Modelling the Key Factors Influencing Faecal Waste's Circular Economy

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ABSTRACT

Strategies such as the adoption of punitive measures, subsidies provision and behavioural change tactics had not significantly improved the global scourge, with over 800 million people still defecating in the open. However, there is a consensus that the quest for open defecation eradication would become more effective through means that prompts households to invest in the construction and maintenance of sanitation facilities. One of such means is the leveraging on the reusability of faecal waste in encouraging households to be more selfishly prone to considering containment of their faeces a profitable venture. However, there is still a gap between the knowledge of faecal waste reuse and actual premiums placed on the resource by households owing to cultural, social, economic, environmental, technological, and awareness factors. Adopting a four-level multi-stage approach, a total of110, 100, and 120 questionnaires were respectively administered in Ogijo/Likosi, Ilaro I, andSodeke/Sale-Ijeun I wards, making 330 altogether. The selected criteria reflect the variance in the populations of 1,250,435(33%), 1,112,761(30%), and 1,387,944(37%) for Ogun East, Ogun West and Ogun Central, respectively. The pooled confirmatory factor analysis process took the form of several re-estimations,based on the deletion of lowly loading factors and correlation of redundant items, validation of the model, assessment of normality,and full structural model analysis.The structural model established a significant positive relationship between Environmental/Health Factors of Faecal Waste Reusability (EV) and Reusability Factor(RF) (β=0.727, $p<0.05$), and similarly, Economic Factors of Faecal Waste Reusability (EC)and Reusability Factor (RF) (β=0.715, $p<0.05$). The study, among all others, recommends a more flexible household-led economic incentive approach to open defecation eradication, in line with the paradigm of the green and circular economy.

Key words: Circular economy, Faecal waste, Open Defecation, Structural Equation Modelling.

1. BACKGROUND TO THE STUDY

Resource recovery and reuse affords incentivizing opportunities for voluntary investment in the construction of households' toilets (Rao *et al.*, 2017). As canvassed by Mittal *et al.* (2017), the incentive alternative of creating values for faecal waste, by virtue of its reusability, offers the promise of greater sustainability as it affords the recovery of both construction and maintenance costs, and the costs recovery is essentially a function of frequent use to make resource available. It needs to be stressed that the scope of faecal waste reuse has now gone beyond the sphere of traditional agricultural application, which was hitherto motivated by easy disposal and not necessarily deliberate commerce driven need to recover and reuse nutrients (Jimenez *et al.*, 2010; Andersson *et*

OlapejuO.O and RafeeMajid M.(2019), Modelling the Key Factors Influencing Faecal Waste's Circular Economy. Paper presented at the i-STEAMS International Conference, Federal Polytechnic Ilaro, Nigeria, 10^{th}-11^{th}, 2019.

al., 2016; Olufunke *et al.*, 2016). In the same agricultural sphere, faecal waste also commands reuse value in the production of feeds for aquaculture livestock (Danso *et al.*, 2017). According to Olapeju *et al.*(2019), the inorganic element in faecal waste have been found useful in the construction industry . The incinerator ash bye-product from sewage sludge incineration, when combined with dried sludge can be used as additives in the production of construction materials such as artificial lightweight aggregates, tiles, cement material and bricks (Semiyaga *et al.*, 2015). The frontiers of reuse, in the light of new interest in green and circular economy and improvements afforded by technology, have extended to applications such as high energy char, which is a product of the microwave thermo-chemical conversion process between 180°C and 200°C, and can be a greener alternative to firewood and charcoal –the main cooking energy sources of poor households in Africa, and eliminating associated environmental impacts (Afolabi and Sohail,2017) . Moreover, as canvassed in Mohson *et al.*(2017), Biogas which is a mix of methane, carbon dioxide and other gases in small quantities which can be converted to heat or electricity (Jouhara *et al.*, 2017; Malinauskaite *et al.*, 2017) can be recovered from faecal waste. The foregoing should make the incentive of reuse in the eradication of open defection an imperative for developing economies that are most beset with budget and capacity constrains to implement and sustain the option of direct intervention through subsidies as their open defecation eradication strategy..

