Circular Construction: Opportunities and Threats

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ABSTRACT

The construction industry is one of the largest consumers of raw materials. Very little of the wastes generated from its activities are recycled or reused constituting a major concern for the environment. Common construction processes in most developing countries follows a linear concept of "take-make-use-dispose": a fragmented process resulting in inefficient use of resources. The circular economy (CE) concept of "take-make-use-regenerate" aims at zero waste of materials, and efficient use and reuse of resources. CE principles include reduce, reuse, and recycle and their adoption within the construction sector has been encouraged by researchers, policy makers, government and non-governmental organisations. Numerous opportunities accrue when the CE concept is applied to the construction industry. This paper introduces circular construction (CC) as the integration of CE into the construction industry. It identifies opportunities and threats for CC across the sector. Opportunities were categorised into economic, social, environmental and technological while threats were professionals, clients, government and industry. The study adopted a qualitative exploratory research design where data were derived from an analysis of secondary sources through a review of literature. In conclusion, the paper recommends the adoption of CC especially at the design phase, and deconstruction rather than demolition.

Keywords: circular construction, circular economy, opportunities, threats, wastes

INTRODUCTION

Infrastructural developments in many developing and developed countries continue to rise owing to economic growth, urbanisation, increased population and advanced technology. Deterioration of the environment and depletion of natural resources have been identified as major environmental consequences of these developments (Huang, 2012; Menikpura, Gheewala, Bonnet, & Chiemchaisri, 2013; Plagányi et al., 2013; Song, Li, & Zeng, 2015; Vieira & Pereira, 2015) due to the activities of various sectors including industrial, manufacturing, construction. Environmental issues across different sectors of the economy may vary. For instance, construction activities (such as carpentry, masonry and trenching) generate waste which leads to pollution. Although, some other issues arising from the industry negatively affect the environment (Abidin, 2010; Dania, Kehinde & Bala, 2007), waste generation has sparked the need for global consideration of its associated risk.

According to Eurostat (2014), the construction industry contributed 33.5% (871m tonnes) in waste generated by economic activities in the European Union in 2014. Wastes from the industry represent one-third of total wastes generated annually in the EU. In the same vein, a report by the UK Green Building Council indicates that the construction and demolition sector generates 120m tonnes of waste every year. This makes the industry the largest contributor of waste. Similarly, in the US, about 40% of solid waste comes from construction and demolition. In Finland, the construction industry is responsible for 18% of the 90m tonnes of waste generated annually (Sitra, 2015). According to Australia Bureau of Statistics (2013), out of the total 53.7million tonnes of waste generated in 2009 and 2010, construction waste accounts for 16.5million tonnes. Despite the high generation rate of wastes across the construction industry globally, less than one-third is recovered, reused or recycled (World Economic Forum, 2016). The European Commission (2001) however identified the potential for re-using and recycling construction and demolition wastes but the reality is that a considerable portion of it is landfilled. About 44% of construction waste in Australia and the UK ends up in landfill, 29% in the US, 54% in Finland and 35% across the globe (DEFRA, 2013; Oyedele, Kadiri and Ajayi, 2014; Solis-Guzman et al., 2009; Sitra, 2015).

The traditional methods and fragmented construction processes commonly practiced across the industry could be responsible for high waste generation. These methods and processes could be equated to a linear economy model ("take-make-use-dispose"), where raw materials are extracted (i.e. Take), manufactured into products (i.e. Make), used by consumers (i.e. Use) and disposed of after use (i.e. Dispose). Traditional construction methods use materials made from natural resources some of which are disposed of during construction and deconstruction or demolition. This model is unsustainable, resource inefficient, wasteful, problematic, uses large amounts of energy and poses serious threats to the environment. It is also uneconomical as increases in demand for natural resources will inevitably make them more expensive and scarce (Bastein et al., 2013). If this trend continues, increased demand for natural resources (European Commission, 2011) could triple by 2050 (UNEP, 2011). It is obvious that our planet is becoming stressed and may not be able to cope with demand for natural resources soon. Therefore, it is crucial that the industry shifts to alternative methods and processes to improve resource and energy utilisation and facilitate sustainable construction. Although the industry has been described as conservative and slow to change (James et al. 2006), a swing to modern construction methods and processes (such as disruptive transformation, analytics, BIM etc.) is evident around the globe.

