Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

Circular Economy: Benefits to Cost of Construction in the Nigerian State (A Review)

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***Abstract*: This review investigates the concept of circular economy, its benefits to cost within the construction industry in Nigeria. A systematic literature review was conducted focusing on the benefits to cost in a circular economy of the construction industry. The key findings from the review are the three pillars of circular economy sustainability (economic, environmental and social) benefits and how the add value directly to the construction industry in the worldwide perspective and how it can potentially add value to the Nigerian construction industry, when wholly applied and enforced by policymaker, such as the government. The application of the concept of circular economy thinking in construction, which is at its infant stage in most developing countries such as Nigeria, has been mainly limited to construction waste minimisation and recycling. Little or no research has been taken on the circular economy from its benefit to cost in the construction industry in Nigeria. The survey results from several literatures and workshops materials were utilized. This paper provides a reviewed analysis on the concept of circular economy (CE), its definition, principles and benefits to cost in the Nigerian construction industry. It also reviewed the construction industry, construction material waste situation, construction waste recovery systems and waste management policies in Nigeria. To encourage greater implementation of circular economy principles throughout the supply chain, a clear economic case is paramount, supported by metrics, tools and guidance, and the support from the government through the regulatory agencies such as COREN, in the case of Nigeria.**

Key word:- Circular Economy (CE), Construction industry, Waste, Benefit, Nigeria

1.0 INTRODUCTION

The circular economy (CE) contributes to raising productivity, optimizing the use of natural and human resources (Sehnem, 2019; Missemer, 2018) and increasing efficiency in resource management (Sehnem, 2019; Linder and Williander, 2017; EEA, 2016). CE proposes to replace wasteful and inefficient linear and open-ended cycles of production (input-output-waste) for a closed-loop where waste is minimized or transformed into inputs and value is created in the process (Sehnem, 2019; Homrich *et al*., 2018; Blomsma and Brennan, 2017). CE ideas have been gaining traction in the past decade in policy formulation, advocacy, consulting and natural sciences (Sehnem, 2019; Reike*et al*., 2018). The concept has been accepted by businesses across different sectors around the world as a solution to promote sustainability (Osobajo*et al*., 2020; Ghisellini*et al*., 2018; Lieder and Rashid, 2016; Preston, 2012) and the construction industry is not an exception.

The construction industry is said to produce more waste than any other industrial sector (Osobajo*et al*., 2020; Rose and Stegemann, 2018). It's from the fact that the construction industry is a major exploiter of natural non-renewable resources and a polluter of the environment. Construction activity contributes to environmental degradation through resource depletion, land use and deterioration, power consumption, air pollution, and the generation of waste in the acquisition of raw materials (Saidu, 2016; Tam, 2008; Dania *et al*., 2007). The majority of this waste has not been well managed, thus causing substantial health and environmental problems (Saidu, 2016; Imam *et al*., 2008), and affecting the performance of many projects in Nigeria (Saidu, 2016; Adewuyi and Otali, 2013; Ameh and Itodo, 2013; Oladiran, 2009). Despite the vast amount of waste from construction activities (Osobajo*et al*., 2020; Bilal *et al*., 2016; Clark *et al*., 2006), and significant impacts of the construction industry on the environment, society and economy (Osobajo*et al*., 2020; Gencel*et al*., 2012), limited studies have been conducted on CE application within the construction industry (Osobajo*et al*., 2020; Lieder and Rashid, 2016). Studies (Tukker, 2015; Pan *et al*., 2015) suggested the need to explore strategies to convert and/ or recover the industrial waste for recycling and reuse. This idea is consistent with Smol*et al*. (2015), views, who argued that the construction sector could benefit maximally from CE. Other studies clamouring for sustainability in the construction industry (Osobajo*et al*., 2020; Ghisellini*et al*., 2018; Kylili and Fokaides, 2017; Lai *et al*., 2017; Lemougna*et al*., 2011) have highlighted the importance of CE in this process. These studies seek to explore the efficacy of CE, understanding its cost and benefits in the construction industry and to understand the extent to best apply the principles of CE in the construction activities.

Therefore, strategic explorations for the acceleration of Nigeria construction industry transition from the traditional linear economy (LE) to CE should be the centre of interest for current and further researches. One such strategy is to identify the extent of research coverage on the cost and benefits of CE implementation in the construction industry from existing literature. Thus, this study systematically analyses literature surrounding cost and benefits of CE in the construction industry.

2.0 CIRCULAR ECONOMY

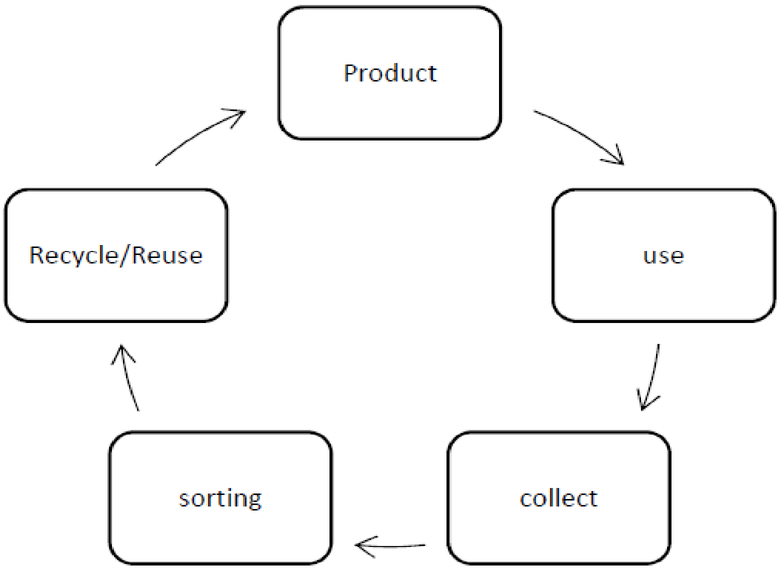
The term 'circular economy' is becoming increasingly commonplace. Countries such as China and Germany have used the term within their legislation, although the emphasis can vary (Adams *et al*., 2017; Benton, 2015). Waste avoidance and closed-loop recycling are the key components within the German legislation (Adams *et al*., 2017; Bilitewski, 2012), while in the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

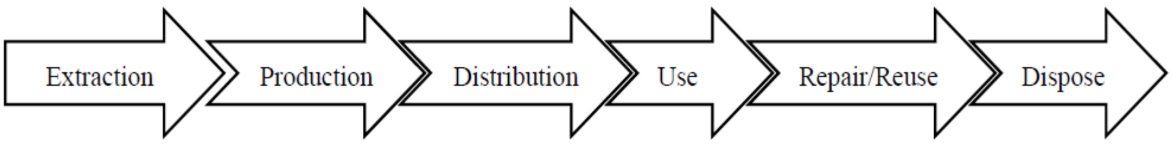
Chinese policy, the term is directed at eco-design, cleaner production and eco-industrial parks and networks to create a recycling-oriented society (Adams *et al*., 2017; Geng *et al*., 2012).