2. STATEMENT OF PROBLEM

There is still a gap between the knowledge of faecal waste reuse and actual premiums placed on the resource by households owing to cultural, social, economic, environmental, technological, and awareness factors. The pragmatism of this incentive strategy should spinoff further interrogations as, at the target households' level, recovery and reusability would be a function of how households perceive such factors.

3. OBJECTIVE

Hence, this study's main objective is to employ the structural equation model to estimate the significant indicators and constructs that directly influence households to recover and reuse faecal waste in Ogun state Nigeria.

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4. METHODOLOGY

4.1 The Research Design

This study adopted the multistage approach in a four-level manner, which was inclusive of all senatorial districts, local governments, wards, and polling units in the geographical scope of Ogun State. The first stage involves the classification of Ogun State into its three main senatorial districts, viz: Ogun East Senatorial District, Ogun West Senatorial District, and Ogun Central Senatorial District.These divisions represent the three fundamental sub-ethnic divisions within the State. Ogun East Senatorial District consists of nine local governments, which are: Ijebu East, Ijebu North, Ijebu-Ode, Ikenne, Ijebu North-East, Odogbolu, Sagamu, Ogun Waterside and Remo North. Ogun West Senatorial District consists of five local governments, which are: Ado-Odo/Ota, Egbado North, Egbado South, Imeko-Afon, Ipokia. Furthermore, Ogun Central Senatorial District consists of six local governments, which are: Abeokuta South, Abeokuta North, Obafemi/ Owode , Odeda, , Ewekoro and Ifo. The second stage involves the random selection of Sagamu, Egbado South, and Abeokuta South Local Governments as the sampling Local Governments in Ogun East Senatorial District, Ogun West Senatorial District, and Ogun Central Senatorial District, respectively. The third stage involves the random selection of a representative ward, based on the wards and polling unit delineations of Independent National Electoral Commision (INEC), from each of the sampling Local governments. In Sagamu Local Government, which consists of 15 political wards namely:

Oko/Epe/Itula I; Oko/Epe/Itula II ;Ayegbami/Ijokun; Sabo I; Sabo II;Isokun/Oyebajo; Ijagba; Latawa; Ode-Lemo;Ogijo/ Likosi; Surulere; Isote; Simawa/Iwelepe; Agbowa; and Ibido/Ituwa/Alara, Ogijo/Likosi ward was randomly selected as the sampling ward. Out of the 10 local governments in Egbado South, namely Ilaro I; Ilaro II; Ilaro III; Iwoye; Idogo; OkeOdan; Owode I; Owode II; Ilobi/Erinja ; and Ajilete, Ilaro I was randomly selected as the sampling ward. Further, Sodeke/Sale-Ijeun II was randomly selected as the sampling ward in Abeokuta South Local Government, which encapsulates 15 political wards,namely, Ake I; Ake II; Ake III; Keesi/Emere; Ijemo; Itoko; Ijaye/Idi-Aba; Erunbe/OkeIjeun; Ago-Egun/Ijesa; Sodeke/Sale-IjeunI; Sodeke/Sale-Ijeun II; Imo/Isabo; Igbore/Ago Oba; Ibara I; and Ibara II.