The circular economy (CE) has been described by several authors (Andrews, 2015; Dorn, Nelles, & Flamme, 2010; Murray, Skene, & Haynes, 2015; Qian & Wang, 2016; Si-yuan & Yuan, 2012; B. Su, Heshmati, Geng, & Yu, 2013) as a sustainable development concept that is restorative and regenerative by intention and design and could be applied to any sector of the economy. It eliminates waste of materials, ensures resource efficiency and low energy use. Guohui and Yunfeng (2012) described it as a "resource-product-waste-regenerate resource" model which utilizes resources and protects the environment effectively. With CE, products at the end of their useful lives are regenerated either by recycling or reusing them. This contrasts with the linear economy where products are disposed of after use. In practice, it hinges on economic development through reduction in resource consumption and pollutant emission, waste re-use and material recycling (Shi et al., 2006). A strong link exists between CE principles (reducing, reusing and recycling), environment and economics (Heshmati, 2015). The CE has been adopted particularly in the manufacturing, steel and agricultural sectors in some countries whilst others are in the process of adopting it. Although some countries have advocated its integration into construction, its adoption is still limited. It presents a huge opportunity for the construction industry to reduce material wastage, limit extraction of finite raw materials and reduce global emissions thereby achieving environmental sustainability. Its integration into the construction industry is referred to as "circular construction". Circular construction (CC) ensures products (i.e. buildings) are regenerative at the end of their lives through recovery, reuse and recycling of their components. Bastein et al (2013 p. 5) argues that "in the transition to a circular economy the focus is no longer solely decoupling environmental pressures from economic growth, but also on the opportunities created if these things remain coupled" (Bastein et al., 2013 p.5). This study aims to answer the following questions:

i. What opportunities are available with the adoption of CC?

ii. What threats inhibit the adoption of CC?

THE CONCEPT OF THE CIRCULAR ECONOMY

Over the last two decades, literature has emerged on the CE covering its origin, founding principles, characteristics, approaches, framework, and implementation. Murray et al. (2015) asserted that its origin is debatable. Damen (2012) supports the assertion that CE's origin cannot be traced to a particular author(s), publication or year. It is mainly rooted in ecological, environmental economics and industrial ecology (Ghisellini et al., 2015; Murray et al., 2015; Preston, 2012). It originates from eco-industrial development (EID) theory and thought (Geng, Fu, Sarkis, & Xue, 2012) and general systems theory developed by Von Bertalanffy (1950; 1968). Qian and Wang (2016) claimed that CE can be traced to environmentalism due to its concern for the environment. It also has roots in some schools of thoughts and theories that disapprove of the linear economy (Allwood, 2014; Ellen MacArthur Foundation, 2013; Preston, 2012). One such theory is the spaceship theory postulated by Professor Kenneth E. Boulding (an American economist) who has been acclaimed by several researchers (George, Lin, & Chen, 2015; Ghisellini et al., 2015; Greyson, 2007; Persson, 2015; Rizos, Behrens, Kafyeke, Hirschnitz-Garbera, & Ioannou, 2015) as the originator of the idea of the CE concept.

Boulding described the earth in his article ("*The Economics of the Space Ship Earth*") as a single spaceship on a journey with a pre-loaded stock of resources. As the journey progresses, the resources are depleted, unless they are recycled. This implies that resources are consumed without an option of recycling. His idea was to evoke a shift from an "*open system*" to a "*closed system*". Stahel and Reday-Mulvey further developed the idea of a closed system in 1976 into a "closed-loop economy" which dwells on improved durability (Murray et al., 2015). Matthew and Tan (2011) however referred to CE as closed-loop economy. The term CE was coined by two British environmental economists, David Pearce and R. Kerry Turner in 1990 in their book titled: Economics of Natural Resources and the Environment (Qian & Wang, 2016; B. Su et al., 2013).

