financial terms.

Life Cycle Analysis(LCA) Models: ISO 14040 describes life cycle analysis models to be environmental consequence of products life cycle, from production to disposal. LCA's are comparative analysis. McDougall, etc., links Integrated Waste Management with LCA since it evaluates waste streams, waste collection, treatment and disposal with the ultimate goal of optimizing environmental benefits, economic efficiency and social acceptability.

Multi criteria decision analysis models: According to Generowicz *et al*.[7], these models identifies and ranks alternative waste management scenarios with the objective of satisfying decision boundaries with the inclusion of risk or environmental impacts. In Literature Multi-criteria analysis of waste management is now popular.

Waste model goals can be simple (waste collection route optimization) or complex (alternative strategy evaluation). Traditional logistics models are usually designed to show the relationship that begins from a source point (where raw material for production are acquired) to the terminal point of the manufacture of

Table 1: Elemental aspects of waste management system design

	Evaluation criteria		
WMLS elements	Technological	Ecological	Economical
1. Waste generator			
Orientation	Solutions include: i. Various awareness media for proper waste categorization (plastic/ paper/ glass/ metal/ organic) ii. Allowed place and method for disposal		Awareness and sensitization media choice driven by: i. cost -benefit analysis ii. media reach/effectiveness
Classification/segregation	Solutions should include: i. Usable waste disposal methods through color coded bins ii. permitted place and methods for proper disposal	Disposal compliance with relevant waste management guidelines/best practices	Classification/ segregation cost (time and money) for generator
2. Collector			
Weighing	Choice of solutions driven by: i. Accuracy and precision ii. Ease of use iii. On/off site weighing	Compliance with relevant waste management guidelines/ best practices	Cost of weighing solutions
Collecting/Stacking	Solutions considered depend on: i. The waste handling suitability with partitioned trucks according to color codes ii. Permitted place and disposal methods according to color codes	Compliance with relevant waste management guidelines/ best practices	Cost of optimal stacking infrastructure solutions (Waste Press containers, balers) Cost of recovery and disposal through accurate sorting (modular containers)
Transport	Transport solutions sole intended for carting waste	i. Solutions to prevent the formation of the associated risks with damage to the containers during transport and ensure proper hygienic condition of the means of transport ii. The use of disposal installations which are located closest to the source of waste generation	i. Transport cost reductio ii. Volume reduction through *in situ* balers and press iii. Storage within the time allowed to enable a reduction in the frequency of waste collection
Segregator			
Recycle/reuse			

Authors Design in 2020

finishes products. The emphasis of this model is on all sub-processes relating to production while little or no inclusion of the waste generated from all such sub-processes are considered[5]. Skowronska notes that logistic chains often comprise of smaller systems linked together for efficiency of which the waste supply chain is a subset. Waste chains flow direction are basically reverse supply chain systems designed by different rules resulting in variations from regular supply chain models. Waste management models consists of four elements as shown in Fig. 1. The first element is the user who uses the product and changes (decreases) its useful properties up to the moment at which the product becomes unusable. The second is the element that organizes the waste collection, the third deals with the segregation of waste and finally disposal, reuse or recycling.

Waste Management Logistics Model (WMLM) design aspects: Marczak[8] proposed three waste management aspects/dimensions to be considered for waste management logistics system design: functional, instrumental and institutional. In designing a waste management system, the functional dimension allows for the consideration of the complex tasks and activities within the campus. The selection of appropriate instruments of planning, monitoring and control activities in waste management are considered the instrumental aspects or dimensions while the placement of the waste management system in the organizational structure of the entity and the identification of actors saddled with the responsibility for waste management is classed institutional. Waste management logistic system design is also evaluated on three criteria: ecological, technological and economical[8]. Table 1 shows evaluation of the elemental aspects of the waste management logistic system.

MATERIALS AND METHODS

Study context: FUTO is a Federal Government University located in Owerri West local government area

Fig. 2: Map of FUTO; Google Maps 2020

ROUTE 1:

FUTO front Gate → Senate → Convocation Square → SBMS → SOHT → NMA → SOES

ROUTE 2:

SMAT Complex → ACE fuels → SICT → Entrepreneurship → Architecture

ROUTE 3

Roundabout → SOPS → SOBS → SLT → Procurement → Business Center → Lecture Hall 2 → Estate & Works → Workshops

ROUTE 4

Roundabout → Old SEET Head → OUD Building → PG School → CCE → ICT

ROUTE 5

Hostel A- E → PG Hostel → NDDC Hostel

ROUTE 6

Hall of Excellence → PMF Building → Okiro → Gender → FUTOWA → UCC Catholic Church → Mechanical → Petroleum → Chemical → SEET → Staff Quarters

Fig. 3: Collection route for FUTO; OUD, FUTO, 2020

of Imo State, established in 1980 bounded by Eziobodo, Obinze and Ihiagwa communities. FUTO began with 225 students and 60 staff (28 academic and 32 non-academic), now with 50 professors, other teaching and non-teaching staff with over 22,000 students and ranks 12th according to the NUC ranking of universities. The growth of FUTO has attendant surge in student and non-student population, businesses and allied services providers within campus. This has also seen an increase in waste generation, improper disposal and management. The new administration has initiated waste management scheme to manage and control waste (Fig. 2).