The fourth stage involves the random selection of polling units in each sampling ward, and the random selection of buildings occupying targeted households and locating within 1 kilometre radius from the polling units. In Ogijo/Likosi ward, out of the available 19 polling units,10 namely: St Paul's school Igbode;St Micheal RCM Fakale;U.A.M.C School Iraye; St Francis school Igbosoro; St John school Ogijo I; LG school Erefun; LG school Igbaga; A.U.D school Imushin-Ogijo; Wesley school Sotunbo; and CAC school Ogijo I, were randomly selected. In Ilaro I, out of the available 17 polling units, 10 namely : State hospital ; Opp Soyinka's house I; Idowu's house(Otegbeye street);U.A.M.C school Pahayi; OritaKajola; Eleja(Oke-Ola); Poly gate;Library/rural health care center;EgboAlaparun, and ItaIyalode, were randomly selected. In Sodeke/Sale-Ijeun II, out of the available 25 polling units, 10 namely: Onijoko Mosque OkebodeII; OppOke-Itoku Mosque II; Ile OgboniOkeItoku; Near Town Planning; Open space Ojulakijena; St Joseph RCM. Oke-bodeI; Primary school Idipape I; All saint school Kobiti; Open space KemtaOdutolu Mosque;and Opp. Bus Stop Bata Itoku, were randomly selected. This made the total number of polling units within the radius of which households were surveyed in the study area to be 30. Using the systematic random sampling technique on the basis of the 5th building interval, 11 households were administered questionnaires within 1 kilometer radius of each of the 10 randomly selected polling units in Ogijo/Likosi ward ; 10 households were administered questionnaires within 1 kilometer radius of each of the 10 randomly selected polling units in Ilaro I; while 12 households were administered questionnaires within 1 kilometer radius of each of the 10 randomly selected polling units in Sodeke/Isale-Ijeun II. The choice of ratio 1.1: 1.0: 1.23 adopted respectively in each ward is to essentially reflect the population variance across the three senatorial districts estimated as 1,250,435(33%), 1,112,761(30%), and 1,387,944(37%) for Ogun East, Ogun West and Ogun Central, respectively, as extrapolated from NPC(2010). The utility of the systematic random method adopted at this stage is to totally make the selection of households a random process, without regards to the physical characteristics of their buildings, which can be suggestive of their sanitary profile. The unplanned nature of most of the settlements in the study area suggests also that there is no systematic pattern in the alignment of buildings, hence eliminating the factor of bias in the adoption of systematic random sampling.Based on the foregoing, a total of 330 questionnaires were administered to representative households in the study area. This implies that 110, 100, and 120 questionnaires were administered in Ogijo/Likosi ; Ilaro I, and Sodeke/Sale-Ijeun II, respectively. The total of 330 households that was surveyed through the probabilistic methods adopted actually represent about 0.06% of the 535,877 households in Ogun state. Given the household survey approach adopted by the research, whereby household members represent the observation units, 1561 observations, which suggest an average of 5 members per household were recorded and coded for data analysis.

5. DATA PRESENTATION

Structural Equation Modeling adopting the AMOS version 22 was used to validate the hypothesized measurement model of the factors of faecal waste reusability. The pooled measurement model is a second-order-construct that premises the faecal waste reusability (RF) on five factors conceptualized as constructs. The endogenous constructs hypothesized in measurement model as shown in Figure 6 are Awareness about Reuse Opportunities Associated with Sludge (AW), Economic Factor of Faecal Waste Reusability (EC), Environmental/Health Factor of faecal waste reusability, Social Acceptability Factor of faecal waste reusability, Sanitation Technology Factor of Faecal Waste reusability.