Several definitions of CE exist indicating the lack of a common definition (Bechtel et al., 2013, Damen, 2012; Yuan et al., 2006). Most are based on individual's perceptions. Some selected definitions are presented in Table 1. Liu (2012, p. 256) gave a detailed definition of CE as "*an economy system which is characterised by principle of sustainable growth and depends less on depletion of natural resources than traditional economies through mechanism of recycling the waste output of its system*". Similarly, Ellen MacArthur Foundation (2012, p. 22) described it as "*an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises, tracks and eliminates the use of toxic chemicals; and eradicates waste through careful design*".

Table 1: Definitions of the CE

Author(s) and year	Definition
Andrews (2015)	CE mirrors natural life cycles where dead organic material decomposes to become a nutrient for the next generation of living organisms.
Dorn et al. (2010)	CE as an economic development system that is focused on environmental protection, avoidance of emissions, and on sustainable development in order to prevent waste and emissions at source, and reduce the formation of such at each production unit.
Guohui and Yunfeng (2012)	CE is in nature an ecological economy which uses ecological principle to direct economic activities in human society. It is an economy focusing on highly

	efficient utilization and reutilization of resources based on the principle of decrement, recycle and resource extending.
Iung and Levrat (2014)	CE is a generic term materializing an economic concept that fits in the context of sustainable development and based on the concepts of green economy, usage (functionality) economy and industrial ecology.
Preston (2012)	CE is an approach that would transform the function of resources in the economy.
Van den Berg and Bakker (2015)	CE describes a model of closing material loops in an economically attractive way to decouple wealth from resource usage.
Wilson (2015)	CE is a generic term for an economy that is regenerative by design.

The central theme of these definitions is environmental protection, waste prevention, resource reuse and material recycling. Although these definitions differ, the purpose and objectives of CE remain unchanged. Therefore, for the purposes of this paper CE is defined as a sustainable concept that ensures zero waste of materials, low pressure on resource consumption and energy through reuse and recycling principles. The philosophy of CE has been explained by several authors. Ellen MacArthur Foundation (2015, p. 5-7) described its principles to include the following:

i. "*Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows*" (p. 5)
ii. "*Optimise resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles*" (p. 7)
iii. "*Foster system effectiveness by revealing and designing out negative externalities*" (p. 7)

Some authors (Preston, 2012; Sakai et al., 2011; B. Su et al., 2013; Zhijun & Nailing, 2007; Ren, 2007; Reh, 2013; Lett, 2014) described the basic principles of CE as the 3R's - Reduce, Reuse and Recycle. Ghisellini et al. (2015) claimed that the 3R principles can be integrated by the principles developed by the Ellen MacArthur Foundation in 2012. Their claim received a boost when Pan et al. (2015) added two more R's to make it 5R (Reduction, Reuse, Recycling, Recovery and Reclamation). However, most literature refers to the 3R principles of CE.

Liu (2012) asserted that reduction is an efficient method where input of materials is reduced so that efficiency can be increased while energy consumption is reduced. Su et al. (2013) agreed, arguing that reduction is aimed at minimising the input of primary energy, raw materials and waste to achieve efficiency in production and consumption processes. The European Commission (2008) described reuse as any operation where products or components used before are used again for the same purpose they were initially used for. Materials are reused to avoid waste, and reduce resource extraction and energy. This benefits the environment since it requires less energy, fewer resources and less labour (Castellani, Sala, & Mirabella, 2015; James, 2011). Recycling is the third principle of CE and the last option to recover the value of a material at its end-of-life (Van den Berg and Bakker, 2015). It involves reprocessing which could be referred to as a recovery operation for materials assumed as waste. These materials can be used either for their original purpose or other purposes (Ghisellini et al., 2015). Recycling is fundamental to CE because of its proven sustainable character over years (Van den Berg and Bakker, 2015) and its help in reducing the consumption of virgin materials (Shi et al., 2006; Su et al., 2013).

