USING PLS-SEM TECHNIQUE IN ASSESSING INTEGRATED SUSTAINABLE WASTE MANAGEMENT FRAMEWORK IN ABUJA, NIGERIA

ABUJA, NİJERYA'DA ENTEGRE SÜRDÜRÜLEBİLİR ATIK YÖNETİM ÇERÇEVESİNİ DEĞERLENDİRMEDE PLS-SEM TEKNİĞİNİN KULLANILMASI

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Abstract: ***Dwindling spaces for landfills in cities today has necessitated developing new ways of sustainably managing solid waste. However, sustainable waste management is guaranteed by adopting widespread recycling programmes such as integrated solid waste management systems (ISWM) that embraces 3Rs (reduce, reuse and recycle). Within the preceding context, this study is borne out and aimed at determining the impact of these 3Rs on long-term solid waste management. The study's goals are based on the hypothesis that the 3Rs positively impact long-term solid waste management. In the light of the preceding, this research creates a theoretical structural model that depicts the impact of these 3Rs variables on Sustainable Solid Waste Management in Nigeria. Data were collected from 178 respondents, including waste management officers, organisations, and Abuja citizens. The obtained data were statistically measured with the Partial Least Square; Structural Equation Model (PLS-SEM 2.0). Cronbach's alpha values for the variables were higher than the industry standard of 0.7, indicating that the research instrument was reliable. With t-values of 2.182 and 7.435, respectively, waste reduction and waste recycling were strongly related to the sustainable management of solid waste except for reuse, which did not support sustainable solid waste management. All hypotheses were shown to be noteworthy at the 10% significance level. Thus, waste reuse, by implication, failed social acceptability. In contrast,waste recycling is acceptable and supportsthe concept of waste to wealth. The more the reduction of wastes, the most efficient and effective sustainable solid waste management is achievable.***

Keywords*: Recycling, reduce, reuse, solid waste, waste management*

Öz: Günümüzde şehirlerde çöplükler için azalan alanlar, katı atıkların sürdürülebilir şekilde yönetilmesi için yeni yollar geliştirmeyi zorunlu kılmıştır. Bununla birlikte, 3R'leri (azaltma, yeniden kullanma ve geri dönüştürme) kapsayan entegre katı atık yönetim sistemleri (ISWM) gibi yaygın geri dönüşüm programları benimsenerek sürdürülebilir atık yönetimi garanti edilir. Önceki bağlamda, bu çalışma doğrulanmıştır ve bu 3R'lerin uzun vadeli katı atık yönetimi üzerindeki etkisini belirlemeyi amaçlamaktadır. Çalışmanın hedefleri, 3R'lerin uzun vadeli katı atık yönetimini olumlu etkilediği hipotezine dayanmaktadır. Öncekilerin ışığında, bu araştırma, Nijerya'da Sürdürülebilir

Katı Atık Yönetimi üzerindeki bu 3R değişkenlerinin etkisini betimleyen teorik bir yapısal model oluşturmaktadır. Atık yönetimi görevlileri, kuruluşlar ve Abuja vatandaşları dahil olmak üzere 178 katılımcıdan veri toplandı. Elde edilen veriler, Kısmi En Küçük Kare ile istatistiksel olarak ölçülmüştür; Yapısal Eşitlik Modeli (PLS-SEM 2.0). Değişkenler için Cronbach alfa değerleri, 0,7'lik endüstri standardından daha yüksekti, bu da araştırma aracının güvenilir olduğunu gösteriyor. Sırasıyla 2.182 ve 7.435 t değerleriyle, atık azaltma ve atık geri dönüşümü, sürdürülebilir katı atık yönetimini desteklemeyen yeniden kullanım dışında katı atıkların sürdürülebilir yönetimi ile güçlü bir şekilde ilişkilidir. Tüm hipotezlerin %10 anlamlılık düzeyinde dikkate değer olduğu gösterilmiştir. Bu nedenle, atıkların yeniden kullanımı, dolaylı olarak, sosyal kabul edilebilirlikte başarısız oldu. Buna karşılık, atık geri dönüşümü kabul edilebilir ve atıktan zenginliğe kavramını desteklemektedir. Atıklar ne kadar azaltılırsa, en verimli ve etkin sürdürülebilir katı atık yönetimi sağlanabilir.