The concept circular economy (CE) has drawn considerable attention among researchers, institutions and policymakers. It is geared towards innovative and regenerative resource consumption, which is different from the usual linear model (Okafor *et al*., 2020; Ezeudu and Ezeudu, 2019). Linear economy (LE) evolved from industrial revolution, as products follow the process of resource extraction–manufacture–distribution–marketing–consumption–repair/re-use-disposal (waste) (Okafor *et al*., 2020; Salguero-Puerta *et al*., 2019). Linear economy is shown in Figure 1b below. However, the CE model promotes the concept that a product that has been perceived to have reached its end-of-life in a particular system might be used as a raw material in another or the same system, as shown in Figure 1a. The circularity principle further reframes the traditional viewpoint by considering waste products as resources that could have an endless or multiple life-span with economic, social and environmental gains (Tunde, 2019; Plastinina*et al*., 2019).

Since the first formal use of the circular economy term by Pearce and Turner (1990), there have been various attempts to define the circular economy influenced by several concepts. A number of authors have provided resource-oriented definitions and/or interpretations, emphasising the need to create closed loops of material flows and reduce the consumption of virgin resources and its attendant harmful environmental impacts. For instance, Kirchherr *et al*. (2017) defined CE as an approach to replacing the end-of-life concept with an economic system that fosters reuse, alternatively reducing, recovering and recycling of materials in distribution/ production and consumption processes. Geissdoerfer*et al*. (2017) describes CE as a regenerative process, which maximizes the utilization of raw materials and reduces emissions and waste generation through repair, remanufacture, reuse, recycling and refurbishing. Also, Sauvé *et al*. (2016), suggest that the circular economy refers to the "production and consumption of goods through closed loop material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste (including pollution)''. In their view, the primary focus of the circular economy is the reduction of resource consumption, pollution and waste in each step of the life cycle of the product. There is also, a consensus that it promotes longer life cycle of components, materials and products through reuse, repair, recycling, remanufacture and refurbishing (Zacho *et al*., 2018).



(a) The circular economy (CE) Model (Ezeudu and Ezeudu, 2019)



(b) Linear economy model (Okafor *et al*., 2020)

Figure 1: Circular Economy (CE) Model against Linear Economy Model

2.1 History of Circular Economy Concept

When investigating how the concept of circular economy arose and where it originates from, it is interesting to see that circular economy is inspired by different authors and influenced by several theories. However, several studies point at David Pearce and Kerry Turner as the founders of the conceptual framework for circular economy (Svendsen and Tang, 2018;

Winans*et al*., 2017;Geissdoerfer*et al*., 2016; Su*et al*., 2013). Even though Geissdoerfer *et al*. (2016) elaborated that the concept of circular economy has gained attention by authors since the late 1970's, and since then gained political awareness. The global attention to the term is not as popular as the term sustainability.

Circular economy has its roots in several concepts such as general system theory, cradle-to-cradle, laws of ecology, looped and performance economy, regenerative design, industrial ecology, industrial symbiosis, eco-city, bio mimicry, and the blue economy, all of which touch upon the idea of closing the loop (Svendsen and Tang, 2018; Winans*et al*., 2017; Geissdoerfer*et al*., 2016; Ghisellini*et al*., 2015). The different theories have all affected and influenced circular economy in how it is perceived today.

In an attempt to change the linear economy, Pearce and Turner's idea of circular economy is to attach the ends of the linear economy resulting in a loop. The loop is used to describe the industrial strategies for waste prevention, resource efficiency, and dematerialisation of the industrial economy (Svendsen and Tang, 2018; Geissdoerfer *et al*., 2016). Furthermore, Pearce and Turner conceptualize circular economy with three R's - reduce, reuse, and recycle (Figure 2).

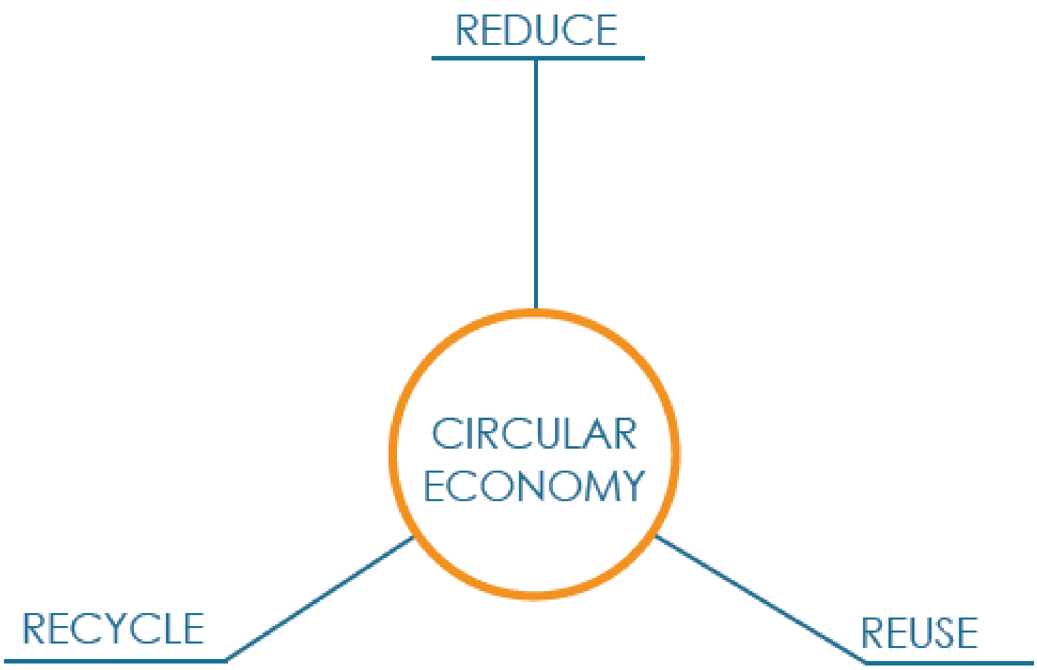


Figure 2: Three R's

Source: Svendsen and Tang (2018)

Reduce refers to reduction of raw materials and the use of polluting energy resources as the primary energy. *Reuse* refers to the reuse of products and by products, as well as handling waste as a resource. Lastly *Recycle* refers to producing products with recyclable materials which also reduces the extraction of virgin materials. Other studies have supplemented the three R's with: Recover, Remanufacture, Redesign, Refurbish, Repair, and the newest R from Advisory Board - Rethink. There is no doubt that all R's promote a wish for closing the loop. In Figure 3, the content of each word is described. However, some of these terms can have the same meanings as other R's and some are identified as broad categories e.g. redesign and rethink (Figure 3).

