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Improvement of Solid Waste Management System in Port Harcourt City using Reliability Tool

Essiet C. Ekong[1], Chukwuemeka. P. Ukpaka[2], Barinyima Nkoi[3]

[1,3] Department of Mechanical Engineering, Rivers State University
[2]Department of Chemical/Petroleum Engineering, Rivers State University
shektecharles@gmail.com +2348068660751

ABSTRACT:

This research adopts the use of first order reliability method (FORM) in managing a waste management system. Questionnaires were distributed to waste management contractors, individuals, residents, schools, corporate bodies, and institutions, companies and industries. Within the questionnaires retrieved, waste generation data of selected zones were added. Vehicles with different capacities in kilogram were selected and the right combination for different vehicles was done based on the factors present, which includes; the expected achievable fixed costs, operations costs, and types of vehicle available. Due to the multiple trial and error method, MATLAB and PYTHON statistical and programming software were used to run mathematical expressions of FORM to output a graph that shows the relationship between operation cost, vehicle capacity and number of the vehicles used. Furthermore, the masses of the waste generated were grouped into three (3); Case 1 (minimum waste generated), Case 2 (mean waste generated) and Case 3 (maximum waste generated) of different capacities - 32011kg/day, 80835kg/day and 122338kg/day respectively. Their summary waste management system capacities were 40000kg, 82000kg and 132000kg respectively. After the application of FORM expressions, Case 1 had a reliability of 74%, Case 2 had 75%, while Case 3 had 77%. The results showed that a system with more vehicles tend to have less reliability. In addition, the results showed that the inter-relationship of these several factors could also affect the reliability of a Solid Waste Management System (SWMS).

Keywords: Disposal rate, First Order Reliability Method, Generation rate, Geomorphic analysis, Reverse logistics, Solid waste

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1. INTRODUCTION:

Port Harcourt, being one of the major cities in Nigeria, struggles diurnally to free its environs of accumulated mounds of solid waste. The Garden City, as it is fondly called reeks of overflowing refuse dumps and accumulated heaps of solid waste. Statistics show that in 2015, Rivers state generated about 1,200,000 metric tons of waste but a little above 300,000 metric tons was disposed in the creeks and aquatic bodies around the state. Hence, the emergence of increased number of dump grounds and accumulated litters of waste deposits in the creeks, rivers, streets and even open places in the state. Consequently, the Rivers State Waste Management Agency (RIWAMA), the Ministry of Environment and her waste contractors seem to find it an uphill task in the efficient tackling of disorderly disposal of solid waste by individuals and the likes thereby contravening the Rivers State Clean Air and Health Edict of 1990 (Gobo, 2014).

Solid waste is known to be an unwanted solid material emanating from commercial, industrial, and residential activities. It can also be an inconsequential solid material resulting from any activity or industrial methods without a present economic usefulness but must be discarded as waste in order to inhibit its ability to pose as a source of harm to people and the ecosystem. Solid waste management has to do with the systematic coordination of generation, collection, storage, transport, source separation, processing and disposal of solid waste. The First Order Reliability Method (FORM) was used as a reliability tool to see how the solid waste management system can be improved. This study covered some specific areas of the metropolis of Port Harcourt, the capital of Rivers state. Port Harcourt was created in 1912 resulting from the interaction of three sets of factors; political, economic and geomorphic (NPC, 2016).

Many people are not aware of the injurious nature of bad waste management culture or perhaps neglect the consequences**,** and ways of improving the system and trend. Therefore, the problems of improper waste management system revolve mainly around wrong waste disposal techniques, insufficient waste management equipment and its inconsistent maintenance. Others include poor financing, inadequate environmental literacy programme on proper waste management and lack of proper documentation of waste management related data for research studies and future improvement of reliability purposes. The aim of this study is to adopt First Order Reliability Method (FORM) to improve solid waste management system in Port Harcourt metropolis.
The objectives include: to find out the existing solid waste management system in Port Harcourt city, to ascertain the various challenges and factors associated with effective waste management methods and to apply First Order Reliability Model to ascertain if the planned system is reliable based on the factors considered
This research work will be useful to many individuals, institutions, corporate entities, industries and Government bodies alike in that it will give insight into the following areas: Enlighten the reader on the ills of improper waste disposal system around the environs, illuminate on ways of curbing and inhibiting the indecent and indiscriminate littering of refuse, point out the advantages of maintaining proper waste management techniques and trends and promote partnership of Government with private establishments to educate the citizens on environmental hygiene and waste recycling/reuse.