Anahtar Kelimeler*: Geri dönüşüm, azaltma, yeniden kullanma, katı atık, atık yönetimi*

INTRODUCTION

One of the most critical issues confounding environmental management in the global south is solid waste management (SWM) (Awomeso *et al.*, 2010). Blight and Mbande (1996) define SWM as the collection, transportation, preclusion, handling, disposal, recycling, reusing, and monitoring of solid waste. That indicates the supervision and control of the waste material generated from various human activities that aim to avoid a negative effect on general human well-being in the environment and its beauty by ensuring effective collection, storage, transportation, and recycling. In addition, it is seen by Nasidi *et al.*, (2018) as part of the programme for urban cleanliness required for managing the municipalities. It has to do with educational, training, planning, and implementation policies. SWM challenges in urban settings vary according to the size of the settlement (mega-cities, small towns or villages), which presents a good indication of effective urban governance (Ogawa, 2008).

The system of urban solid waste management in developing countries, unlike in advanced nations, has been observed as the challenges that require immediate attention from governments. The main issues with SWM in wealthy countries revolve around the high expense of disposing of the vast volume of waste generated by homes, businesses, and industries. In contrast, the main issues in developing countries revolve around collection and disposal. For a fact, one-third to half of all solid wastes generated in third world countries remains uncollected (Ikhlayel, 2018). In the wake of this, more environmental problems in consonance with an increased rate of solid waste generation is brewing in developing countries. This intertwined relationship is beyond the management capacity of many cities, mainly due to financial, technical, institutional, regulatory factors coupled with the noted shortcoming in the public participation efforts (Oteng-Ababio *et al.*, 2013; Sule, 2017). Solid waste management sustainability is a global concept that requires global attention.

For example, Hoornweg and Bhada-Tata (2012) reported that solid wastes are estimated to be about 1.3 billion tonnes on a global scale. It is expected to increase to about 2.2 billion tonnes by 2025. In 2003, Africa's total municipal solid waste generation was predicted to reach 2.02 billion tonnes in 2006, reflecting a 7% yearly growth (UNEP, 2002). It was also guesstimated that municipal creation of hazardous solid waste would rise to 37.3%, with an annual increase of around 8%. According to UNEP (2002), every year, the total healthcare waste ranges between 0.5 and 3kg for individuals in countries with low income. Similarly, the European Union have reported about 700 million tonnes of agricultural wastes per annum from its 25 member states. Although, no estimate of worldwide industrial waste creation has been made, if solid wastes could be transformed into valuable materials and resources, waste might be reduced significantly and used to produce revenue to fund waste management. Because income levels and urbaniaation rate sare inextricably linked, solid waste generation impacts economic development. When one's income and standard of living rise, so does one's consumption of goods and services, resulting in a growth in solid waste volume in the future. However, the resulting change will threaten environmental safety in developing countries worldwide, particularly social implications (Davidson, 2011).The rapid growth in the amount and varieties of solid and hazardous wastes poses a growing dilemma for most governments in maintaining solid waste management's efficacy and long-term viability (Igoni *et al.*, 2007).This paper evaluates the interaction between IWM and SSWM systems employing the 3R strategy to achieve the study purpose.

1. DEFINITION OF CONCEPTS

The operational definitions of some concepts used in this study are given as follows:

1.1. Sustainable Solid Waste Management (SSWM)

SSWM concept ensures human health and environmental safety for the protection of the general public and health workers mainly to avoid spreading diseases. In addition, its target I sto make environmental operations economical, less expensive and satisfactory in social terms (Wilson, 2011).

1. To be effective, a waste management system must reduce and protect the environment from incorrect garbage disposal while also avoiding hazards.

2. A sound waste management system should be affordable to the general public in terms of costing and operation, focusing on the improved standard of living of all people in the community.

3. For a waste management system to be satisfactory, it must meet its social requirements and achieve its full cooperation and support.

A waste management system must reduce and protect the environment from incorrect garbage disposal and avoid hazardous situations for its effectiveness to be known. Waste Management System encompasses waste management policy, planning, implementation and operation, checking and remedial action, and management evaluation, according to Poon *et al.* (2001). Some research stressed the need of having a waste management plan in place (WMP).