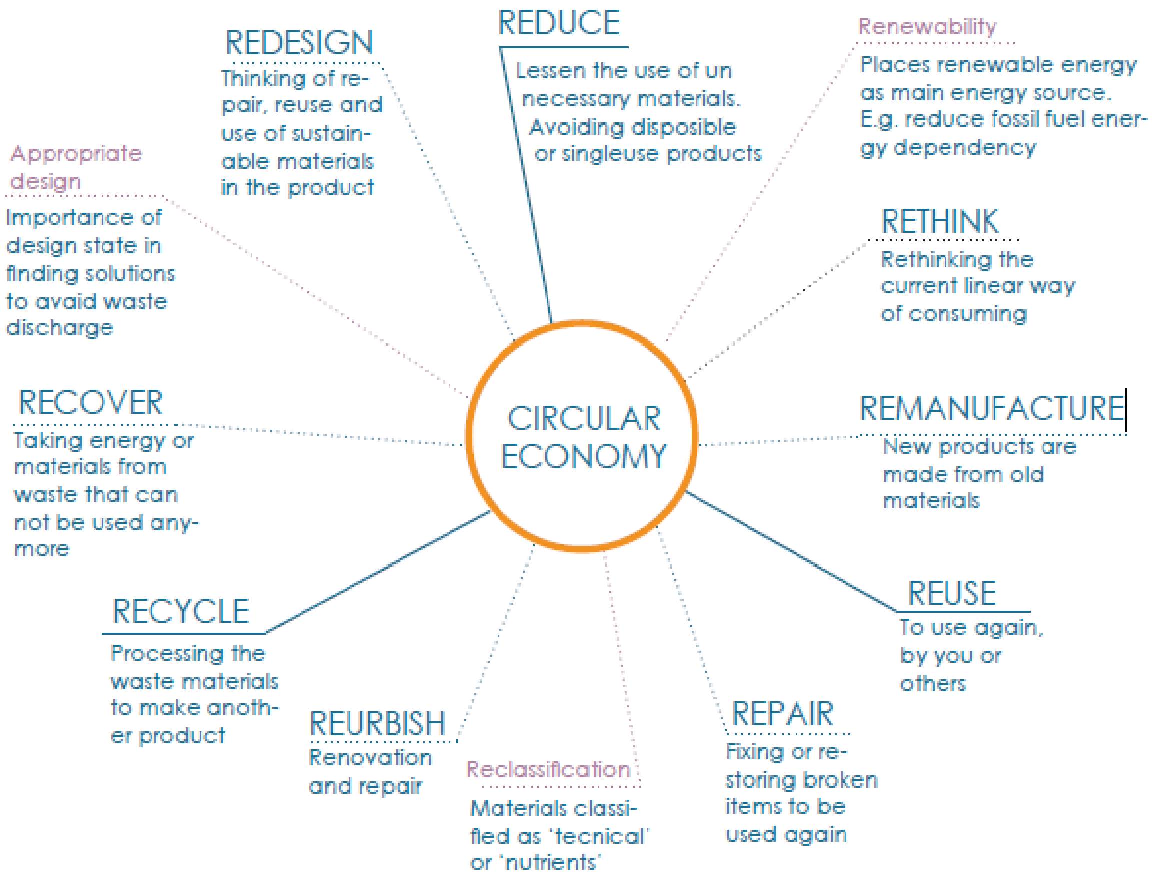


Figure 3: All R's

Source: Svendsen and Tang (2018)

2.2 *Circular Economy in the Construction Industry*

The current view suggests that it is likely impossible to reuse materials within the construction industry considering that buildings are often disposed of at the end of their useful life. For example, demolition and construction waste in the United Kingdom is at an annual average of 45.8 million tons (Akanbi *et al*., 2018). In response to Nunez-Cacho *et al*. (2018) observation that the construction industry requires a closer attention due to its environmental impact, the industry should improve its resource consumption (Smol*et al*., 2015). The current trends and practices in the construction industry suggest that CE can facilitate the sustainability of the industry. The starting point is to understand how CE could contribute to the construction industry, given that CE can be instrumental in reducing the environmental impact of the construction activities (Ghisellini *et al*., 2018). This is in line with van Stijn and Gruis (2019) assertion that "the transition to a circular economy in the built environment is key to achieving a resource-effective society". As a result, this study is designed to assess the current research focus on the cost and benefits of CE in the construction industry in Nigeria.

3.0 STUDY AREA: NIGERIA

Nigeria is located in West Africa. The total land area of Nigeria is 910,770 km^2, while water bodies accounts for 13,000 km^2. The population of Nigeria has been approximated at 198 million people as of 2018, calculated with 3.2% annual population growth index and also based on the 2006 population census figure of 140,431,790 (PRB, 2018). Nigeria accounts for 2.6% of global population. It is the 7thmost populous country of the world (Okafor *et al*., 2020; NNPC, 2019). Thirty-six states and a Federal Capital Territory (Abuja) make up the country. The country is characterized with a very young population. The average age of the population is 17.9 years (Okafor *et al*., 2020; Olaniyan *et al*., 2018). The country has enormous prospects, specifically in the areas of natural resources and human capital potential. It has a great endowment in crude oil and natural gas, solid minerals, vast and suitable land for agriculture and water and forest resources (Tunde, 2019; Ezeudu*et al*., 2019).
However, the country's rich endowment in natural resources somehow has facilitated enormous economic prosperity, such that it has been consistently rated among the largest economies in sub-Sahara Africa since 2004. But Nigeria is currently contending

with enormous social-economic challenges, such as a high unemployment index, technological backwardness, an underdeveloped agricultural sector and per capita poverty index. Hence, Nigeria was recently rated the poverty capital of the world (Adebayo, 2018). The National Bureau of Statistics (NBS) recently released the "2019 Poverty and Inequality in Nigeria Report", which highlights that 40 percent of the total population (almost 83 million), live below the country's poverty line of 137,430 Naira ($381.75) per year.

3.1 Brief Overview of Waste Management Policies in Nigeria

Solid waste management in Nigeria came with the establishment of the Federal Environmental Protection Agency (FEPA) in 1988 (Abila and Kantola, 2013). The FEPA was later merged with other key government agencies to form the Federal Ministry of Environment in 1999. The responsibility of this ministry is to issue guidelines on how key environmental issues, including solid waste management, should be tackled. However, the task of making laws, implementations and enforcement mostly lie on the state governments through various state ministries of the environment and municipal councils. The guideline on solid waste management in the country was released in 2005 by the Federal Ministry of Environment.