Solid waste management is a critical burden and a profound challenge to society due to the modernization and rapid development of the tourism industry in developing countries (Song-Toan *et al.*, 2019). According to Shivika *et al.* (2017), while metropolitan solid waste system in developing countries is nearing sustainability, it appears to be a burden that developing countries are struggling to solve. Sustainability is the aim of a long-term process that municipal solid waste system has to be implemented and upgraded gradually in which planning an oriented strategy for the municipal solid waste management system is vital.

On the international scene, as it relates to Port Harcourt city, Zamoranoa *et al.* (2011) analyzed the characteristic nature of industrial waste production and management in the city of Granada (Spain), and pointed out its strengths, weaknesses, opportunities and threats, its weaknesses being insufficient proper waste management tools and inadequate training of waste management personnel. Others include low percentage of selective waste collection and the activities of unsanctioned vendors. Based on these findings,
Hamza (2009) examined the effects of industrial and small scale manufacturing wastes on urban settlements of developing countries and suggested that the widely dispersed small and medium scale enterprises in urban settings that generate numerous pollutants and toxic refuse pose immediate source of harm and an unbearable environmental hazards to urban dwellers such as residents of Port Harcourt.

According to Kanakaraj *et al.* (2010) out of 1000kg of raw hide, almost 850kg is churned out as solid waste during leather processing, hence only 150kg of the raw material is transformed into leather. Therefore, Tannery industries generate huge amount of solid waste which comprises; hair, 2-5%, fleshing, 50-60%, skin trimmings, 5-7%, chrome shaving, chrome splits and buffing dust, 35-40%. This is just one out of many cases of environmental pollution caused by industries resident in Port Harcourt city. In order to tackle this challenge, a conscious approach must be taken such as the encouragement of waste minimization, application of pollution prevention methods, proper sensitization of entrepreneurs in waste management and centralized waste treatment of effluents.

Ichim (2007) asserted that there are five vital factors which if neglected might oppose the successful execution and operation of effective waste management strategies: government must give aid, financial support must be adequate to cater for the increasing operating cost of the waste management, best composting practices must be put in place, sufficient training for waste workers must be provided, and a market (or end use) for the final product must be set up. Waste transportation is a major problem in Nigeria. But sadly, about 40% of the waste collection vehicles and handling machinery owned by the government are not in good operating conditions.

According to Adedibu (1999), solid waste management should involve its generation, collection and final disposal of waste in a sanitary way to bring about good environmental sanitation management. The study further suggested that a good management procedure must consist of plans for storage, collection, processing, recovery of resources, recycling and final disposal. The technique to be used depends on the constituents and rate of generation by the residents.

Aujum and Deshazo (1996) asserted that most cities in developing countries spend 20% to 50% of their revenue on the collection, transportation and disposal of solid waste. Attempts to curb the menace of improper solid waste management in developing countries have been directed on collection and disposal, disregard of waste recycling, reuse, reduction, avoidance and incineration. It is stated that if solid wastes are not recycled, the landfills are exhausted very fast, prompting the construction of new ones thereby occupying available land spaces. Also, many scholars believe there has to be improvement in public and private sector partnership that will engineer speedy growth of the waste management industry in Nigeria. The modelling of waste management can improve the system to a certain extent. Hu and Sheu (2013) regarded disaster waste clean-up as a reverse logistics system and formulated it as a multi-objective linear programming model, in which psychological cost and the aggregate reverse logistics costs were both considered.

2. MATERIALS AND METHODS

2.1 Materials for Data Collection:

The two (2) main instruments that were used were Personal interview and Questionnaire. 300 copies of structured Questionnaires were administered at random to six (6) selected areas in Port Harcourt city namely; old Port-Harcourt - UTC junction - Diobu - Wimpey, GRA, Rumuokuta – Elekahia, Elelenwo, Artillary – Waterlines, Ogbunabali – Abuloma. Individuals, residents, schools, corporate bodies, institutions, companies and industries were respondents to these Questionnaires. Random sampling method was used in the case of survey Questionnaires which is best suitable for this research.