1.2. Integrated Waste Management (IWM)

According to McDougall *et al.* (2008), IWM is an all-planned design for solid waste management that considers every component (creation, setting apart/sorting, transfer, disposal, treatment and recovery) in an all-inclusive and efficient way. It was defined further by McDougall (2005) as the system that combines all streams of wastes, its collection, treatment and disposal methods and to achieve a comfortable environment and of economic and social acceptability. This aim is to achieve a workable waste management strategy for any given area.

According to McDougall *et al.* (2001), the components of IWM include a good overall approach; diversified means of collection and treatment; all-inclusive waste stream materials; effectiveness for environment suitability; affordable economically; and acceptability by the society. Perteghella, Gilioli, Tudor & Vaccari (2020) believed that difficulties regarding the interpretation of data and unavailability of data are among the tools hindering the progress of sustainable solid waste management practices. Furthermore, integrating the relevant stakeholders in the decision-making process and tools and the availability of reliable data in developing countries is a major challenge (Perteghella *et al.,* 2020). Amongst the Integrated Solid Waste Management approach (3R's Reduce, Reuse and Recycling) are the reduction in generating wastes, a decrease of waste generated through recovery, recovered wastes reuse, recyclable materials to be recycled for other uses. Others include electricity/energy generation through decomposting of organic wastes, and the last option to be sanitary landfills disposal (Ugwu *et al.,* 2021).

The IWM's goal was to minimise the environmental impact, lower costs, and increase revenue from the Ikhlayel base (2018). It also focused on achieving societal acceptance and conservation of natural resources in terms of energy production and recovery of metals and materials from collected wastes. IWM is aimed at attaining prevention, avoidance, and minimization of wastes. The characteristics of IWM have led to its being a prevalent nomenclature for solid waste management practitioners and policy makers to achieve long-term management of solid waste (Opeyemi, 2012). According to de Campos *et al.* (2021), the consequences of the pollutant gases pose severe impacts to the environment and society, among the know-hows for sequestration and capturing carbon dioxide as hopeful measures for reducing the atmospheric pressure concentration of pollutant gases. "Specific transference opportunities identified range from measures to promote waste prevention, waste separation and waste reduction, generating additional value via mechanical recycling, implementing chemical recycling as a recycling option before energy recovery to extending energy recovery opportunities".

Opeyemi (2021), emphasised that the principles and mechanisms of IWM and their importance for technology selection and system design were presented in the context of technology and innovation. The study observed IWM as a waste management system but not a conventional or general approach (Opeyemi, 2012). Before disposal, modern-day management of solid waste places a premium on the 3Rs. The discussion of integrated waste management systems revolves around these three words. The term "reduction"refers to the use of fewer throw-away items. Reuse is the practice of repurposing goods after they have served their original use. Recycling is the process of recovering an item's highest material or energy worth after it has been subjected to a series of operations. The enforcement of existing rules and client choice can help to improve waste management implementation. "Waste quantification, waste segregation, and the application of the 3Rs (reduce, reuse, and recycle)" are the practices pursued.

1.3. Waste Reduction

Waste reduction is an attempt to optimise resources through waste prevention practice and materials efficiency". It is a deliberate way of eliminating the quantity of on-site waste material utilisation before disposal to landfill. According to Vleck (2001), this can include lowering or compacting the amount of garbage before sending it to the waste treatment site or utilising other effective farming methods to reduce the number of packaging materials dumped at the waste site. The waste reduction process should commence from the industrial source by ensuring that less production material is used to generate a reduced quantity of waste at production. This process can be linked to the individual level when products of durable capacity are utilised. Less waste can be generated if there is consciousness in people's attitude to the kitchen and shopping activities. The habit of buying goods that are liable to toxicity is avoided. Waste reduction practice as the most preferred method must be instituted into the waste management processes and operations. It will prevent waste generation as well as protect the environment (Esin and Cosgun, 2007). Therefore, the waste reduction approach is derived by means which a community decreases the level of waste it generates.

1.4. Waste Reuse

The second level in the waste management process is the reuse of waste generated towards ensuring desirable outcomes for waste prevention. Reuse means using the same material again to play a dual role of primary and secondary purposes. This process implies a product has a pen chant for being used more than once for the same or different purposes. Giving to charity, reusing empty jars to store food, and engaging in collecting paint are all have examples of resource reuse. According to Joe *et al*. (2007), other strategies to reduce waste include mending items, donating them as gifts to charities and community groups, or selling them.

