

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 1, January 2018

E- Waste Management; A Collaborative Approach Towards Sustainability

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ABSTRACT: Rapid economic growth, increasing urbanization and globalization have increased customers' tastes and preferences for the desire to have access to new technologies. The challenge has been the disposal of the discarded, old or the defective electronic wastes. Africa is more challenged as a result of the relatively low income levels of citizens which result is a high demand for such electronic waste since they have comparatively very low prices. Africa has almost become a dumping place for electronic waste which has enormous effects on economic, social and environmental sustainability. This research seeks to find out how a collaborative approach among key stakeholders (government, manufacturers/ assemblers, media and waste management companies) in the management of electronic waste can contribute to curb this menace. Based on a structured questionnaire, data was collected from staff and management of these stakeholders from selected institutions and organizations in Ghana. The findings indicate that all key stakeholders have a role to play in the control and management of electronic waste and their roles have a positive effect in the achievement of a sustainable e- waste management. However, the effects of the roles played by waste management companies and the media seems to be more significant than that of manufacturing/ Assembling companies and the government. The conclusion for the study is that, every stakeholder has a role to play in the fight against unsustainable e- waste management, however, there is the need for governments to establish control mechanisms and play an administration role to collaborate with all stakeholders.

KEYWORDS: E- Waste; Electronic waste; E- Waste management; Sustainable E- waste; components of electronic waste; methods of e- waste management; structural equation model; smart PLS.

I. INTRODUCTION

E-Waste or Waste Electrical and Electronic Equipment (WEEE) is the term used to describe old, end-of-life or discarded appliances which use electricity to power their operation. During the last few decades, the electrical and electronics industry has experienced an enormous growth. The popularity of devices such as laptop computers, mobile phones, personal digital assistants, smart cards, digital cameras, flat screens and touch screen television sets, etc has rapidly increased. The increase in the consumption and production of electronic waste have been facilitated by rapid economic growth and an increasing urbanization and globalization (Remesh B.B., Parande A.K. & Ahmed B.C.,2007). The rapid changes in technology and the falling prices of electronic gadgets have all contributed significantly to this fast-growing surplus of electronic waste around the globe (Cynthia S. and Kalyani P., 2017). E-waste is a highly complex waste stream which contains both very scarce and valuable as well as very toxic components. If proactive measures are not put in place, it is expected that by 2020 e-waste from old computers in South Africa and China will grow by 200-400% and by 500% in India (Kumar U. & Singh D. N., 2013).

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Environmental sustainability has become a major concern for the world in recent times as a result of the numerous consequences that awaits the world in the short or long term if the unsustainable consumption practices, and disposal processes and methods are not well managed. According to UN estimates, between 20 to 50 million tons of e-waste are generated worldwide annually, accounting for about 5% of all municipal solid waste (BAN/SVTC, 2002).

Various countries and unions have developed different approaches for managing e-waste, by enacting legislations and developing policies to curb this menace. The Waste Shipment Regulation (WSR) passed in 1993 and amended in 2007 emphasizes that no EU member state is allowed to export e-waste classified as hazardous to non-OECD (Organisation for Economic Cooperation & Development) countries, however this has not contributed enough to the solution of the problem especially in developing countries.

According to Ghana E- waste Assessment Report in 2011, e- waste imports into Ghana in 2009 added up to 215'000 tons. About 30% of the tonnage comprised of new products and 70% of second hand EEE. Around 15% of the second hand imports was estimated to be unsellable (i.e. would not respond to power, broken or outdated), a significant portion of which was destined directly to informal recycling. Another 20% of the imports could be serviced (repaired/refurbished) to get them functioning. According to Schmidt (2006) and Yu *et al.* (2010), there is still a drive for the importation of used electronics into developing countries and there are no distinct policies in Ghana for the regulation and management of e-waste as at now (Oteng A., 2012) although e- waste poses very real environmental threats.

There is the need to have an effective collaboration among all key stakeholders of waste management from both developed and developing countries in order to find a sustainable control and management of this challenge. This study seeks to investigate the management of e- waste in the context of Ghana.