2.2 Sources of Data:

The sources of data for this research were derived from a primary source and a secondary source. Both sources are important due to the factual nature of this work. However, the primary source was given a more preferential treatment compared to the secondary source. The Primary Source comprises the Questionnaires and personal interviews conducted. Personal interviews were also conducted to extract information as supplementary means of getting information. The Secondary Source includes the extensive review of existing literatures on solid waste management systems useful during this research work as they include: textbook materials, academic journals and publications, online news articles, and information gotten from company reports.

2.3 Data Analysis Method:

Based on the data collected through the questionnaires, the reliability of the system depends on two major factors; Waste Generation Rate G_r and System capacity. First Order Reliability Method (FORM) as established in Cheng *et al.* (2018) was used to develop an algorithm that helps in computing the reliability of a Waste Management System (WMS). PYTHON programming language and MATLAB software were used to perform rigorous mathematical operations based on the derived mathematical model.

2.4 Disposal Rate (Dr):

Disposal rate can be defined as the amount of waste in kg disposed from an allocated community's dumpsite to the main dump site per unit time, the time unit can be in hours, days, weeks or months within a given period. In this research however, its unit is kg/day.

Let; w_c = waste generated in a given time, D_r = disposal rate, w_d = dumpsite capacity, w_v = vehicle capacity. The selection of the proper disposal rate will depend on the following conditions:

Condition 1: If w_c for a given time t is approximately equal to the maximum of w_v, then the disposal should be done within that given time$t$.

$$Dr = \frac{w_c}{t}, \; w_c \cong w_v, \tag{1}$$

Condition 2: If w_c for a given a time t is less than the maximum of w_v, and the ratio r_n between w_v: w_c is greater than 1 provided that w_c doesn't exceed w_d within time $r_n \times t$, then the disposal rate is given by;

$$Dr = \frac{w_v}{r_n \times t}, \; w_c < w_v, \; r_n > 1 \tag{2}$$

$$r_n = \frac{w_v}{w_c} \tag{3}$$

Condition 3: This is based on Case 2, it applies when w_c exceeds w_d within time $r_n \times t$, then the disposal rate is given by;

$$Dr = \frac{w_d}{r_n \times t}, \; w_c > w_d, r_n < 1 \tag{4}$$

$$r_n = \frac{w_d}{w_c} \tag{5}$$

To get the Total vehicle capacity for a given waste in kg in a WMS where c is the vehicle capacity and k is the number of vehicle type respectively while considering the fixed maintenance cost and the operation cost, then;

$$w_v = c_1k_1 + c_2k_2 + \cdots c_nk_n = c_1k \ldots + c_nk \tag{6}$$

2.5 Waste Generation Rate (Gr):

Waste Generation rate is defined as the amount of waste generated in a given time. To Estimate the waste generation of Port Harcourt municipality, questionnaires were sent out and then received. The Data obtained from the questionnaire responses were analysed to estimate Gr using MATLAB supplemented by PYTHON. Type of settlement, Population and Location were also explored.

2.6 Introduction to First Order Reliability Method (FORM):

Based on the method used in Cheng et al. (2018), for a waste management system with a disposal rate, D_r and a Generation rate, G_r, probability of $D_r < G_r$ is the probability that expresses the possibility of Disposal rate not being sufficient to balance the Generation rate. Thus, the reliability of the system is derived as follows:

$$P_f = P_r(D_r < G_r) = P_r(D_r - G_r < 0) = P_r(Z < 0) \tag{7}$$

$$Z = D_r - G_r \tag{8}$$

Considering equation Z = D_r - G_r if the mean function μ_Z is considered relatively then;

$$\mu_Z = \mu_{D_r} - \mu_{G_r} \tag{9}$$

and the standard deviation σ_Z is given by;

$$\sigma_Z = \sigma_{D_r} - \sigma_{G_r} \tag{10}$$

Journal of Newviews in Engineering and Technology (JNET)
Vol 2, Issue 1, March, 2020
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Relating Equations 8, 9 and 10:

$$P_f = \phi[-{}^{\mu_Z}/_{\sigma_Z}] \quad (11)$$

Also, probability index is given as;