1.5. Waste Recycling

Waste recycling is an ancient practice predicated on the efficient segregation technique. It follows waste reuse in the order of importance. The process of gathering and processing objects that would otherwise be dumped as waste and changing them into new products is known as recycling. It separates the collected waste into recyclable materials and those that can not (Winkler, 2010). Therefore, according to Brito and Saikia (2013), the wastes that can be recycled can also be reused in manufacturing new items. The populace is empowered by adopting this recycling strategy and new livelihood leeways are offered through jobs. Several investment opportunities are made available; waste materials will become converted and recycled to new products, the environment becomes safer than before. At the same time, the economy is improved (Jaillon *et al*., 2009).

Recycling is the act of collecting and separating resources from waste, then processing them to create marketable products. Recycling transforms waste materials into valuable resources, resulting in several benefits, which may be environmental, social, and financial. In the transformation of wastes, materials that are not biodegradable like glass, metallic substances, papers, polythene, and plastics are first separated once collected and delivered for conversion into new products (Winkler, 2010). According to data from the European Environment Agency (EEA), the recycling rate of municipal and packaging waste has increased significantly. In

Florida, the recycling business employs over 13,000 people (Vleck, 2001). Municipal waste recycling rates between 2004 and 2014 increased by 13%, whereas packaging waste recycling rates increased by 10% between 2005 and 2013.

Furthermore, in 2014, over 43% of municipal trash were produced, and 65% of Norway's packaging waste generated in 2013 were recycled. It cannot be discounted that expanding the waste recycling programmes usher in new ways of reducing pollution due to solid waste. However, to permanently deal with solid waste issues, the world must reduce the waste generated. Similarly, manufacturing industries must now be innovative in altering the ways products are designed or manufactured, as it is geared towards making the wastes amenable to reduction, reuse and recycling.

2. CONCEPTUAL FRAMEWORK

This study used the multidimensional independent variables of waste reduction, reuse, and recycling to measure integrated sustainable waste management. In contrast, the dependent variable was sustainable solid waste management. They were set out to attest to the impact of one on the other to verify the reality of several previous studies' findings.

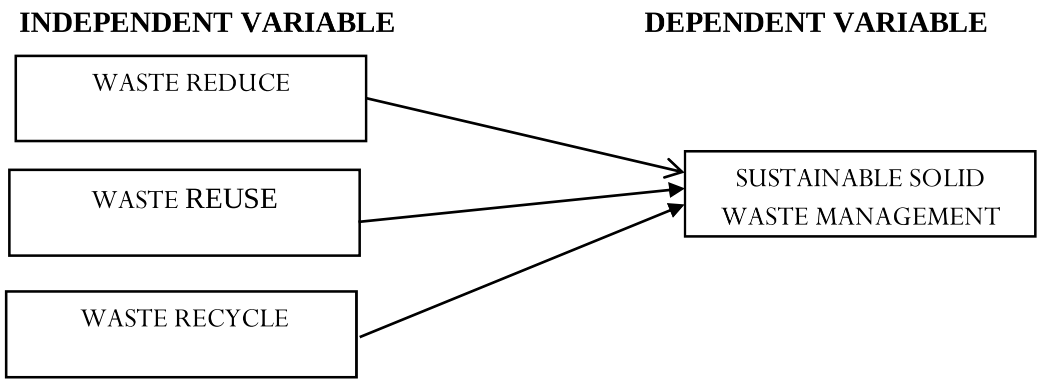

Figure 1: Analytical Framework for Integrated Sustainable (Solid) Waste Management

2.1 Hypotheses

The study hypothesised that:

H1: There is a significant influence of waste reduction on the sustainable management of solid waste.

H2: There is a significant influence of waste reuse on the sustainable management of solid waste.

H3: There is a significant influence of waste recycling on the sustainable management of solid waste.