II. LITERATURE SURVEY

II.1 Components of Electronic Waste

The components of electronic waste include: cathode-ray-tubes (CRT), liquid-crystal display (LCD) and Printed circuit boards (PCB) which are used to support and connect electronic components. These components may be metals, plastics, glass, etc. However, according to Schlummer *et al.* (2007), plastics constitute more than 20% of e-waste. Electronic waste may also contain certain common metals (Aluminum, Copper, Iron, Lead, Tin, Zinc, etc.) and/or certain precious metals such as: silver, gold, etc. Refrigerating circuits in refrigerators, freezers and air-conditioners for instance may contain Freon's, i.e. chlorofluorocarbons, hydro chlorofluorocarbons and fluorocarbons, which after emissions to the atmosphere have deleterious effects on the ozone layer (Solomon, 1999). All these substances have various effects on the ecology, and the health and safety of people (Widmer *et al.*, 2005; Bai J, Cui B, Chen B. *et al.*, 2011).

II.2 Methods of E- Waste Management

E- waste management refers to the practice of collecting, transporting, sorting, processing, disposing- off, and monitoring the final disposal of various components of e- waste. Electronic waste (e-waste) is one of the fastest-growing pollution problems worldwide given the presence of a variety of toxic substances which can contaminate the environment and threaten human health, if disposal protocols are not meticulously managed (Peeranart K., Ravi N., Ming H. W., 2013). Dealing with the growing generation of waste and its related impact on human health, economy and the eco- system requires the ability to reduce, re- use or ensure a sustainable final disposal. Reducing the toxic contents of e- waste helps to reduce the health and environmental impact of such wastes on the health and safety of the environment. According to Kang and Schoenung (2005), e- waste can be managed by dismantling and sorting re-useable hazardous materials; shredding and grinding waste in order to reduce the size of waste to be disposed- off; by incineration and landfilling.

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II.3 A Collaborative Approach Towards Sustainable E- Waste Management

The management of e- waste may require a collaborative approach of all supply chain partners, right from their point of manufacturing through to their point of final disposal. Importers, waste management companies, repairers, users, the media and the public at large play a key role in the fight against unsustainable e- waste management.

II.3.1 Manufacturers

In Japan, e-waste policies require manufacturers and importers to take-back electronics for end-of-life management. Japan's "Home Appliance Recycling Law" (1998) mandates that four types of household e-wastes must be collected: televisions, refrigerators, washing machines and air conditioners. Consumers are required to pay an end-of-life fee that covers a portion of the recycling and transportation costs. Manufacturers may recollect e- waste materials from consumers and ensure that components that are re- usable are used. This will help to reduce the depletion of natural resources and promote economy. By ensuring that components of electronic equipment are separable, repairable and have a long life span, the risk of disposing large amounts of e- waste may also be reduced.

II.3.2 Government

The flow of e- waste is difficult to control by national authorities however with a high degree of influence and an interest in dealing with such a menace, a positive outcome may be achieved. Lack of national regulation has been shown to significantly hinder recycling rates in some nations. According to Brown et al. (2014), agencies and governments must engage more critically with these issues so that green growth benefits the society at large.

In fighting the challenge of managing e- waste, it is important for government to provide the necessary leadership. Government needs to create the awareness of the risk of exposure to hazardous components of e- waste. Setting up regulations to monitor the flow of e- waste importation; establishment of legislation to sanction organizations who dispose-off e- waste inappropriately; setting up, training and resourcing institutions etc are key roles which government may embark on in the fight against this challenge.

II.3.3 The Media

The demand for second hand or outmoded electronic devices and the unsustainable disposal of e- waste may be due to a lack of adequate knowledge on its effects on society, environment and on the economy. According to Akpoghiran P. & Okoro F. (2014), broadcast media can help to influence people's attitudes. Heavy dependency and exposure to the media tend to shape people's beliefs, attitudes and perceptions about solid waste management. The management of household refuse, according to Banjo A.D., Adebambo, Dairo O.S. (2009) is tied to perceptions and socio-cultural beliefs and practices. Consistent communicative effort to bring people to the knowledge of environmental problems around them; encourage them to desist from actions that are harmful to the environment and sensitize them to show greater commitment to activities aimed at safeguarding the environment (Nwabueze C., 2007). The media's role in assisting in the fight against unsustainable e- waste management is therefore of utmost importance.