Waste generated: Data collected from Office for University Development from July 2019 to February 2020 was 15607.5±183 cm^3 of solid waste generated daily. The logistics performance indicators isolated from the data were frequency of collection, waste volume and waste tonnage (Fig. 3).

Waste collection routing: Figure 3 shows the collection route for FUTO.

RESULTS AND DISCUSSION

The relative performance of these indicators on logistics were regressed and present below thus:

$$Y = b_0 + b_1X_1 + b_2X_2, ..., + b_nX_n + \varepsilon$$

Table 2: Model summary[b]

Model	R	R^2	Adjusted R^2	SE of the estimate	Durbin-Watson
1	0.980[a]	0.960	0.952	0.006511	1.978

[a]Predictors: (Constant), log_Wvol, log_Lton, log_freq; [b]Dependent Variable: Logistics

Table 3: Coefficients[a]

	Unstandardized coefficients		Standardized coefficients			95.0% confidence interval for B		Collinearity statistics	
Models	B	SE	Beta	t-values	Sig.	Lower bound	Upper bound	Tolerance	VIF
1 (Constant)	0.555	0.037	-	15.122	0.000	0.476	0.633	-	-
log_Wvol	0.037	0.008	1.265	4.590	0.000	0.020	0.054	0.035	8.750
log_Lton	0.018	0.007	-0.618	-2.370	0.032	-0.033	-0.002	.039	5.748
log_freq	-0.034	0.005	-0.432	-6.338	0.000	-0.045	-0.022	0.568	1.761

[a]Dependent Variable: Logistics

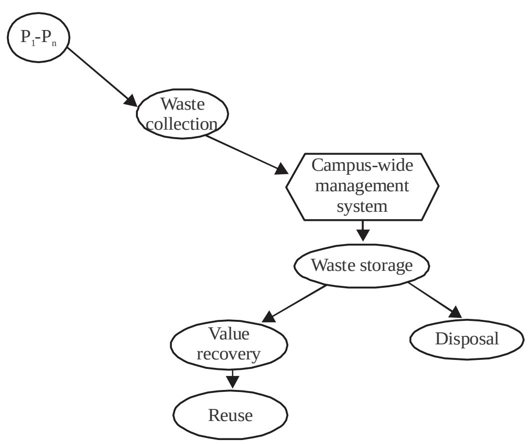

Fig. 4: Waste Management logistics loop for FUTO; Authors Design in 2020

Table 2 show the degree of relationship between the collected indicators and logistics performance in FUTO, as indicated by the R = 0.980 a strong positive correlation (98%) can be inferred between the collective indicators and logistics performance. Also an R^2 value of 0.96 defines the predictive powers of these indicators on logistics performance in FUTO with only 4% due to factors outside (Collection frequency, waste volume per day and waste tonnage per trip).

At 5% statistically significant inferences can be made from Table 3. The indicators are statistically significant as shown from the sig column but an inverse relationship exists between frequencies of carting waste from respective locations per route with logistics performance. This may be due to the 30 L day^{-1} of diesel constraint or the age and effectiveness of the waste truck used.

Thus, for predictive and prescriptive purposes the logistics performance of waste can be modeled, thus:

$$Y = 0.555+0.037X_1+0.018X_2-0.034X_3+0.006511$$

Where:

Y = Logistics performance
X_1 = Waste volume
X_2 = Loading tonnage
X_3 = Loading frequency

Proper waste management logistics loop for FUTO would include these objects (Fig. 4).

CONCLUSION

The finds of this research shows a prescriptive model for waste management in FUTO. Logistic performance can be modified by unit variation in Waste volume collected and tonnage per trip. These critical indicators isolated from this research can be used for optimization given the constraints of quantity of diesel and other factors.

RECOMMENDATIONS

As governments and legislators are encouraging ever greater resource efficiency as many countries are now recognizing the environmental damage caused by waste, laws are now made with the aim of improving material recovery from waste. Technological developments are resulting in effective waste management and disposal systems. The cost-benefit analysis for waste recycling and recovery are now being considered with the environmental consequence of sending waste to landfill or incineration. Thus waste management solutions aimed at zero-impact should be adopted with net positive environmental strategies which ensures long term competitiveness. Waste management logistics system designed for FUTO should implement technological, environmental and economic considerations together with a suitable functional, instrumental and institutional evaluation.

Again as Dima *et al*.[5] notes waste management logistic systems are premised on processes and objects thus, waste management logistics system for FUTO should be built on proper segregation and classification such a framework designed to handle categorized waste is key to a smooth functioning waste management system.

Objects of interests includes: waste prevention, waste generation, waste separation, value/energy recovery, material(s) recycling and waste disposal[9].

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