$$\beta = {}^{\mu_Z}/_{\sigma_Z} \quad (12)$$

$$Z = D_r - G_r = \sum_{i\in V} v_i c_i r_i - g \quad (13)$$

Where;
Z is Probability function
β is reliability index (%)
μ_Z is Mean probability function
μ_{D_r} is Mean disposal rate (kg/day)
μ_{G_r} is Mean generation rate (kg/day)
μ_{r_i} is Mean of routes that can be taken
σ_Z is Standard deviation function
σ_{D_r} is Standard deviation of disposal rate (kg/day)
σ_{G_r} is Standard deviation generation rate (kg/day)
σ_{r_i} is Standard deviation of routes that can be taken
V is Set of vehicle types
r_i is Total routes which can be made by a type ($i\in$V) vehicle in a whole period
c_i is Capacity of type ($i\in$ V) vehicle(kg)
v_i is Total number of type ($i\in$ V) vehicle;
g is Estimated waste generation based on population (kg/day)
Relatively,
equation $\mu_z = \mu_{Gr}$ and $\sigma_z = \sigma_{D_r} - \sigma_{G_r}$ can be transformed using the new variables;

$$\mu_Z \approx \sum_{i\in V} v_i \mu_{c_i} \mu_{r_i} - \mu_{G_r} \quad (14)$$

$$\sigma_Z{}^2 \approx \sum_{i\in V} \left[(v_i \mu_{r_i})^2 \mu_{c_i}{}^2 + (v_i \mu_{r_i})^2 \sigma_{r_i}{}^2 \right] - \sigma_{G_r}{}^2 \quad (15)$$

2.7 Valuation of the Questionnaires:

The reliability and validity of the Questionnaires were made valid in that; the questions were framed in words comprehendible to the least educated, the response category was mutually exclusive, questions asked were bias free and neutral in tone and respondents were expected to provide their answers where necessary. These are some of the questions; state type of waste generated, identify type of waste storage facility used, duration taken to generate the waste, weight of the waste generated, and method of solid waste disposal used.

3. RESULTS AND DISCUSSION

Based on the data obtained from the questionnaires, it was realized that the most used means of solid waste disposal is dumping of waste in the Receptacles situated by the government at strategic points in the city. However, in the absence of these Receptacles, residents of that settlement are normally implored to package their waste materials and dump them on the road median to be later evacuated by waste cleanup officials. This method of waste disposal is not very effective as respondents do not comply accordingly and at other times, these waste materials accumulate overtime, abandoned, littered everywhere thereby becoming environmental and health nuisance to the dwellers and road users alike. The other types of waste generated by corporate entities, institutions and industries receive significant attention as most are recycled and sold to other industries as raw materials. This is enabled by the activities of scavengers who rummage the dumps and landfills, while some build squatter colonies on the edges of dumps, ignoring the health and environmental risks involved.
Based on the data obtained from the recovered questionnaires, a waste generation data was obtained for the selected zones.

Table 1: Waste generation data

	Type of Settlement	**Waste Generated per day (Kg/day)**
Zone 1	Urban	94170
Zone 2	Rural	94447
Zone 3	Rural	75533
Zone 4	Rural	122338
Zone 5	Urban	78225
Zone 6	Rural	97482

Journal of Newviews in Engineering and Technology (JNET)
Vol 2, Issue 1, March, 2020
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Zone 7	Urban	118780
Zone 8	Urban	47118
Zone 9	Urban	53052
Zone 10	Urban	55661
Zone 11	Urban	83530
Zone 12	Urban	76269
Zone 13	Urban	94870
Zone 14	Rural	93586
Zone 15	Urban	101737
Zone 16	Urban	96365
Zone 17	Urban	85999
Zone 18	Rural	104414
Zone 19	Urban	32011
Zone 20	Rural	42304
Zone 21	Rural	49645

The information as presented in Table 1 were obtained from the waste generation data of zones considered. As cited in Section 2.1 (Materials for Data Collection), 6 selected areas in Port Harcourt municipality were chosen. They were further grouped into 21 zones based on the type of settlement. An average set of values of their estimated waste generation data were calculated to arrive at the resultant information.

These waste generation data were analysed in 3 cases: minimum waste generated in a given time (32011kg/day), average waste generated in a given time (80835kg/day) and maximum waste generated in a given time (122338kg/day). The operation cost of the waste disposal vehicles and the number per vehicle type were also considered. Table 2 shows the parameters of the vehicle types selected for waste disposal.

Table 2: Vehicle types input

Vehicle type	1	2	3	4
Capacity (kg)	10000	12000	18000	20000
Operation cost (₦/kg)	61	46	37	34
Fixed cost (₦/year)	196900	507200	791700	1497000

Based on this study, questions were thrown to waste management contractors about the capacities, operation cost and Fixed cost of the various trucks basically used for waste disposal and an average set of values were obtained.