3. METHODOLOGY

Based on the existing literature, this study constructed an ISWM framework with three latent components, with which the indicators were identified and enhanced. The study took a quantitative approach and used a cross-sectional methodology. The questionnaire survey was based on a stratified random sampling technique purposely to obtain data from the waste managers, waste management organisations and residents of the Federal Capital City, Abuja, Nigeria. While the items for measuring integrated waste management systems are multi-dimensional, the questions were altered based on previous literature.; (waste reduction, waste reuse) the study adapted from Vleck (2001), waste recycling was only adapted from Nasidi *et al*. (2016), and that of sustainable solid waste management was adapted from Ezeah and Roberts (2012). A 5-point Likert scale scoring system was explored and used (1, 2, 3, 4 and 5, which represent strongly disagree, disagree, neutral, agree and strongly agree, respectively). The statistical package, SPSS, was engaged in data entry, coding and analysis. The clever PLS statistical package from the structural equation model (SEM) was utilised to analyse data in the validity study and reliability testing to measure the construct. This model consists of the integrated 3R concept (waste reduction, reuse, and recycling) and sustainable solid waste management. Out of 310 copies of questionnaires administered, 178 were duly completed, returned and 57.4% of those who responded were included in the analysis. The respondents have sufficient experience to comprehend the study's importance.

3.1 Statistical Analysis and Results

3.1.1 *The Measurement Model (Outer Model)*

The measurement model filters the data and confirms validity and reliability before establishing the data's goodness of fit to analyse the indicators'reliability (Hussain *et al*., 2018). Both the loading level of 0.4 and the internal consistency level of 0.7 are acceptable. When using convergent validity and factor loading discriminate validity, according to Chin (1998), the composite reliability, Cronbach's Alpha, and Average Variance Explained (AVE) must all be at least 0.5, and the item(s) loading that is higher on the other construct than their construct should be deleted (Chin 1998; Hair *et al.* 2010).WRD05, WRU01, and WRC01 were deleted from the measurement model due to lack of fit to the minimum benchmark (Chin, 1998; Hair, 2010). Due to multi-collinearity, SSWM04 and SSWM02 were also deleted. As a result, all of the adapted instruments in this study are trustworthy, as all items are over 0.4.The items loaded on their separate constructs range from 0.635 to 0.883; they are acceptable because they are higher than the cut-off mark value of 0.4, consistent with Chin's recommendations (Chine 1998; Hair 2011). Cronbach's alpha ranges from 0.773 to 0.850. Similarly, the composite reliability ratings vary from 0.846 to 0.899, higher than the benchmark value of 0.7. (Hair, 2011). The AVE is used to determine convergent validity. The AVE ranges from 0.527 to 0.694, higher than the 0.5 thresholds (Hair, 2011). The factor loading is shown in Table 1 below.

Table 1: Factor Loading

Items	Factor Loading	Composite Reliability	Cronbach's Alpha.	AVE
WRD01	0.767			
WED02	0.774			
WRD03	0.742	0.874	0.825	0.690
WRD04	0.791			
WRD06	0.739			
WRU02	0.751			
WRU03	0.666	0.849	0.783	0.582
WRU04	0.810			
WRU05	0.692			
WRC02	0.635			
WRC03	0.649			
WRC04	0.683	0.846	0.773	0.530
WRC05	0.801			
WRC06	0.837			
SSWM03	0.849			
SSWM04	0.793			
SSWM05	0.794	0.899	0.850	0.527
SSWM06	0.883			

Note: WRD= Waste Reduce, WRU= Waste Reuse, WRC= Waste Recycle and SSWM= Sustainable Solid Waste Management, AVE= Average Variance Extracted