II.3.4 The Public

According to NEMA (2007), one of the major factors that have contributed to poor waste collection and management is limited community participation in solid waste management. The knowledge of the public on the effects of unsustainable waste management can change their attitudes and practices of e- waste disposal. The public can also mount pressure on the government to establish and well- resource institutions to promote sustainable e- waste management. The motivation of the public to seek for a sustainable waste disposal may however depend on the benefits they perceive to obtain.

II.4 Effects of Ineffective E- Waste Management

The contamination of the ecosystem with electronic waste occurs most often when methods of disposing e-waste are poor or primitive. According to Gaidajis G. , Angelakoglou K. & Aktsoylou D. (2010), the consequences of electronic waste on the ecosystems, human health and environment are not sufficiently documented, however according to Swedish Environmental Protection Agency Report in March 2011, even short-term exposure to large amounts of

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certain components such as barium can cause disturbed heart rhythm, vomiting, abdominal cramps, diarrhea, difficulties in breathing, increased or decreased blood pressure, numbness around the face and muscle weakness, paralysis or even death in humans (ATSDR, 2007). Studies have also shown that Long-term exposure to smaller amounts can lead to heart and kidney damages, increased blood pressure as well as decrease in body weight and survival (ATSDR, 2007).

Facilitating the recycling of discarded electronics may be very expensive. However, compared to the risks of unsustainable disposal on the environment, the society, and the economy, it is worth it. The priceless asset to the world is life and the dangers of being exposed to the electronic waste cannot be easily quantified since they have devastating effects on all living organisms. It is therefore worth spending on the management of sustainable e- waste. An effective e- waste management can generate several economic benefits such as : the conservation of resources and energy through the preservation of precious metals and other important rare earth materials, creation of jobs are seen as cost effective and sustainable economic strategies as compared to the production of brand new components parts (<http://shiftrecycling.com/articles/economic-benefits-of-electronics-recycling-and-disposal-in-toronto-and-the-gta.php>, accessed, May 2017). Better standard of living can also be enjoyed by the society as they have access to quality water, food and an enhanced health.

II.5 Conceptual Model

A structural Equation model is used as the model for this study. The model makes use of two types of measurement scales; reflective and formative. These reflective and formative indicators are used to measure their respective constructs.