The policy document recognized the fact that strategies for waste management at the grassroots level should interface with the local culture, land use type, economic base, climatic condition, existing urbanization level and institutional arrangements (EPHW, 2005). The guideline, however, was not detailed on each aspect of solid waste management, such as waste reuse, recycling, and final disposal techniques.

Despite the high levels of material waste, Wahab and Lawal (2011) observed that little attention is given to construction waste in Nigeria and argued that a low means of disposal and the lack of awareness may be responsible. In support of their observation, Kareem *et al*. (2015) further explained that the high volume of wastes is due to the availability of inexpensive disposal methods, suggesting the need for government regulatory policies and organisational policies.

According to the Lagos State Waste Management Authority (LAWMA) (2014), there are five landfill sites (three major sites and two temporary sites) in the state, where all types of waste (including construction) are disposed. The recycling of construction waste in Lagos has been described to be very low (Ogunmakinde*et al*., 2019; Igbinomwanhia, 2011), while some household wastes (such as plastics and papers) are recycled to some extent (Ogunmakinde*et al*., 2019; LAWMA, 2014).

3.2 Construction Material Waste Situation in Nigeria

Material wastage has become a serious problem, which requires urgent attention in the Nigerian construction industry. This constraint harmfully affects the delivery of many projects (Adewuyi and Otali, 2013). Teo *et al*. (2009) observed that extra construction materials are usually purchased due to material wastage during the construction process. Adewuyi and Otali (2013) argue that despite the 5 percent allowance made to take care of material wastage in the course of preparing, an estimate for a project is usually inadequate, because there is a lot more waste generated by construction projects in Nigeria. Babatunde (2012) emphasises that the problem of construction material waste is well known in Nigeria; but it seems not to be given the recognition or the attention it deserves. Most of the material waste is sent to landfills without considering its economic importance, through recycling or reprocessing into new products. This would reduce the burden on the landfill, as well as the environmental effects (Wahab and Lawal, 2011).

The factors contributing significantly to construction material wastage in the Rivers State of Nigeria, as outlined by Adewuyi and Otali (2013) are: "rework as a result of non-compliance with drawings and specifications", "variation and modification in design", and "waste from inefficient and wasteful shapes", respectively. Insufficient construction materials waste was rated least among the factors. Adewuyi and Otali (2013) highlighted the fact that contractors and consultants have the same insight on the factors causing construction waste generation in the Delta state of Nigeria. In the view of Ameh and Itodo (2013), poor supervision of construction workers is the major factor contributing to material wastage in the Nigerian construction industry.

Wastage of material is common in construction projects in Nigeria; and this is as a result of several sources and causes. These occurrences pose a lot of challenges and have negative implications for the stakeholders in the form of high transportation cost to landfills and so on. The identification of these causes and the application of relevant control techniques to minimise their occurrence could be a step towards alleviating the consequences (Oladiran, 2009).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

Plate 1: Pictures of Common Construction Waste in Nigeria

Source: Ogunmakinde (2017).

3.3 Construction Waste Recovery Systems (Re-use and Recycling)

The recovery of construction waste, according to the United State Environmental Protection Agency (USEPA, 2000) encompasses the choice of the material to be recovered, which depends on factors, such as the type of project, on-site space, the existence of markets for secondary materials, the cost-effectiveness of recovery, the project duration, and the contractor's experience. Countries such as China, Australia, Japan, USA, Germany, and the United Kingdom have successfully recovered numerous materials: (for instance, paper, plastic, metals, and glass). However, Germany has the highest recovery rates for paper, plastic, metals, and 88 percent for glass, respectively (Tam and Tam, 2006).

Tam and Tam (2006) noted that the re-use and recycling of material waste are the only options to recover the generated waste. The benefits of recovering construction materials are summarised by USEPA (2000) as: reducing the project costs through avoided disposal costs; reduction in purchases of new materials; revenue earned from secondary material sales, compliance with state and local regulations, such as disposal bans and recycling goals; raising the public image of companies, and reserving space in existing landfills. In the context of material waste recovery, the word "reuse" was mostly used to signify the salvage or rescue of building materials for subsequent resale and use in another project (Winkler, 2010). However, if waste generation could not be prevented or minimised to a certain degree, the subsequent stage was to re-use or recycle, as much as possible (Esin and Cosgun, 2007). Apart from prevention and minimisation, most countries used this approach to reduce construction waste on-site, before disposing the waste to landfills (Wang and Li, 2011)

The Siemens Company in Germany uses a very advanced waste-handling technology for the re-use of construction materials. The process includes drying, distillation and burning to enable the waste material to be re-used (Wang and Li,2011).

In Hong Kong, the sorting process of waste materials is common among the construction practitioners; and this action promotes the re-use of some of the generated waste (Poon *et al.,* 2004) Consequently, a trip-ticket scheme in Hong Kong encourages the separation of inert waste for possible re-use (Nagapan *et al.,* 2012).

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4.0 BENEFITS OF CIRCULAR ECONOMY IN CONSTRUCTION

The global increase in the rate of material waste generation has led to the practice of recycling to become re-usable (Mueller, 2012). Winkler (2010) added that as raw materials are becoming more expensive and scarcer; and municipalities are resisting landfill extensions, so, the practice of waste management becomes more economical and important. Therefore, policymakers and construction managers must select which recycling practices to implement from the available options, in order to best divert material waste from going to landfills (Mueller, 2012). The benefits of the CE include, economic, environmental and social advantages and various authors argue that it is a sustainable approach.

4.1 Economic Benefit

Literatures in all the approaches under analysis claims substantive financial profits when moving from linear to circular production (Linder and Williander, 2017; Garza-Reyes *et al*., 2016; Lehr *et al*., 2013; Liu *et al*., 2012). This is an unanimously claimed result of value creation (Nassir *et al*., 2017; Aitken and Harrison, 2013; Kabongo and Boiral, 2011). Value creation results, on the one hand, thus reduce costs (Moreno et al., 2015). Those costs may be lessened from reduced marginal costs (Liu *et al*., 2012), reduced costs of buying virgin materials (Lehr *et al*., 2013); reduced waste disposal (Esmaeili *et al*., 2015); or from lower environmental taxes (Anctil and Le Blanc, 2015; Paquin *et al*., 2015). Value creation can also be addressed from the other perspective of enhancing profits. Increased revenues result from exchange flows, selling waste as input for another industry (Lehr *et al*., 2013; Geng *et al*., 2012), generating energy out of waste (Chaabane *et al*., 2012)or increasing brand and reputation effects (Tognetti *et al*.,2015). An increase in market share and reduced risks is also mentioned by the literature in closed loops (Alblas *et al*., 2014). Preston (2012) has asserted that the CE could assist in the industrialisation of developing countries and reduce the vulnerability to resource price shocks in developed countries.