The CE is widely practiced in China while similar concepts have been implemented in other countries (Japan, USA, UK and the EU). According to Ghisellini et al. (2015), CE practice in China resulted from a top-down approach. This is a system of command and control from the government to the people. It was implemented on a three-layer approach (micro, meso and macro) with four practice areas (design, production, consumption and waste management) as shown in Table 2. At the micro (enterprise) level, emphasis is on cleaner production involving resource reuse and recycling of by-products to achieve dual environmental and economic performance goals (Ren, 2007; Wang & Li, 2006; Zhu et al., 2010). At the meso (inter-firm) level, implementation of CE hinges on reuse and recycling of resources within industrial parks and clustered industries (Wang and Li, 2006). The macro level considers products, collection, processing, storage and distribution systems at the regional, municipal, provincial or city level (Wang and Li, 2006).

China has successfully implemented the CE concept in some industries including iron and steel, paper making, process and manufacturing, tourism, construction, agricultural and electric power. The adoption of CE across the globe is generally sparse but is being considered by the European Union and some other countries. Its adoption in the construction industry has been advocated in some countries (Netherlands, Sweden, UK, Austria, Australia and US) while its implementation is a work in progress. Several authors have identified possible threats and opportunities associated with the CE. For example, Moreno et al. (2015) ranked threats to CE as high, medium and low. The high ranked threats are "*cost restraints, consumer perception and behaviour, producers and consumers locked into the current economic/market system*" (p. 7). The medium ranked barriers include: "*cultural expectations for new models, closed loop supply chains and reverse loop supply chain could increase cost of logistics, transportation and energy*" (p. 7). They identified "*cost restraints (lack of operational capital, lack of investment capital to develop and build new facilities), time constraints, lack of knowledge, lack of certification procedures for alternative practices, complex supply chains and complex information flows within the supply flow and unknown take back process*" as the low ranked challenges. Geng et al. (2012) identified the opportunities of CE to include improved public awareness of environmental issues and improved relationships between local societies and industrial sectors. In the same vein, Andrews (2015) emphasised that CE will create employment opportunities from recycling business.

Table 2: Implementation structure of CE in China

Areas	**Micro (Enterprise)**	**Meso (Inter firms)**	**Macro (Provinces, Region, State and Cities)**
Design	Eco-design	Environmentally friendly design	Environmentally friendly design
Production	Cleaner production	Eco-industrial park	Eco-city Eco-municipality Eco-province
Consumption	Green purchase and consumption	Environmentally friendly park	Renting service
Waste management	Product reuse and recycle system	Waste trade market Industrial symbiosis	Urban symbiosis

Source: Adapted from Su et al. (2013)

The aforementioned literature identified CE as a sustainable concept that could be adopted in the construction industry. Its application to construction activities is referred to as circular construction (a sustainable concept that ensures efficient and effective reuse and recycling of all materials throughout construction and demolition phases). Opportunities and threats of the CE require careful consideration before its adoption in the construction industry.

METHODOLOGY

This study adopted a qualitative exploratory research design. Babbie (2012), Neuman (2006) and Zikmund (2003) described exploratory research as that which investigates a new phenomenon to develop propositions for future research. It utilises literature searches, focus groups, surveys, interviews, observations, experiments, case studies and / or archival analysis as strategies (Saunders et al., 2007). Exploratory research seeks to create hypotheses, answer 'what' questions (Neuman, 2006) and produces qualitative data. Since this study seeks to answer 'what' questions, a review of literature provides a clear focus for the research questions.