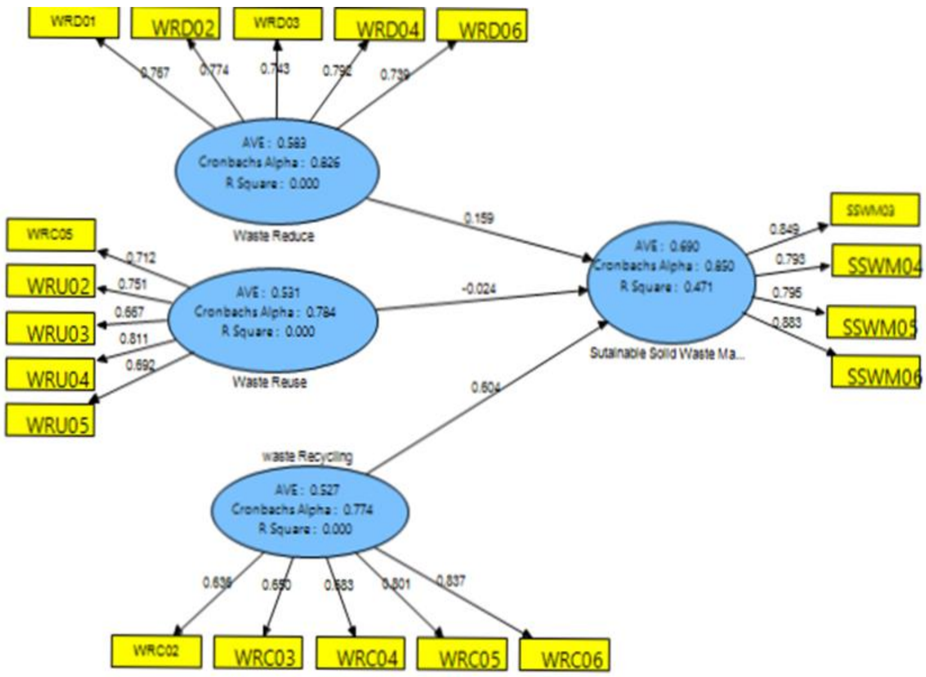

Figure 2: Measurement Model

The coefficient of determination is used to quantify the general effect size, and variation explained in the dependent construct, and it is used to assess the model's prediction accuracy (Hussain *et al.*, 2018). Figure 2 shows that the endogenous construct's inner path model had R2 = 0.471. As a result, the three independent components marginally explain 47.1percent of the sustainable management of solid waste variance. R2 less than 0.10 is considered a flawed model, whereas R2 between 0.11-0.30 is modest, 0.31-0.50 is moderate, and R2 greater than 0.50 is deemed to be strong (Cohen *et al.*, 2007). As a result, R2 is moderate in this study.

3.1.2 *Structural Model*

The measurement model meets construct validity and reliability, and the structural model is evaluated to test the study's hypotheses by establishing the significance of path coefficients, which was done using a sample of 178 instances using PLS algorithms and Bootstrapping (Hair *et al.* 2012; Hulland 2010; Akter *et al.*, 2011). Table 2 shows the hypothesis testing findings, whereas Figure 2 depicts the model route.

Table 2: Path Coefficient and T-Statistics Results

Hypothesis	Hypothesised Paths	Beta	Std. Error	T-Statistics	P-Value	Decision
H1	WRD-> SSWM	0.161	0.072	2.182	0.01	Supported
H2	WRU-> SSWM	0.077	0.057	0.410	0.01	Not Supported
H3	WRC-> SSWM	0.600	0.081	7.435	0.01	Supported

Note: WRD= Waste Reduce, WRU= Waste Reuse, WRC= Waste Recycle and SSWM= Sustainable Solid Waste Management

In H1, it was hypothesised that waste reduction significantly impacts the sustainable management of solid waste. The results in Table 2 and Figure 2 revealed that the waste reduction related factor had a substantial positive impact on long-term solid waste management (= 0.161, T = 2.182, p 0.01). As a result, hypothesis H1 was confirmed. Also, the hypothesised H3 predicted that waste recycling has a significant impact on the sustainable management of solid waste. The results in Table 2 and Figure 2 show that waste recycling significantly impacts the sustainable management of solid waste (β = 0.600, T = 7.435, p <0.01). Therefore, the hypothesised H3 was confirmed and supported. However, the hypothesised H2 predicted that waste reuse significantly impacts solid waste's sustainable management. As shown in Table 2 and Figure 2, the outcomes are statistically significant but do not impact substantially sustainable solid waste management (β = 0.077, T = 0.057, p < 0.01). As a result, the H2 hypothesis was disproved. The more the observed impact of an exogenous latent construct on the endogenous latent construct, the higher the beta coefficient (β). Compared to the other constructs in the model, the waste recycling construct or related factor had the highest path coefficient of β = 0.600. Statistically and practically, the 60% variance explained by waste recycling on sustainable solid waste management is acceptable and recommended. While waste reduction and waste reuse factors had 16% and 7% variance explained, respectively.

3.1.3 *Predictive Relevance of the Model (Q^2)*

The cross-validated redundancy method is used to measure a model's predictive significance (Chin 2010; Hussain *et al.*, 2018). After executing the Smart PLS blindfolding processes, which cross-validated the communality and cross-validated the redundancy, the value of cross-verified relevance for this model is 0.314. This result is consistent with Stone (1974) and Geisser (1974), who said that any "model" with a Q2 greater than zero is invariably predictive and should be cross-validated. The benchmark standards for estimating model predictive relevance using the value of cross-verified significance, according to Chin (1998), are 1) 0.02 for small, 2) 0.15 for medium, and 3) 0.35 for large. The predictive relevance of this model was significantly based on Chin (1998), as demonstrated in Figure 3 and Table 3. Respectively.