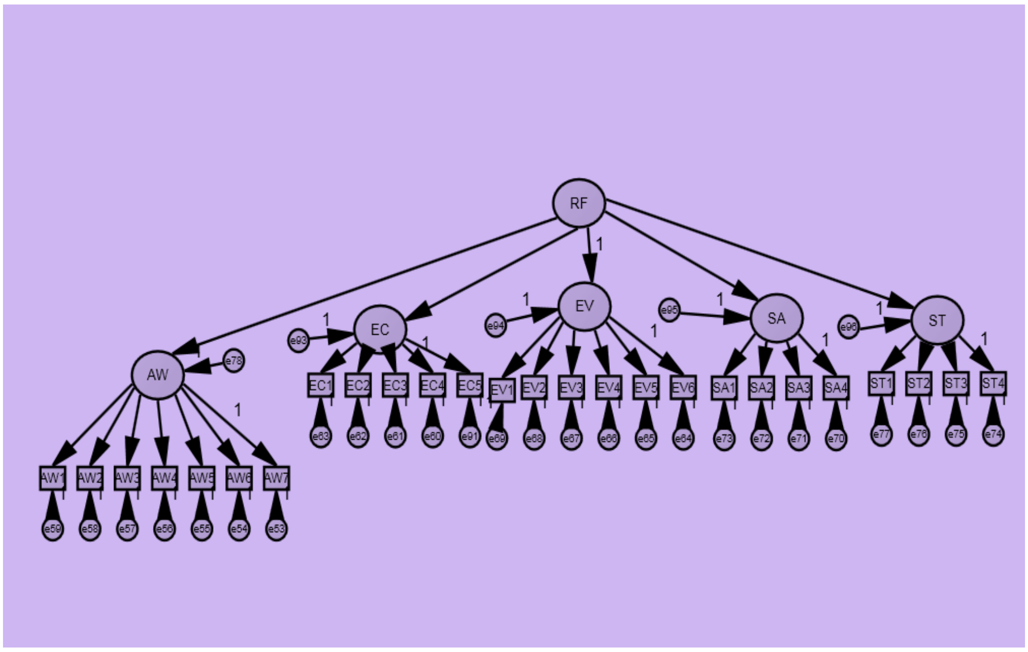

Figure 1: Hypothesized Measurement Model using Pooled CFA Estimates

The sub-construct -Awareness about Reuse Opportunities Associated with Sludge (AW) contains seven measuring items namely, AW1 - AW7. Five items, namely EC1- EC5 measure the sub-construct- Economic Factor of Faecal Waste Reusability (EC). The first order construct-Environmental/Health Factor of faecal waste reusability was measured with six items, namely, EV1 - EV6. Moreover, Social Acceptability Factor of faecal waste reusability sub-construct was measured with four items, after one item had indicated a poor reliability result. The items are SA1 - SA4. Finally, the sub-construct Sanitation Technology Factor of Faecal Waste reusability was measured with four items, after one of the items failed the reliability test. The items are ST1 - ST4. Following a pooled confirmatory factor analysis process, which took the form of several re-estimations,based on the deletion of lowly loading factors and correlation of redundant items, validation of the model , assessment of normality,and full structural model analysis. In order to improve the model's fitness indexes, all constructs and items with low factor loadings were expunged from the model. This is in line with Zainudin (2015) that items or first order constructs with factor loading less than 0.5 are considered poor and should be deleted from models. In light of this, three constructs (AW, ST, and SA) and one item EV1 were removed, after which the model was re-estimated. After the re-estimation based on low factors removal, only two fitness indexes, NFI and CFI, at 0.913 and 0.917, respectively, achieved their required fitness levels, despite all items loading above 0.5. The RMSEA (0.116), GFI (0.864), TLI (0.890), and CMIN/Df(19.276) values did not achieve their required level of fitness. The ensuing recourse to modification indices after subsequent correlations of e62 and e63; e62 and e66; e67 and e 97; e61 and e67; e63 and e66; e 65 and e91; e62 and e93; e66 and e68, e67 and e68, and e62 and e67, ensured the eventual achievement of all fitness indexes (RMSEA = .041; GFI = .987, TLI = .991, NFI = .993, CFI =.996 and Chisq/Df = 2.429)