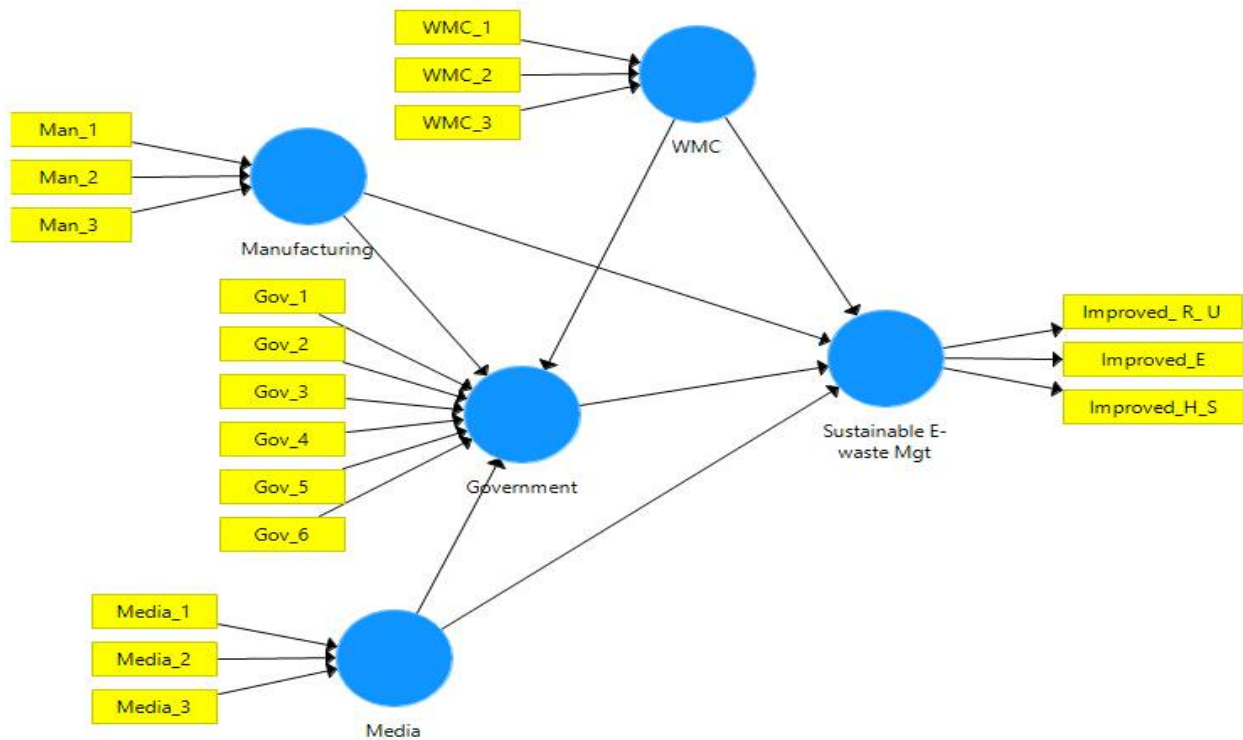


Fig. 1- Conceptual and measurement model

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SmartPLS is one of the prominent software applications for Partial Least Squares Structural Equation Modeling (PLS-SEM). It was developed by Ringle, Wende & Will (2005). The software has gained popularity since its launch in 2005 not only because it is freely available to academics and researchers, but also because it has a friendly user interface and advanced reporting features.

For measuring the role of manufacturers/ assemblers, three formative indicators are used: Extending the useful life of electronic materials (Man_1), making electronic components separable (Man_2) and standardizing electronic components (Man_3). For measuring the role of government, six formative indicators are used: Sanctioning of Culprits (Gov_1), establishment of legislation (Gov_2), the setting up of institutional structures (Gov_3), the Resourcing of Institutions (Gov_4), restriction of importation of inferior electronic goods (Gov_5) and Collaboration with key stakeholders (Gov_6). For measuring the role of waste management companies, three formative indicators are used: sorting (Comp_1), recycling (Comp_2) and Crushing of e- waste are used (Comp_3). For measuring the role of the media, three formative indicators are used: sensitization of the public (Media_1), monitoring (Media_2) and reporting unsustainable practices (Media_3). To measure the effects of sustainable procurement on society, environment and the economy, three reflective indicator were used: Improved resource utilization (Improved_R_U), Improved environment (Improved_E) and Improved health and safety (Improved_H_S).

III. METHODOLOGY

The study seeks to establish the relationship between effective collaboration of stakeholders of e- waste management and the achievement of sustainability goals. The population for this research comprises management and staff of selected media, waste management companies, and staff of selected municipal and district assemblies whose work are associated to waste management in Ghana. Using the standard sample size formula and a confidence interval of 95% for a population of 120, a sample size of 92 is used for the purpose of the study. The data collection instrument was a specially designed two-part questionnaire. The first part required respondents to provide information about themselves whilst the other sought the views of respondents on the role of manufacturers, the government, the media and waste management companies in fighting the menace of inappropriate e- waste disposal. Respondents were asked to report on their experiences on these variables on a ten- point likert scale, where 1, 2, 3, 4 to 10 represented lowest to highest relationships.

The study also used multiple cases with the aim to obtain information from all key stakeholders who can promote or ensure a sustainable e- waste management. Organizations were purposively sampled based on researchers ability to obtain adequate information and for reason of closeness to the researcher. The choice of a multiple method was imperative as it provides better opportunities to answer research questions and to evaluate research findings to make inferences and also helps to lessen the time taken in conducting the survey although there is a potential for the responses to be bias (Tashakkori and Teddlie, 2003, as in Saunders et al. 2009). Interviews and self-administered questionnaire are major tools used to obtain both qualitative and quantitative data from respondents. The questionnaire had a very simple structure to enable the researcher cover all research questions and enabled respondents to answer questions easily and within the shortest possible time. Completed questionnaires were checked and it was found out that there was no pattern of ratings, and respondents had rated on different methods. The main method of distribution of questionnaires were by hand, thus the researchers engaged trained individuals to distribute them.