Table 3: Construct Cross - Validated Redundancy

Sum	SSO	SSE	1-SSE/SSO
SSWM	1000.00	685.84	0.314

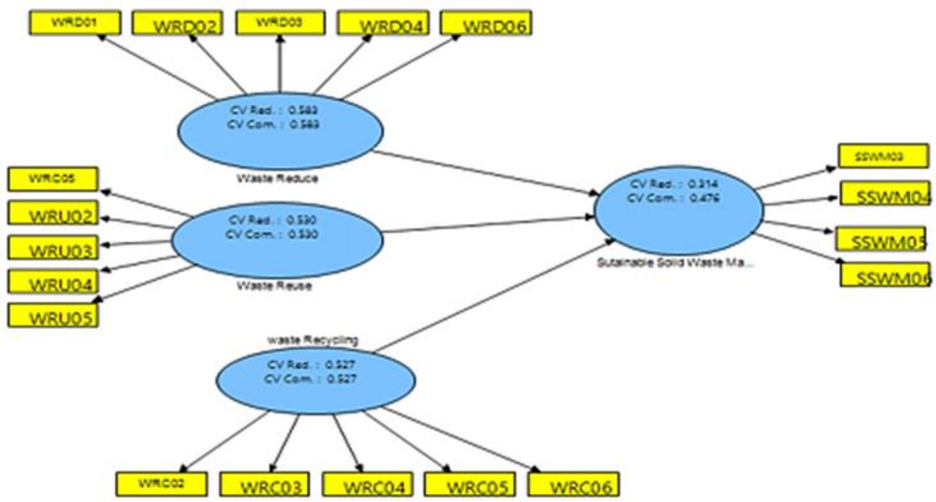

Figure 3: Predictive Relevance

DISCUSSION AND CONCLUSION

This study assesses the interaction that exists between an integrated waste management system (WRD), waste reuse (WRU), waste recycling (WRC), and sustainable solid waste management (SSWM). Statistically, this investigation revealed that hypotheses H1 and H3 are supported. However, hypothesis H2 is not. In the first hypothesis, waste reduce (WRD) –sustainable solid waste management (SSWM) showed significance (β =0.161, t = 2.182273, p-value=0.01). As a result, it agreed with reports from Nasidi *et al.* (2018), which showed positive significance. Although this concept of waste reduction has been employed in various contexts, the results align with the present study.

On this note, there is a high degree of waste reduction, optimal levels of efficiency, and effectiveness of sustainable management of solid waste.The second hypothesis that is the link between waste reuse (WRU) and sustainable solid waste management (SSWM) is not significant (β = 0.057, t = 0.410, P=0.01), was not supported. The third hypothesis confirmed that waste recycling WRCs have a substantial and positive association with SSWM (β = 0.081, t = 7.435, P-Value = 0.01). The study also assessed the relationship which exists between integrated waste management and sustainable solid waste management, as a result of the notion that in terms of efficiency, efficacy, and long-term sustainability, sustainable solid waste management lags is discarded (Hassell, Wong, Houser, Knopman, & Bernstein, 2003). One of the feats of this present work is properly defining the place of sustainable solid waste management in Nigeria in terms of sustainability, efficiency, and effectiveness. At the same time, previous literature such as Perteghella, Gilioli, Tudor and Vaccari (2020) believed that difficulties regarding the interpretation of data and unavailability of data are among the factors hindering the progress of sustainable solid waste management practices.

Also, integrating the relevant stakeholders mostly in the decision-making process, tools, and the availability of reliable data in developing countries is a significant challenge (Perteghella *et al.*, 2020). It has also enhanced knowledge theoretically and practically. In terms of theory, the present work contributes to the body of knowledge on integrated solid waste management, which is conceived as WRD - SSWM, WRU –SSWM and WRC – SSWM. Furthermore, this research is amongst a few to look into the link between integrated solid waste management and long-term waste management. The outcomes of this study will aid interested and concerned governments and other agencies that are non-government affiliated to design policies, make decisions that will determine the efficiency and efficacy in practising sustainable solid waste management. These will also assist waste managers in comprehending the importance of a waste management technique that is efficient, effective, and integrated.

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