Khor *et al*. (2016) found that recycling, repair, reconditioning and remanufacturing improve profitability but only reconditioning and remanufacturing improve sales growth. Paquin *et al*. (2015) used secondary data from 313 waste exchanges in the UK shows positive results in terms of eco-efficiency, as a reduction in waste also increased firm-level value through additional income and cost reductions. Values created, however, depended on the experience of the firm with industrial symbiosis, the volume of waste transacted, and the involvement of waste dedicated firms.

4.2 Environmental Benefits

Most cited environmental benefits for all the CE practices include reduction in the use of raw materials (Fraccascia *et al*., 2017; Linder and Williander, 2017; Esmaeili *et al*., 2015;Choudhary *et al*., 2015; Paquin *et al*., 2015) and the minimization of waste (Kähkönen *et al*., 2015; Chileshe *et al*., 2016; Garza-Reyes *et al*., 2016; Hsu *et al*., 2013; Minner and Kiesmüller, 2012). Reductions in carbon and greenhouse gases emissions are also claimed (Choudhary *et al*., 2015; Esmaeili *et al*., 2015), with several mathematical models showing that products from non-linear production processes have significantly lower carbon emissions during their life-cycle than products made with linear production (Nassir *et al*., 2017; Hazen *et al*., 2016;Zhalechian*et al*., 2016).Studies in energy use reduction are also frequent. Positive impacts have been found for closed-loop (Zhalechian*et al*., 2016), industrial ecology (Chertow and Miyata,2011) and industrial symbioses practices (Fraccascia *et al*., 2017; Paquin *et al*., 2015).

According to Geng *et al*. (2012), the potential environmental benefits of the CE are numerous, and include: "*conservation of natural resources (especially non-renewable resources such as water, fossil, fuels and minerals), reduced environment impacts through efficient energy and material and less water discharge, avoidance of toxic materials, extended life cycle of landfill sites, and recovery of local ecosystem*". Similarly, Jun and Xiang (2011) revealed that the CE is expected to conserve resources and provide adequate environmental protection. While Ghisellini*et al*. (2016) claims that the objective of the CE was to split environmental pressure from a thriving economy. The CE model is expected to reduce unsustainable pressure on natural resources, which will reduce environmental challenges (Preston, 2012; Zhu *et al*., 2010).

4.3 Social Benefits

Murray *et al*. (2015) observes "of the three pillars of sustainability (social, economic and environmental) it is the former that is least expanded in most of the conceptualizations and applications of the CE."Employment and community development are the main social impacts analysed. Three studies factored in social welfare in closed loop and reverse logistics modelling (Wang and Hanzen, 2016; Zhalechian *et al*., 2016; Pishvae *et al*., 2014). Wang and Hanzen (2016) finds that increasing government incentives and penalties over the closed loop supply chain leader – either the manufacturer or the waste collector – enhances social welfare.

Geng *et al*. (2012), have identified its potential social benefits, including improved relationships between local societies and industrial sectors, improved public awareness of environmental issues and health benefits, as well as employment opportunities from recycling businesses. Andrews (2015) has emphasised that the CE creates employment opportunities for design graduates and professionals with related expertise across all industries. He notes that the CE has the potential to reduce unethical practices and corruption in the industry. It is expected to facilitate the selection of ethical suppliers while encouraging others to change (Andrews, 2015). Yuan *et al*. (2006) has added that it could reform environmental management and create opportunities for collaboration between consumers and producers that will prolong commercial relationships between them. Similarly, Moreno *et al*. (2015) have supported the claim of Yuan *et al.* (2006), adding societal benefits to the list of benefits. With the CE, national security will be strengthened owing to increased sustainable energy supplies (Su*et al*., 2013). Zhijun and Nailing (2007) acknowledge the potential social impacts of the CE to integrate populations, close income gaps, promote social justice and prevent environmental poverty.

Pishvaee *et al*. (2014) compared the environmental and social impacts of supply chains with the recycling of waste and supply chains with land-filling. They evaluated social impact considering local development, created job opportunities, consumer risk and worker health and safety. They found that supply chains with recycling not only have higher costs but also higher environmental and social benefits. However, they did not analyse more advanced nonlinear production options such as remanufacturing.

Paquin *et al*. (2015) use secondary data from 313 waste exchanges in the UK to show positive results in terms of eco development, defined as an increase in employment with a decrease in carbon emissions. They observe that the involvement of waste specialists (green logistics firms) in closed-loop supply chains significantly increases the social benefits of industrial symbiosis but at the expense of decreasing the economic gains of manufacturers.

5.0 CONCLUSION

This study reviewed the concept of circular economy (CE) its definition, principles and benefits to cost in the Nigerian construction industry. And it also reviewed the construction industry, construction material waste situation, construction waste recovery systems and waste management policies in Nigeria. The key findings from the review are the three pillars of circular economy sustainability (economic, environmental and social) benefits and how the add value directly to the construction industry in the worldwide perspective and how it can potentially add value to the Nigerian construction industry if and when wholly applied, and enforced by policymaker such as the government. To encourage greater implementation of circular economy principles throughout the supply chain, a clear economic case is paramount, and supported by metrics, tools and guidance. The support from government through the regulatory agencies such as COREN, in the case of Nigeria is very important.

REFERENCES

[1] Abila, B. and Kantola, J. (2013). Municipal solid waste management problems in Nigeria: Evolving knowledge management solution. *International Journal of Environmentaland Ecological Engineering*, 7- 6.

[2] Adams, K.T., Osmani, M., Thorpe, T. and Thornback, J. (2017). Circular economy in construction: current awareness, challenges and enablers. *Proceedings of the Institution of Civil Engineers*, 1600011.

[3] Adebayo, B. (2018). Nigeria overtakes India in extreme poverty ranking. www.cnn.com

[4] Adewuyi, T. O. and Otali, M. (2013). "Evaluation of Causes of Construction Material Waste: Case of River State, Nigeria." *Ethiopian Journal of Environmental Studies and Management*,6: 746-753.

[5] Adewuyi, T.O. and Otali, M. (2013). Evaluation of Causes of Construction Material Waste: Case of River State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*,6: 746-753.

[6] Aitken, J. and Harrison, A. (2013). Supply governance structures for reverse logistics systems. *International Journal of Operations & Production Management*, 33(6): 745-764.

[7] Akanbi, L.A., Oyedele, L.O., Akinade, O.O., Ajayi, A.O., Delgado, M.D., Bilal, M. and Bello, S.A. (2018). Salvaging building materials in a circular economy: a BIM-based whole-life performance estimator. *Resources, Conservation and Recycling*, 129: 175-186.