IV. RESULTS AND DISCUSSION

To well analyze our conceptual model, a structural equation modeling (SEM) was adapted. SEM combines both econometric and psychometric perspectives in statistical modeling and attempts to estimate simultaneous relationships among observable predictor and predicted constructs. We adopted the partial least square method since the research aims at establishing the role of key stakeholders as a collaborative effort towards a sustainable e- waste management. Data was analyzed with SmartPLS (Ringle, et al., 2005).

Out of the 92 questionnaires administered, 81 completed sets were received giving a response rate of 88%.

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IV.1 Table 1: Demographic Characteristics of Respondents (N=81)

This section elaborates the demographic characteristics of the surveyed respondents. The section shows the gender, age, place of work, job description, educational background and number of years of work experience.

Description	f	%	Description	F	%
Gender:			Qualification:		
Male	35	43	Masters	5	6
Female	46	57	Degree	18	22
Age:			S.H.S	20	25
Below 24	0	0	J.H.S	15	19
25- 34	29	36	No formal Education	23	28
35- 44	34	42	Working Experience with organization:		
Above 44	18	22	Below 5 years	34	42
Place of Work:			5- 10 years	39	48
Municipal Assembly	17	21	10- 15 years	8	10
District Assembly	18	22	15-20 years	0	0
Media	12	15	Above 20 years	0	0
Waste Management Company	19	23			
Manufacturing/Assembling Org./	15	19			
Repairers					
Job:					
Management	29	36			
Technician	35	43			
Journalist	7	9			
Labourer	10	12			

Source: Authors' field survey, 2017

IV.2 Measurement of Conceptual Model

The measurement model used three reflective indicators for measuring sustainable e- waste management: improved resource utilization, improved environment and improved health and safety. The outer loadings, composite reliability and convergent validity were used by determining the average variance extracted (AVE) to assess these indicators. An indicator reliability determines which part of an indicator's variance can be explained by the constructs and loadings of indicators on the constructs of more than 0.7 is preferred whilst 0.4 or above is considered acceptable (Götz et al., 2010; Hulland, 1999). The loadings of the three reflective indicators exceed this standard (0.820, 0.556 and 0.836 for improved resource utilization, improved environment and improved health and safety respectively).

Traditionally, "Cronbach's alpha" is used to measure internal consistency reliability in social science research but it turns to provide a conservative measurement in PLS-SEM. Prior Literature have suggested the use of "Composite reliability" as a replacement (Bagozzi and Yi, 1988 and Hair et al., 2012). A composite reliability is used to assess how well a construct is measured by its indicators, and values of more than 0.7 are considered reliable (Fornell and Larcker, 1981). A composite reliability of 0.787 for sustainable e- waste management is satisfactory.

Another criterion for assessing reflective measurement models is convergent validity by determining the average variance extracted (AVE), the average variance shared between a construct and its indicators is considered sufficient if the value is more than 0.50 (Chin, 1998; Götz et al., 2010), which is the case for sustainable e- waste management construct with an AVE of 0.56.

The measurement model also includes formative indicators for measuring the contribution of waste management companies/ organizations, manufacturing/ assembling/ Repair of defective electronic gadgets, the media and government. Formative indicators are primarily evaluated on the basis of their weights (Hair et al. 2012). The estimation of this validity is performed by the Partial Least Square (PLS) approach with a bootstrapping method to calculate item weights (or PLS scores or outer weights) of each formative indicator to determine their degree of significant (Bruhn et

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al., 2008, Diamantopoulos and Winklhofer, 2001, Chin, 1998). However, Petter, Straub et al. (2007) suggests that indicators with insignificant weight may be eliminated (Diamantopoulos and Winklhofer, 2001), or remain insignificant indicators to preserve content validity (Bollen and Lennox, 1991), since the elimination of formative indicators carries the risk of changing the theoretical perspective of the constructs (Nunnally and Bernstein, 1994). Outer weights therefore vary from -1 to +1. Weights closest to absolute 1 reflect the strongest paths whilst weights closest to 0 reflect the weakest paths.