3.1 Resolution of Vehicle Capacity:

To resolve the best combination of vehicles needed for the three cases of waste generated (minimum, mean and maximum), the iteration was done using Equation 6 as cited in Section 2.4 (Disposal Rate, Dr).

This employs the interaction between the operation cost of the suitable waste disposal vehicles and its number per vehicle type. MATLAB and PYTHON languages were called on to perform rigorous mathematical operations. For the minimum waste generated, the graph in Figure 1 was obtained. Here the operation cost is reduced from 214 (₦/kg) to about 199 (₦/kg). This reduction in the operation cost is due to the change in the combination of the vehicles. Starting from 2 quantities for each vehicle, the number of Vehicle 2 increased from 2 to 3 and that of Vehicle 1 reduced from 2 to 1. It shows that it is better to use more of the bigger vehicle than the smaller ones to avoid redundancy thereby affecting system reliability.

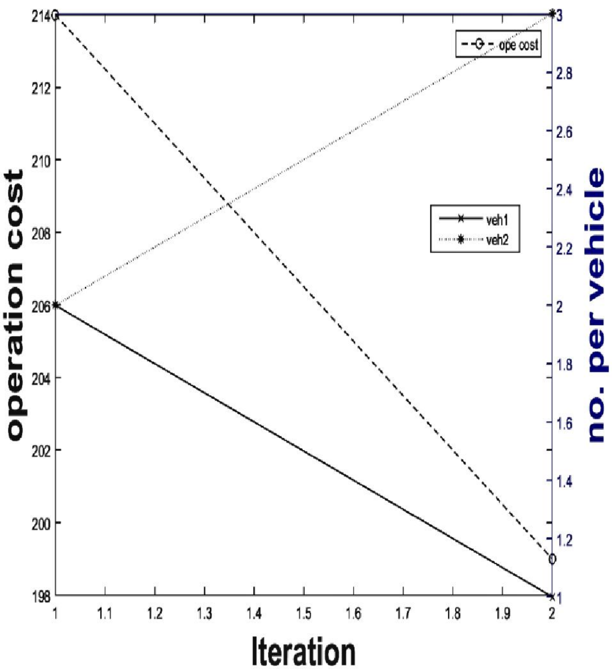

Figure 1: For Minimum waste generated

For average waste generated in a given time (80835kg/day), when the vehicle capacity is resolved, a graph in Figure 2 is obtained. It follows the same pattern as Figure 1. The operation cost is reduced from 356 (₦/kg) to about 322 (₦/kg). Starting from 2 quantities for each vehicle, the number of Vehicle 1 increased from 2 to 5 and that of Vehicle 2 reduced from 2 to 1. It reiterates the fact that there is no need to opt for a smaller vehicle to do a job that a bigger vehicle can do in one trip. However, as the operation cost reduces because of the increase in quantity of the smaller vehicles, the Fixed cost reduces also.

For maximum waste generated in a given time(122338kg/day), the same vehicle resolution takes place and graph of Figure 3 is obtained. It follows the same pattern as in Figure 1. The operation cost is reduced from 534 (₦/kg) to about 450 (₦/kg). Starting from 2 quantities for each vehicle, the number of Vehicle 4 increased from 2 to 9 and that of Vehicles 1,2,3 reduced from 2 to 1.

Note that the iteration does not always optimally select the best combination since it has its limits.