Data were derived from secondary sources through a systematic review of literature. Electronic searches of the following databases were conducted; Scopus, Elsevier, Science direct and Google Scholar. Keywords and terms used for search strategies include: "circular economy", "opportunities", "threats", "sustainable construction", "resource efficiency" and "construction wastes". The searches produced an extremely large number of results. These were refined using the following criteria:

i. Time period was limited from 1996 to 2017
ii. Only peer reviewed articles were selected
iii. Abstracts were screened to determine inclusion

From the foregoing, 172 publications including journal articles, conference papers, book reviews, technical notes and theses were downloaded into Endnote. A search was conducted to locate additional publications and bibliographies of articles for diverse terminologies. Of all the publications downloaded, refereed journal articles were prioritized. Overall, 75 articles were selected for review. These yielded opportunities and threats associated with circular construction which were analysed in the study.

FINDINGS AND DISCUSSION

Opportunities. Circular Construction has been argued by several authors as a sustainable approach. The studies reviewed indicate that its opportunities comprised social, economic, technological and environmental opportunities.

Social opportunities. The social opportunities of CC justify its sustainable development potential of meeting present and future social needs. In the construction industry, CC can create opportunities for collaboration between clients and construction teams, which will prolong the commercial relationship between them (Yuan et al., 2006). It can improve relationships between local societies and industrial sectors leading to the socioeconomic development of the nation (Geng et al., 2012). It also has the potential to reduce unethical practices and corruption in the industry (Andrews, 2015). More likely, it is expected to facilitate the selection of non-corrupt suppliers as a result of changes in value chains while encouraging others to change. Su et al. (2013) assert that it can strengthen national security due to increased sustainable energy supply while Zhijun and Nailing (2007) affirm that it can integrate population, close income gaps and promote social justice.

Economic opportunities. Several economic opportunities are linked to the CC. Ghisellini et al. (2015), Persson (2015), Jun and Xiang (2011) and Zhu et al. (2010) claim that it can achieve economic growth without extracting more resources. Resource productivity, material cost reduction, and increased revenue from waste sales (Yuan et al., 2006; Moreno et al., 2015; Geng et al., 2012) are some of its potential economic opportunities. More so, it can allay demand-driven price volatility of raw materials and supply risks (Crowther and Gilman, 2014) as well as create new business models thereby increasing profits (Moreno et al., 2015). It can also create employment opportunities for design graduates and professionals with related expertise (Andrews, 2015). Benton, Hazell, and Hill (2014) posits that it can bring direct cost savings to businesses, offer reputational advantages and become a market differentiator without placing undue pressure on resources.

Environmental opportunities. The potential environmental opportunities of CC are numerous as they may be seen as a possible alternative to traditional methods of construction. They include: "*conservation of natural resources (especially non-renewable resources such as water, fossil, fuels and minerals), reduced environmental 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*" (Geng et al., 2012, p. 221). It can reform environmental management (Yuan et al., 2006) thereby improving public awareness of environmental issues as it relates to their health (Geng et al., 2012). As a sustainable approach, CC will result in positive environmental outcomes through efficient waste and resource minimisation (Andersen, 2007). It is also expected to mitigate environmental pollution (Wang, 2009), improve eco-efficiency (Yuan et al., 2006), prevent environmental poverty (Zhijun and Nailing, 2007) and reduce unsustainable pressure on natural resources, thereby reducing environmental challenges (Preston, 2012; Zhu et al., 2010).

Technological opportunities. Within the CC, technological initiatives are expected to serve as a support in achieving social, economic and environmental characteristics. The construction industry is faced with several challenges ranging from management to methodologies. It is imperative that modern technologies are explored as possible solutions. The CC can provide technological opportunities such as increased innovation and adoption of cleaner technologies (Andersen, 2007) to ensure resource efficiency and waste minimisation. It could also assist in industrialisation (Preston, 2012) through industrial symbiosis (i.e. the exchange of waste materials between two or more companies). Kalundborg (in Denmark) is a good example of industrial symbiosis in practice (Damen, 2012).

Threats. Threats to successful acceptance, adoption, transition, and implementation of the CC are categorised as professionals, clients, government and industry related threats.