[8] Alblas, A.A., Peters, K. and Wortmann, H.J.C. (2014). Fuzzysustainability incentives in new product development: anempirical exploration of sustainability challenges inmanufacturing companies.*International Journal of Operations & Production Management*, 34(4): 513-545.

[9] Ameh, J. O., and Itodo, E. D. (2013). Professionals‘Views of Material Wastage on Construction Sites. *Organization, Technology and Management in Construct ion. An international Journal*,5(1): 747-757.

[10] Anctil, A. and Le Blanc, D. (2015). “An educational simulation tool for integrated coastal tourism development in developing countries”. *Journal of Sustainable Tourism*, 24(5): 783-798.

[11] Andrews, D. (2015). The circular economy, design thinking and education for sustainability. *Local Economy Local Economy, 30*(3): 305-315.

[12] Babatunde, S.O. (2012). "Quantitative Assessment of Construction Material Wastage in Nigerian Construction Sites." *Journal of Emerging Trends in Economics and Management Sciences*,3 (3): 238-241.

[13] Benton, D. (2015). *Circular Economy Scotland*. Green Alliance, London, UK.

[14] Bilal, M., Oyedele, L.O., Akinade, O.O., Ajayi, S.O., Alaka, H.A., Owolabi, H.A., Qadir, J., Pasha, M. and Bello, S.A. (2016). Big data architecture for construction waste analytics (CWA): a conceptual framework. *Journal of Building Engineering*, 6: 144-156.

[15] Bilitewski, B. (2012). The circular economy and its risks. *Waste Management*, 32(1): 1–2.

[16] Blomsma, F. and Brennan, G. (2017). The emergence of circular economy: a new framing around prolonging resource productivity. *Journal of Industrial Ecology*, 21(3): 603-614.

[17] Chaabane, A., Ramudin, A. and Paquet, M. (2012). “Designof sustainable supply chains under the emission tradingscheme”.*International Journal of Production Economics*,135(1): 37-49.

[18] Chen, S. and Ravallion, M. (2010). The developing world is poorer than we thought, but no less successful in the fight against poverty. *Quantity Journal of Economics*, 125: 1577–1625.

[19] Chertow, M. andMiyata, Y. (2011). Assessing collective firmbehavior: comparing industrial symbiosis with possiblealternatives for individual companies in Oahu, HI.*Business Strategy and the Environment*, 20(4): 266-280.

[20] Chileshe, N., Rameezdeen, R., Hosseini, M.R., Lehmann, S.and Udeaja, C. (2016). Analysis of reverse logisticsimplementation practices by South Australian constructionorganisations. *International Journal of Operations and Production Management*,36(3): 332-356.

[21] Choudhary, A., Sarkar, S., Settur, S. and Tiwari, M.K. (2015). A carbon market sensitive optimization model forintegrated forward-reverse logistics.*International Journal of Production Economics*, 164(6): 433-444.

[22] Clark, C., Jambeck, J. and Townsend, T. (2006). A review of construction and demolition debris regulations in the United States. *Critical Reviews in Environmental Science and Technology*, 36(2): 141-186.

[23] Dania, A. A., Kehinde, J.O. and Bala. K. (2007). A study of Construction Material Waste." *the third Scottish conference for Post-Graduate researchers of built and national environment (PROBE).* Baufach.

[24] Environmental and Public Health Watch (EPHW). (2005). Policy Guidelines on Solid Waste Management. Developed by Federal Ministry of Environment Abuja. Available online: https://tsaftarmuhalli.blogspot.com/2011/12/ policy-guidelines-on-solid-waste.html (accessed on 13 March, 2021).

[25] Esin, T., and Cosgun, N. (2007). "A study Conducted to Reduce Construction Waste Generation in Turkey." *Building and Environment* 42: 1667–1674.

[26] European Environment Agency (EEA). (2016). Circular economy in Europe: developing the knowledge. available at: www.eea.europa.eu/publications/circular-economy-in-europe.

[27] Ezeudu, O. and Ezeudu, T. (2019) Implementation of circular economy principle in industrial solid waste management: case studies from a developing economy (Nigeria). *Recycl* 4: 1–18.