From Figure 2, the following indicators are observed to be of significance to their respective constructs: Gov_6 for Government construct (Weight= 0.836), Man_2 for manufacturing/ assembling/ repair construct (Weight=0.842), media_2 for the media construct (0.949) and WMC_3 for the WMC construct (0.630). However, if an indicator has a non-significant outer weight its outer loading are also to be considered (Hair et al., 2014: 129). Although the Man_1, Media_1, Media_3, WMC_1 and WMC_2 indicators have relatively insignificant relationship with their respective constructs, as a result of their outer weights (0.287, 0.062, 0.009, 0.399 and 0.359 respectively) , their outer loadings show significant values of 0.517, 0.730, 0.704, 0.674 and 0.634 respectively.

It is also worth noting that although Man_3, Gov_1, Gov_2, Gov_3, Gov_4 and Gov_5 indicators show insignificant weights, at least they possess some level of importance on their respective constructs.

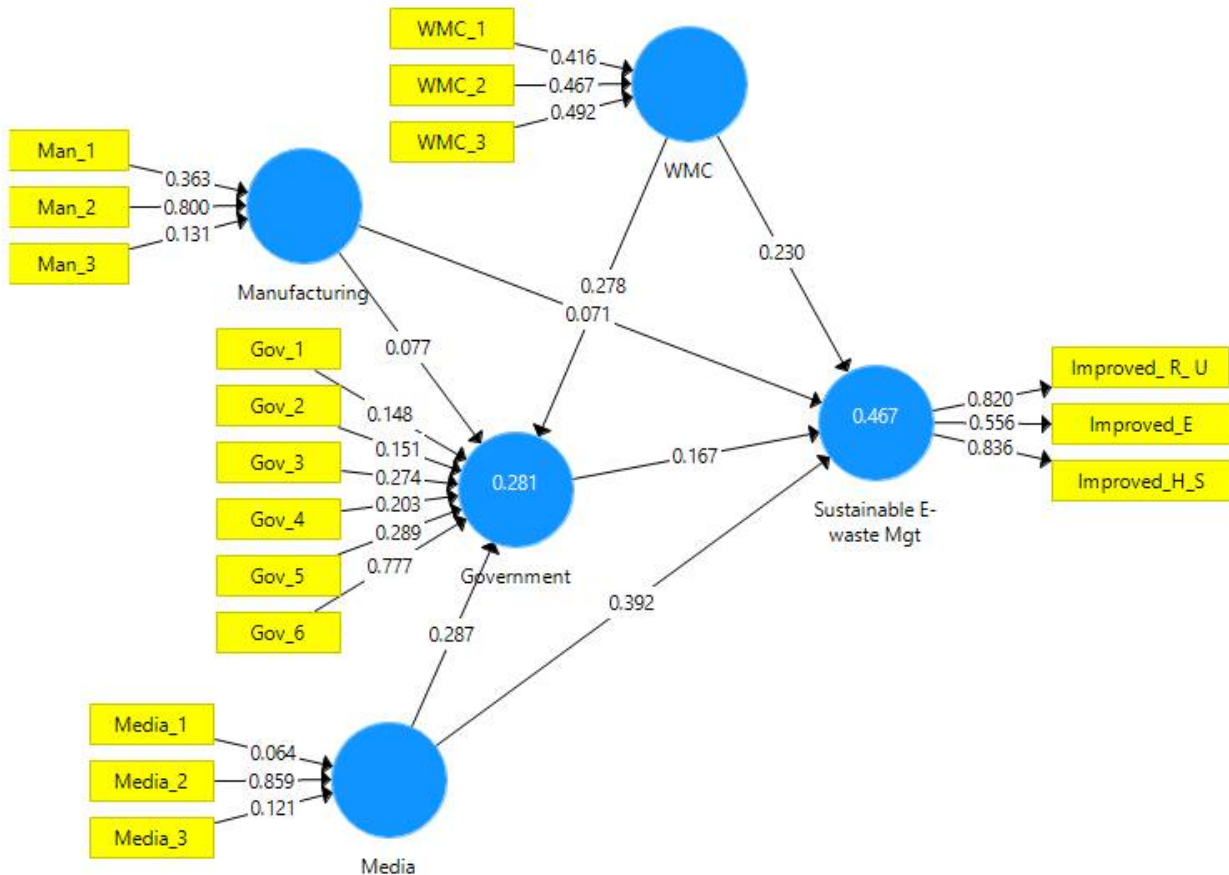


Fig. 2: Results of the model's analysis

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In the case of the government construct, respondents explained that government only plays an administrative role for other. key stakeholders (waste management companies, media and manufacturers of electronic products) in the management of electronic waste and that a sustainable e- waste management can be well influenced by the actions or inactions of these key stakeholders. Gov_ 6 (Collaboration with key stakeholders) is perceived by respondents to be of the highest role government can play. Respondents are of the view that necessary structures: the Environmental Protection Agency(EPA), National Media Commission, National Environmental Sanitation Policy Coordinating Council etc are laid down by government, Legislations are set up (Hazardous and Electronic Waste Control and Management Bill, 2016; Local Government Act ,1994; the Environmental Protection Agency Act, 1994; the Environmental Assessment Regulations, 1999; etc yet the challenge of e- waste management is still evident. Respondents believe that a good collaborative role between government and all key stakeholders can help to reduce the challenge. This is in line with Edga N. (2008) assertion that through sensitization; creation of guidelines and standards; and building an e- waste legal framework and policies in collaboration with the private sector and individuals, e- waste can be well controlled.

The central criterion for the assessment of the structural model is the coefficient of determination R^2 , which is used to characterize the ability of the model to explain and predict the dependent variables (Ringle et al., 2012). The R^2 of 0.492 for sustainable e- waste management as a dependent variable in our research is quite satisfactory. Thus almost 50% (49.2%) of the variance can be explained by the role of waste management companies, manufacturing/ assembling/ repair organizations, media and the government.