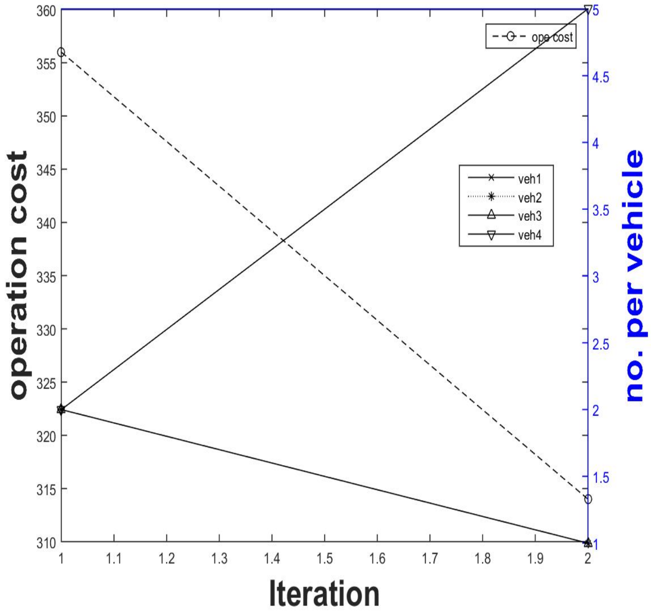

Figure 2: Mean waste generated

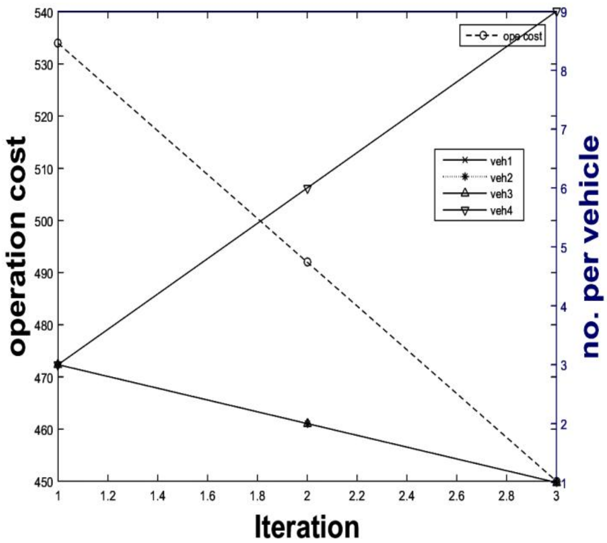

Figure 3: Maximum waste generated

However, after the combination was improved, it was realized that the minimum waste generated had a disposal system capacity of 40000kg, the average waste generated had a system capacity of

Journal of Newviews in Engineering and Technology (JNET)
Vol 2, Issue 1, March, 2020
Available online at http://www.rsujnet.org/index.php/publications/2020-edition

82000kg and that of maximum waste generated stood at 132000kg respectively.

3.2 Application of First Order Reliability Method (FORM):

The reliability index can be obtained while assuming that each vehicle has only one route to take and the standard deviation of the routes is assumed to be zero. This is constant for all cases.

For Case 1 being minimum waste generated in a given time:

$v_i = 4$

$u_{ci} = 40000$

Using Equations 14 and15

$\mu_Z = 87989$

$\sigma_Z = 119243$

Therefore, the reliability index, β for Case 1 is:

$\beta = 0.74 \equiv 74\%$

For Case 2 being mean/average waste generated in a given time

$v_i = 4$

$u_{ci} = 82000$

Using Equations 14 and 15

$\mu_Z = 247165$

$\sigma_Z = 327724$

Therefore, the reliability index, β for Case 2 is:

$\beta = 0.75 \equiv 75\%$

For Case 3 being the maximum waste generated in a given time:

$v_i = 4$

$u_{ci} = 132000$

Using Equations 14 and 15

$\mu_Z = 405662$

$\sigma_Z = 527390$

Therefore, the reliability index β for Case 3 is:

$\beta = 0.77 \equiv 77\%$

3.3 Reliability Check:

Based on FORM, if the reliability is greater than 70%, then the system is reliable for the condition analysed. The combination was analysed using the Reliability plot shown in Figure 4.