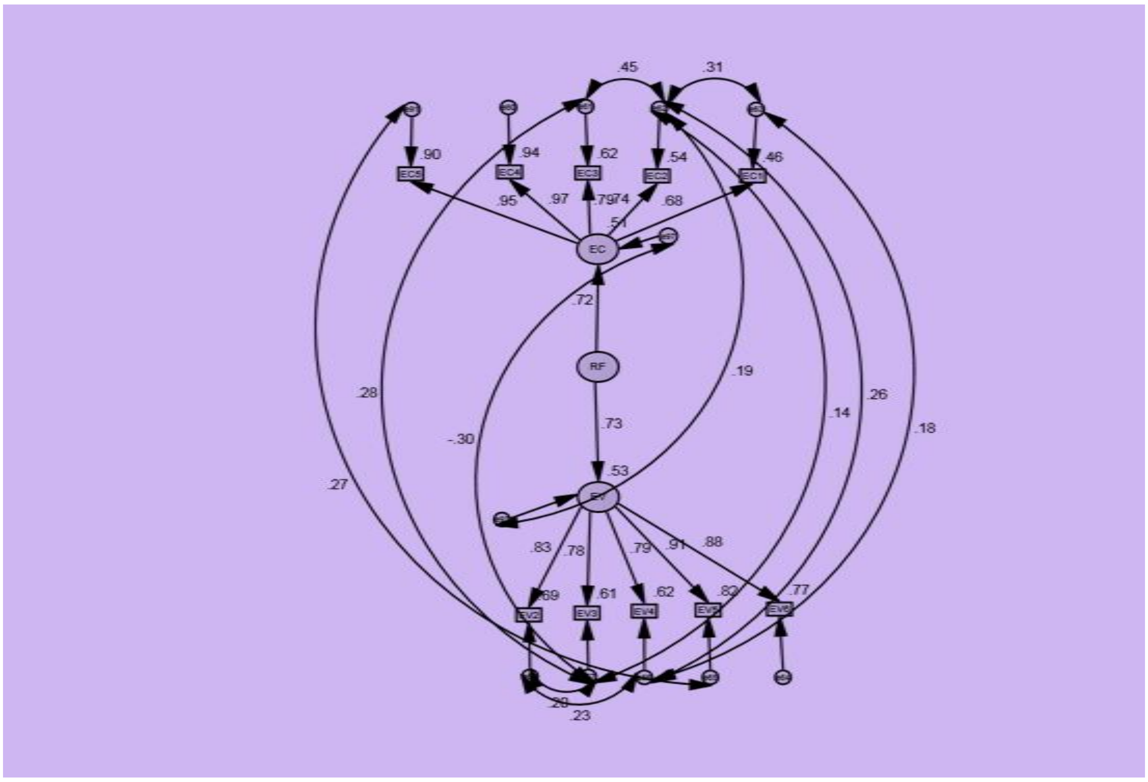

Figure 2: The Structural Model Showing the Path of Interest to be tested

6. DISCUSSION OF FINDINGS

In this study, as evident in the squared multiple correlations obtained, 53% (R^2=0.53) of variation of inclination to reuse faecal waste is essentially explained by Environmental/health factors, while 51 % (R^2=0.51) of the information on faecal waste's reusability can be estimated by the impacts of economic factors. Moreover, the structural model established a significant positive relationship between EV and RF (β=0.727, $p<0.05$), and similarly, EC and RF (β=0.715, $p<0.05$). The model pointedly revealed that 0.727 increment in the value of EV would culminate in a unit increase in RF. It further indicates that the possibility of achieving the regression weight estimate of 1.55 standard error above zero (Critical Ratio) is lesser than 0.05. This implies that the beta coefficient of EV in the determination of RF is significant. Similarly, a unit increase in the tendency for faecal waste reuse would be a function of 0.715 increments in EC. The probability of achieving a critical ratio of 1.54 is less than 0.05, which also indicates the significance of EC in the prediction of RF.

7. CONCLUDING REMARKS

Finally, given that punitive measures, governmental interventions, and psychologically exploiting behavioural change tactics adopted by governmental authorities around the world still would not prevent over 800 million people from defecating in the open, the study recommends improved marketing of awareness-raising and social/commercial marketing campaigns in respect of faecal waste reuse by both sanitation inclined non-governmental organizations and the public authorities.With the prospect of toilets construction and maintenance costs' recovery, households, mostly poor ones, who defecate in the open, would be better incentivized to be favourably disposed to faecal waste containment and management options that allow for greater yields of recovery as opposed to the use of chemicals and burying that are the commonplace in the study area. By creating value for faecal waste and optimizing the sanitation value chain, households who already have sanitation facilities whose technology would not afford economically viable recoveries and those not yet served with sanitation facilities would be nudged to adopting simple onsite low-cost technologies such as urine diversion dry toilets (UDDTs) canvassed by Rao *et al.* (2017) and anaerobic biogas latrine, that can afford in-situ resource (energy or nutrient) recovery, represent a business model for poor households and ultimately culminate in the improvement of households' sanitation.

8. CONTRIBUTIONS TO KNOWLEDGE

It has contributed to bridging a knowledge gap on the cultural, economic, social, environmental, and technological dimensions to the faecal waste's reusability and essentially their willingness to deem them a valued resource, which reusers can pay for in the quest to enhance the value for household faecal waste and encourage the construction of toilets.

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