The analysis of the path coefficients reveals a positive influence of all four variables (Government, Media, WMC and manufacturing/ assembling/ repair organizations), suggesting that the better the role played by the government, media and manufacturing/ assembling/ repair organizations, the higher the effect will be on sustainable e- waste management. After applying bootstrapping all the four path coefficients are positive with the media and waste management companies showing the most significant effects (0.375 and 0.261 respectively). Although the path coefficient of the government is very low (0.180), there is a clear indication that it affects the achievement of sustainable e- waste management. Respondents explained that there are very few manufacturing and assembling companies in Ghana and most consumed electronic products are imported. They further explained that although there are numerous electronic gadget repair organizations in the nation, most of them are not registered businesses and are mostly of small sizes set up by individuals in the low- income bracket and with little or no formal education. Other respondents are of the view that majority of Ghanaians are of the low income level bracket, they do not have the purchasing power to buy new electrical gadgets/ equipment thereby creating the high demand for less durable electronic products. The high demand for less durable, used and old electronic materials especially in Africa, leave advocates in the fight against unsustainable e- waste management in an uncertain believe of achieving positive results.

V. CONCLUSION

This study sought to investigate the roles of key stakeholders in the management of electronic waste: the government, waste management companies, the media and manufacturing/ assembling/ repair organizations and the effects of government collaboration with all these stakeholders on the achievement of sustainable e- waste management. While the data for the research were collected from stakeholders in Ghana, the findings may be used to generalize the role of stakeholders of e- waste management who share such similar characteristics with that of Ghana. This includes African countries whose markets have become dumping grounds for e- waste as indicated by Kumar U. and Singh D. N. (2013). Governments, waste management companies, the media and manufacturing/ assembling/ repair organizations will also use these findings to critically reflect on their key roles in helping to deal with the control of e- waste.

The study reveals that all key stakeholders to e- waste management have at least a little role to play in sustainable e- waste management, although the effect of the roles played by waste management companies and the media seems to be more significant than that of manufacturing companies and the government. The conclusion for the study is that, every stakeholder has a role to play in the fight against unsustainable e- waste management however, there is the need for

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governments to establish control mechanisms and play an administration role to collaborate with all stakeholders for a more effective and lasting management of the canker.

This research is limited to the Ghanaian context and the perspective of the media; Staff and management of manufacturing/ assembly/ repair organizations of electronic products and gadgets; waste management companies; staff from the municipal and district assemblies. Future studies seeks to bring to light the role of the society in sustainable e-waste management since some respondents indicated that there are no outstanding pressure groups in the nation to sensitize the public to create the awareness of the negative effects of improper e- waste management on economic, social and environmental sustainability, and pressurize government to better address this challenge.

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