[28] Ezeudu, O.B., Agunwamba, J.C., Ezeasor, I.C. and Madu, C.N. (2019). Sustainable production and consumption of paper and paper product in Nigeria: A review. *Resources*,8: 52-53.
[29] Fraccascia, L., Albino, V. and Garavelli, C.A. (2017),"Technical efficiency measures of industrial symbiosisnetworks using enterprise input-output analysis". *International Journal of Production Economics*, 183(1): 273-286.
[30] Garza-Reyes, J.A., Villarreal, B. and Kumar, V. (2016). "Lean and green in the transport and logistics sector – a case study of simultaneous deployment". *Production Planning and Control*, 27(15): 1221-1232.
[31] Geissdoerfer, M., Savaget, P., Bocken, N. and Hultink, E. (2016). The Circular Economy – A new sustainability paradigm. *Journal of Cleaner Production*, 143: 757-768.
[32] Gencel, O., Ozel, C., Koksal, F., Erdogmus, E., Mart_ınez-Barrera, G. and Brostow, W. (2012), Properties of concrete paving blocks made with waste marble. *Journal of Cleaner Production*, 21(1): 62-70. doi: 10.1016/j.jclepro.2011.08.023.
[33] Geng, Y., Fu, J., Sarkis, J. and Xue, B. (2012). Towards a national circular economy indicator system in China: an evaluation and critical analysis. *Journal of Cleaner Production*, 23(1): 216–224.
[34] Geng, Y., Fu, J., Sarkis, J. and Xue, B. (2012). Towards a national circular economy indicator system in China: an evaluation and critical analysis. *Journal of Cleaner Production*, 23(1), 216-224.
[35] Ghisellini, P., Cialani, C. and Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*,114: 11-32.
[36] Ghisellini, P., Ripa, M. and Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. *Journal of Cleaner Production*, 178: 618-643.
[37] Hazen, B.T., Mollenkopf, D.A. and Wang, Y. (2016). Remanufacturing for the circular economy: an examinationof consumer switching behaviour. *Business Strategy and the Environment*, 26(4): 451-464.
[38] Homrich, A.S., Galvão, G., Abadia, L.G. and Carvalho, M.M. (2018). The circular economy umbrella: trends and gaps on integrating pathways. *Journal of Cleaner Production*, 175(6): 525-543.
[39] Hsu, C.C., Tan, K.C., Zailani, S.H.M. and Jayaraman, V.(2013). Supply chain drivers that foster the development ofgreen initiatives in an emerging economy.*International Journal of Operations & Production Management*, 33(6): 656-688.
[40] Igbinomwanhia, D.I. (2011). *Status of waste management*. In Integrated Waste Management-Volume II; InTech: London, UK.
[41] Imam, A., Mohammed, B., Wilson, D.C. and Cheeseman, C.R. (2008). Country Report: Solid Waste Management in Abuja, Nigeria. *Waste Management*,28: 468–472.
[42] Jun, H. and Xiang, H. (2011). Development of Circular Economy Is A Fundamental Way to Achieve Agriculture Sustainable Development in China. *Energy Procedia*, 5: 1530-1534.
[43] Kabongo, J. and Boiral, O. (2011). "Creating value with wastes: a model and typology of sustainability within firms". *Business Strategy and the Environment*, 20(7): 441-455.
[44] Kareem, W.A., Asa, O.A. and Lawal, M.O. (2015). Resources conservation and waste management practices in construction industry. *Arabian Journal of Business Management Review (Oman Chapter)*, 4: 20.
[45] Khor, K.S., Udin, Z.M., Ramayah, T. and Hazen, B.T.(2016). Reverse logistics in Malaysia: the contingent role ofinstitutional pressure. *International Journal of Production Economics*, 175(5): 96-108.
[46] Kirchherr, J., Reike, D. and Hekkert, M. (2017). Conceptualizing the circular economy: an analysis of 114 definitions. *ResourcesConservation and Recycling*, 127: 221-232, doi: 10.1016/j.resconrec.2017.09.005.
[47] Kylili, A. and Fokaides, P.A. (2017). Policy trends for the sustainability assessment of construction materials: a review. *Sustainable Cities and Society*, 35: 280-288. doi: 10.1016/j.scs.2017.08.013.
[48] Lagos State Waste Management Authority (LAWMA). (2014). *Landfill—Monthly Dump Reports*. Available online: http://www.lawma.gov.ng/insidelawma/ departments/landfill/ (accessed on 13 March, 2021).
[49] Lai, X., Liu, J., Shi, Q., Georgiev, G. and Wu, G. (2017). Driving forces for low carbon technology innovation in the building industry: a critical review. *Renewable and Sustainable Energy Reviews*, 74: 299-315. doi: 10.1016/j.rser.2017.02.044.
[50] Lehr, C.B., Thun, J.H. and Milling, P.M. (2013). "From waste to value – a system dynamics model for strategic decision making in closed-loop supply chains". *International Journal of Production Research*, 51(13): 4105-4116.
[51] Lemougna, P.N., Melo, U.F.C., Kamseu, E. and Tchamba, A.B. (2011). Laterite based stabilized products for sustainable building applications in tropical countries: review and prospects for the case of Cameroon. Sustainability, 3(1): 293-305.
[52] Lieder, M. and Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, 115: 36-51.
[53] Linder, M. and Williander, M. (2017). Circular business model innovation: inherent Ncertainties. *Business Strategy and the Environment*, 26(2): 182-196.
[54] Liu, D., Li, H., Wang, W. and Dong, Y. (2012).Constructivism scenario evolutionary analysis of zeroemission regional planning: a case of Qaidam circulareconomy pilot area in China. *International Journal ofProduction Economics*, 140(1): 341-356.
[55] Minner, S. and Kiesmüller, G.P. (2012). Dynamic productacquisition in closed loop supply chains. *International Journal of Production Research*, 50(11): 2836-2851.
[56] Missemer, A. (2018). Natural Capital as an economic concept, history and contemporary issues. *Ecological Economics*, 143(C): 90-96.
[57] Moreno, M., Braithwaite, N. and Cooper, T., (2015). Moving beyond the circular economy. *Proceedings of Going Green-CARE Innovation*, 1-10.
[58] Mueller, W. (2012). The Effectiveness of Recycling Policy Options: Waste Diversion or Just Diversions.*Waste Management*,33: 508–518.
[59] Murray, A., Skene, K. and Hayne, K. (2015). The circulareconomy: an interdisciplinary exploration of the concept andCircular economy under uncertainty within a closed-loop supply chain. *International Journal of Production Economics*, 135(1): 81-93.
[60] Nagapan, S., Abdul-Rahman, I., Asmi, A., Memon, A.H. and Latif, I. (2012). Issues on Construction Waste: The Need for Sustainable Waste Management. *IEEE Colloquium on Humanities, Science & Engineering Research (CHUSER 2012)*, Kota Kinabalu, Sobah, Malaysia. 325-330.
[61] Nassir, M.H.A., Genovese, A., Acquaye, A.A., Koh, S.C.L. and Yamoah, F. (2017). Comparing linear and circular supply chains: a case study from the construction industry. *International Journal of Production Economics*, 183(1): 443-457.
[62] Nigerian National Petroleum Corporation Nigeria (NNPC). (2019). Nigerian National Petroleum Corporation Nigeria Profile, 2019. Available from: http://www.nnpcgroup.com/NNPCBusiness/nigeria-profile.
[63] Nunez-Cacho, P., Gorecki, J., Molina-Moreno, V. and Corpas-Iglesias, F. (2018). What gets measured, gets done: development of a circular economy measurement scale for building industry. *Sustainability*, 10(7): 23-40.
[64] Ogunmakinde, O.E. (2017). *Developing a Circular Economy-Based Construction Waste Minimisation Framework for Nigeria*. School of Architecture and Built Environment. Faculty of Engineering and Built Environment. Pp.1-2.
[65] Ogunmakinde, O.E., Sher, W. and Maund, K. (2019). An Assessment of Material Waste Disposal Methods in the Nigerian Construction Industry. *Recycling*, 4(13): 1-15.
[66] Okafor, C., Ajaero, C., Madu, C., Agomuo, K. and Abu, E. (2020). Implementation of circular economy principles in management of end-of-life tyres in a developing country (Nigeria**)**. *AIMS Environmental Science*, 7(5): 406–433.

[67] Oladiran, O.J. (2009). Causes and Minimization Techniques of Materials Waste in Nigerian Construction Process. *Fifth International Conference on Construction in the 21st Century (CITC-V).* Istanbul, Turkey. Pp. 20-22.

[68] Olaniyan, K., McLellan, B.C. and Ogata, S. (2018) Estimating Residential Electricity Consumption in Nigeria to Support Energy Transitions. *Sustainability*,10: 1–22.

[69] Osobajo, O.A., Oke, A., Omotayo, T. and Obi, L.I. (2020). A systematic review of circular economy research in the construction industry. *Smart and Sustainable Built Environment*, 1-27. doi: 10.1108/sasbe-04-2020-0034.

[70] Pan, S.Y., Du, M.A., Huang, I.T., Liu, I.H., Chang, E.E. and Chiang, P.C. (2015). Strategies on implementation of waste-to-energy (WTE) supply chain for circular economy system: a review. *Journal of Cleaner Production*, 108: 409-421.

[71] Paquin, R.L., Busch, T. and Tilleman, S.G. (2015). "Creating economic and environmental value through industrial symbiosis". *Long Range Planning*, 48(2): 95-107.