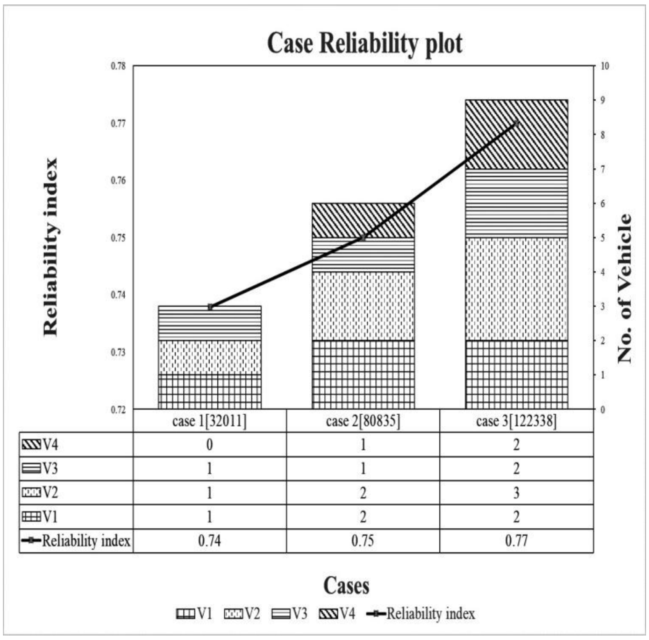

Figure 4: Case reliability plot

Since all the vehicle combinations go beyond 70%, hence, all the systems are reliable and can work based on the factors considered. The following points were deduced from Figure 4: Reliability can either increase or decrease as the number of vehicles increases, different combination with same factors can affect the reliability index and for a system to be reliable, the probable chances of the disposal rate being lower than generation rate must be very low.

4. CONCLUSION

The existing waste management system practised in Port Harcourt is the conventional waste management system which basically involves waste collection, waste treatment and waste disposal. This however is not very efficient as little or no emphasis is laid on recycling. The various challenges facing solid waste management in Port Harcourt city are numerous but majorly it borders on the administration and regulation of these practises by Government and also the residents who play a vital role of maintaining the environment hygiene and reduction of waste generation to its barest minimum.

The First Order Reliability Method (FORM) was applied as a reliability tool to the quantifiable variables such as the number of vehicles for waste disposal while considering the operation cost in order to improve the reliability of the solid waste management system. There was shortage of accurate data and status of the current system since no planned system is set out for the processes of disposal. In addition, a lot of contractors were reluctant about giving important information about their affairs.

REFERENCES

Adedibu, A. A. (1999). Solid Waste Characteristics and Management in Ilorin. *Journal of the Nigerian Institute of Town Planners*, 3(1), 33–42.

Aujum, M. A. & Deshazo, J. R (1996). House Hold Demand for Improved Solid Waste Management: A Case Study of Gujranwala. *International Journal of Pakistan Water Development* 24(5), 857-868.

Cheng, C., Lihai, Z., & Russell, G. T. (2018). Reliability Analysis for Disaster Waste Management Systems. Department of Infrastructure Engineering, the University of Melbourne, VIC 3010, Australia,78 (2018)31-42.

Gobo, A. (2014). Solid Waste Management Option for the Niger Delta, *Proceedings of the 3rd National Workshop on Waste management and Pollution in the 21st Century*, Rivers State Ministry of Environment and Natural Resources, Port Harcourt.

Hamza, A. (2009). Impacts of Industrial and Small-Scale Manufacturing Waste on Urban Environment in Developing Countries. A Technical Paper Presented at the Urban Management Program/United Nations Centre for Human Settlement, Nairobi.

Hu, Z. H., & Sheu, J. B (2013). Post Disaster Debris Reverse Logistics Management Under Psychological Cost Minimization. *Transport Research Part B Methodology*. 55, 118-141.

Ichim, G. E. (2007). Assessing the Challenges and Potential of Implementing Composting as Part of a Municipal Solid Waste Management System in Baisha, Hainan, China. A Thesis Presented to the University of Waterloo, Ontario, Canada.

Kanakaraj, J., Velappan, K. C., Chandra-Babu, N.K., & Sadulla, S. (2010). Solid Waste Generation in the Leather Industry and its Utilization for Cleaner Environment. A Review, *Journal of Scientific and Industrial Research,* 6(5), 541-548.

National Population Commission (2016). Population and Housing Census: Population Distribution by Sex, State, L.G.A and Senatorial District, National Population Commission, Abuja, Nigeria.

Song-Toan, P. P., Takeshi, F., Giang, H. M., & Dinh, P. V. (2019). An Analysis of the Commercial Waste Characterisation in a Tourism City in Vietnam. *International Journal of Environment and Waste Management,* 23, 319-335.

Shivika, M., Minal, P., Priyadarshi, R. S., & Erik, A. (2017). GHG Mitigation and Sustainability Co-benefits of Urban Solid Waste Management Strategies: A Case Study of Ahmedabad, India. *Chemical Engineering Transactions* 56, 457-462.

Zamoranoa, M., Grindlay, A., Molero, E. & Rodriguez, M. I. (2011). Diagnosis and Proposals for Waste Management in Industrial Areas in the Services Sector, Case Study in the Metropolitan Area of Granada (Spain). *Journal of Cleaner Production,* 3(6), 1-10.