Clients threats. Threats posed by clients play crucial roles in the adoption and successful implementation of CC. Several authors (Xue et al., 2010; Guohui and Yunfeng, 2012; Rizos et al., 2015; Su et al., 2013; Li and Li, 2011, European Commission, 2014) have reported lack of awareness, knowledge and understanding of environmental protection and benefits of CC. Many clients do not consider the environmental impacts of their projects, they concentrate more on the cost and aesthetics (Hayles, 2015). This could be attributed to their lack of awareness and attitudes to environmental threats posed by their actions. More so, Preston (2012) identified lack of enthusiasm, life style and fashion of clients as possible threats to the adoption of CC. Clients' taste, fashion and life style at times determine their preference.

Professional threats. Similar to clients' threats, professionals in the industry also lack awareness, knowledge and understanding of the CC. Several authors (Meqdadi, Johnsen, and Joh, 2012; Wooi and Zailani, 2010; Xue et al., 2010; Rizos et al., 2015; Li and Li, 2011) attributed this to their attitude and resistance to change. According to Andrews (2015), most products (i.e. buildings) are not designed for disassembly. This is a result of design professionals' inability to adopt new technologies, systems and methods of designing (such as designing out waste, designing for resource efficiency and designing for deconstruction and disassembly). Lack of motivation to reuse or recycle materials (Löfgren and Enocson, 2014; EC, 2014) is another threat. Some professionals are not motivated because of the common belief that recycled materials are inferior (Andrews, 2015).

Industry threats. Threats posed by the industry are enormous due to their fragmented nature. The industry has been criticised for its poor leadership and management (Su et al., 2013) which is a major threat to the adoption of CC. Lack of reliable information systems and shortage of advanced technologies (Su et al., 2013; EC, 2014; Liu et al., 2009; Xue et al., 2010) experienced in the industry also pose serious threats. Similarly, changes in industrial practices and patterns as well as lack of independent organisations to certify CC (Preston, 2012) often discourages their adoption. Innovation challenge, lack of appropriate quantitative tools for design, and lack of standardization for performance and structures (Su et al., 2013; Preston, 2012; Greyson, 2007; Zhu, 2000) are potential threats.

Government threats. Government agencies and institutions are key to the success of CC. For example, the role of the Chinese government was critical in the adoption and implementation of the CE concept. Policies, regulations and legislation are a government's instruments in developing a sector or a nation. These instruments could also serve as threats. Lack of policy coherence (Xue et al., 2010), lack of legal system on CC (Geng et al., 2012) and difficulties in enforcing environmental laws have been identified as potential threats to the adoption of CC. More so, lack of financial support was widely reported as a major threat to its adoption and implementation. It therefore seems possible that the private sector may be co-opted to relieve the burden on the government. Lack of enforcement of legislation (Su et al., 2013; Xue et al., 2010; Liu et al., 2009) is also a threat especially in some developing countries. Other threats include: lack of support and encouragement (Calogirou et al., 2010; Struder et al.,2010); weak economic incentives (Su et al., 2013; EC, 2014) and high cost of green investment for firms (Preston, 2012; Andrews, 2015; Rizos et al., 2015).

CONCLUSION

This study has described the CE concept as a viable alternative to the linear economy and identified reduction, reuse and recycling of materials as basic principles of CE. It discussed current CE practice in China and identified design, production, consumption and waste management as areas of practice. It highlighted CE as a sustainable concept that could achieve sustainable construction when adopted in the construction industry. This study has proposed the adoption of the CE concept in the construction industry as circular construction. Resource efficiency, low energy use and waste minimisation could be achieved in the construction industry. The research revealed that the adoption and practice of CC could be difficult to implement due to the fragmented nature of the industry. However, it is achievable. Several opportunities of CC were identified and categorised into social, economic, environmental and technological opportunities. More so, the study identified threats to adopting CC and categorised them into clients, professionals, industry and government-posed threats. The implementation of CC would require the industry to review its opportunities and threats. CC provides significant benefits, especially at the design and deconstruction phases. The former could involve design for disassembly while the latter could adopt pre-demolition audits. The adoption would require a framework involving all stakeholders in the industry. Possible areas of improvement of the CE could be explored and country specific implementation processes developed. These are recommendations for future investigations.

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