[72] Pearce, D.W. and R.K. Turner (1990). *Economics of Natural Resources and the Environment*, Hemel Hempstead: Harvester Wheatsheaf.

[73] Pishvaee, M.S., Razmi, J. and Torabi, S.A. (2014), "Anaccelerated benders decomposition algorithm for sustainablesupply chain network design under uncertainty: a case studyof medical needle and syringe supply chain".*Transportation Research Part E: Logistics and Transportation Review*, 67(7): 14-38.

[74] Plastinina, I.; Teslyuk, L.; Dukmasova, N.; and Pikalova, E. 2019. Implementation of circular economy principles in regional solid municipal waste management: The case of Sverdlovskaya Oblast (Russian Federation). *Resources*,8: 90-102.

[75] Population Reference Bureau (PRB). (2018). Available online: https://www.prb.org/wp686content/uploads/2018/08/ 2018_WPDS.pdf.

[76] Preston, F. (2012). A global redesign? Shaping the circular economy. *Energy, Environment and Resource Governance. London: Chatham House*.

[77] Preston, F. (2012). A Global Redesign?: Shaping the Circular Economy, Chatham House, London, available at: https://www.chathamhouse.org/publications/papers/view/182376/bp0312_preston.pdf.

[78] Reike, D., Vermeulen,W.J. and Witjes, S. (2018). The circular economy: new or refurbished as CE 3.0? Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options", Resources, Conservation& Recycling, 135(8): 246-264.

[79] Rose, C.M. and Stegemann, J.A. (2018). From waste management to component management in the construction industry. *Sustainability*, 10(1): 229-232.

[80] Saidu, I. (2016). *Management of Material Waste and Cost Overrun in the Nigerian Construction Industry*. Ph. D Thesis. University, Port Elizabeth, South Africa. Pp. 1-338.

[81] Salguero-Puerta, L., Levya-Diaz, J. and Cortes-Garcia, F. (2019) Sustainability indicators concerning waste management for implementation of the circular economy model on the University of Lome (Togo) Campus. *International Journal of Environmental Research and Public Health*,16: 1–21.

[82] Sauvé, S., S. Bernard and P. Sloan (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, 17: 48-56.

[83] Sehnem, S., Vazquez-Brust, D., Farias-Pereira, S.C. and Lucila M.S. Campos, L.M.S. (2019). Circular economy: benefits, impacts and overlapping. *Supply Chain Management: An International Journal*, 24(6): 784–804.

[84] Smol, M., Kulczycka, J., Henclik, A., Gorazda, K. and Wzorek, Z. (2015). The possible use of sewage sludge ash (SSA) in the construction industry as a way towards a circular economy. *Journal of Cleaner Production*, 95: 45-54. doi: 10.1016/j.jclepro.2015.02.051.

[85] Su, B., Heshmati, A., Geng, Y. and Yu, X. (2013). A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production*, 42: 215-227.

[86] Svendsen, L. and Tang, S. (2018). *Circular economy in the construction industry*. MSc in Sustainable Design Aalborg University - Copenhagen School of Architecture, Design and Planning (SADP), pp. 1-116.

[87] Tam, V.W.Y. (2008). On the Effectiveness in Implementing a Waste-Management-Plan Method in Construction. *Waste Management*, 28: 1072–1080.

[88] Tam, V.W.Y. and Tam, C.M. (2006). "Evaluations of Existing Waste Recycling Methods: A Hong Kong study." *Building and Environment* 41: 1649–1660.

[89] Teo, S.P., Abdelnaser, O. and Abdul, H.K. (2009). "Material Wastage in Malaysian Construction Industry." *International Conference on Economic and Administration, Faculty of Administration, University of Bucharest Romania*,257-264.

[90] Tognetti, A., Grosse-Ruyken, P.T. and Wagner, S.M. (2015). "Green supply chain network optimization and the trade-offbetween environmental and economic objectives". *International Journal of Production Economics*,170(B): 385-392.

[91] Tukker, A. (2015). Product services for a resource-efficient and circular economy–a review. *Journal of Cleaner Production*, 97: 76-91. doi: 10.1016/j.jclepro.2013.11.049.

[92] Tunde, A.A. (2019). Implementation of Circular Economy Principles in Industrial Solid Waste Management: Case Studies from a Developing Economy (Nigeria)Graduate Assistant University of Ilorin, Nigeria. Pp.1-12.

[93] USEPA. (2000). *Building savings*: Strategies for Waste Reduction of Construction and Demolition Debris from Buildings. Solid Waste and Emergency Response (5306W).

[94] van Stijn, A. and Gruis, V. (2019). "Towards a circular built environment: an integral design tool for circular building components". *Smart and Sustainable Built Environment*, 10: 1–22.

[95] Wahab, A.B. and Lawal, A.F. (2011).An evaluation of waste control measure in construction industry in Nigeria. *African Journal of Environment Sciences and Technology*, 3: 246–254.

[96] Wang, R., and S. Li. (2011). "*Re-using of Construction Waste view in Foreign Countries*." Economic reference paper, Japan, 1-4.

[97] Wang, Y. and Hanzen, B.T. (2016), "Consumer productknowledge and intention to purchase remanufacturedproducts", International Journal of Production Economics,181(12): 460-469.

[98] Winans, K., Kendall, A. and Deng, H. (2017). The history and current applications of the circular economy concept. *Renewable and Sustainable Energy Reviews*, 68: 825-833.

[99] Winkler, G. (2010). *Recycling Construction and Demolition waste: A leed-based toolkit.* Edited by Brian Taylor. New York, USA: International Code Council ICC.

[100] Yuan, Z., Bi, J. and Moriguichi, Y. (2006). The circular economy: A new development strategy in China. *Journal of Industrial Ecology*, 10(1-2), 4-8.

[101] Zacho, K.O., Mosgaard, M. and Riisgaard, H. (2018). Capturing uncaptured values—a Danish case study on municipal preparation for reuse and recycling of waste. *Resources, Conservation and Recycling*, 136: 297-305, doi: 10.1016/j.resconrec.2018.04.031.

[102] Zhalechian, M., Zahiri, B., Tavakkoli-Moghaddam, R. andMohammadi, M. (2016). "Sustainable design of a closed-looplocation-routing-inventory supply chain network undermixed uncertainty".*Transportation Research Part E: Logistics and Transportation Review*, Vol. 89No. 5, pp. 182-214.

[103] Zhijun, F. and Nailing, Y. (2007). Putting a circular economy into practice in China. *Sustainability Science*, *2*(1), 95-101.

[104] Zhu, Q., Geng, Y. and Lai, K.H. (2010). Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. *Journal of Environmental Management*, 91(6): 1324-1331.