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Prioritizing barriers to adopt circular economy in construction and demolition waste management

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ABSTRACT

Construction and demolition (C&D) waste dreadful impacts increasingly cause public concerns. Aiming to boost resource exploitation efficiency, circular economy is contemplated a pertinent C&D waste management practice. However, transitioning to circular economy in C&D waste management is hindered by barriers which are to be found and overcome to adeptly handle this kind of waste. In this paper 22 potential crisp barriers are identified through reviewing the seminal literature which could be categorized under three dimensions of behavioral, technical, and legal. Six experts in behavioral, technical, and legal sciences working in sustainable C&D projects were asked to rate the dimensions and the barriers through a questionnaire survey on the results of which fuzzy TOPSIS method is applied to prioritize the barriers followed by advancing a framework to facilitate pushing C&D waste management toward circular economy. The study concluded that from behavioral, technical, and legal perspectives, using finitely recyclable construction materials; ineffective C&D wastes dismantling, sorting, transporting, and recovering processes; and using finitely recyclable construction materials are ranked first. Also from an aggregate perspective, agency and ownership issues in C&D waste management, lack of integration of sustainable C&D waste management, and uncertain aftermaths of moving toward circular economy in C&D waste management are three high priority barriers which should be removed before transforming current linear economy to circular economy in C&D waste management.

1. Introduction

C&D waste management is an environmental dimension of sustainable construction (Chethana et al., 2016). C&D waste is combination of inert (Zheng et al., 2017) and non-inert (Hossain et al., 2017) solid waste consisting of abandoned substances due to construction, renovation, or demolition of civil structures (Wu et al., 2016). C&D waste is often managed imprudently (Hossain et al., 2017) posing intertwined technical, economic (Bovea and Powell, 2016); environmental, organizational, legal, operational (Abba et al., 2013); and social (Jin et al., 2017) problems in developed (Chen and Lu, 2017) and developing countries (Lockrey et al., 2016). The detriments include but are not limited to terrestrial and aquatic acidification, ozone layer depletion, global warming, respiratory impacts caused by inorganics, non-renewable energy consumption, and aquatic eutrophication (Hossain et al., 2017); asthma attacks, premature deaths, reduction of lung function in children (Marzouk and Azab, 2014); aesthetic ramifications of illegal C&D waste dumped at road sides and open spaces, virgin resources depletion (Ma et al., 2014; Cha et al., 2009); and public concerns (Li et al., 2018). The pressing matters elucidate indispensability of managing C&D wastes (Esa et al., 2016). Obtaining momentum as an

emerging paradigm (Pomponi and Moncaster, 2017), circular economy is promptly administering waste management realm and is evolving into a preminent notion to sustainable C&D waste management (Liu et al., 2017). By definition circular economy is “an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts toward the use of renewable energy, eliminates the use of toxic chemicals impairing reuse, and aims at eliminating waste through the superior design of materials, products, systems, and business models” (Ellen MacArthur Foundation, 2016). Circular economy roughly eliminates C&D wastes by preserving the added value in building materials as long as possible (Smol et al., 2015) through recirculating them to close their loops and manufacture new products (Singh and Ordonez, 2016). Circular economy has received significant governmental, academic, and organizational attention (Ranta et al., 2017) as an alternative to existing linear economy (Singh and Ordonez, 2016) since its line of reasoning is underpinned by cradle-to-cradle, take-make-recreate, and eco-effectiveness schools of thoughts in lieu of cradle-to-grave, take-make-dispose, and eco-efficiency (Dumlao-Tan and Halog, 2017). Circular economy is a stepping stone to an optimal C&D waste management as it reduces resources escaping from the loops and simultaneously maintains their quality (Smol et al., 2015). All the

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same, transformation to a circular economy in C&D waste management is hindered by barriers (Ritzén and Sandström, 2017) which have to be identified and taken up to accelerate the transitioning progress in practice (Ranta et al., 2017; Ritzén and Sandström, 2017). Evidently, all identified barriers cannot be removed at once necessitating prioritization of the barriers and removal of high-priority ones first.

2. Literature review

The circular economy research community has worked on identification of barriers to move toward a circular economy since its propagation by the European Union (Smol et al., 2015).

Veleva et al. (2017) reported that companies' efforts for transition to circular economy are insufficient. They explored three barriers to advance a circular economy according to lessons learned from 8 biotech and pharmaceutical companies being recognized for their sustainability efforts. The recognized barriers were relying on not-environmentally preferred methods to reduce wastes, non-standardized waste reduction reporting that lacks appropriate indicators to measure source reduction and reuse, undeveloped employee engagement and awareness of zero waste and circular economic initiatives. They proposed a model for expanded zero waste including 11 new measures of circular economy environmental, social and economic outcomes as well as enhanced employee engagement by means of informing, educating, empowering and rewarding. Liu et al., 2017 reviewed waste prevention through reduce, reuse, and recycle under the concept of circular economy in China. They reported that circular economy tackles the problems caused by waste generation e.g. environmental degradation and resource scarcity. They focused on municipal solid waste, electric and electronic waste, and end of life vehicles as typical wastes in China and reported that circular economy pilot projects have developed waste utilization industry in China. Today 1.9 million employees, 230000 waste recovery network points, 5300 collecting and processing plants, and over 6700 renewable resources enterprises are acting in China. However existing problems e.g. inadequate regulations and management policies hinder achieving a zero waste society and widen the gap in development of circular economy in waste management between China and developed countries e.g. Japan. Ritzén and Sandström (2017) contended that circular economy is implemented fragmentally because not only is it complicatedly multi-dimensional and multi-domain but also it encounters connected barriers which frequently occur in the literature. After a specific literature review, they found 9 barriers including “*measuring financial benefits of circular economy, financial profitability, missing exchange of information, unclear responsibility distribution, infrastructure/supply chain management, perception of sustainability, risk aversion, product design, and integration into production processes*”. They concluded that removing the barriers requires radical innovations and disruptive changes. Ranta et al. (2017) explored region-specific barriers to and drivers of circular economy in China, the USA, and Europe using institutional theory. They identified institutional barriers and drivers in six selected cases. They found that circular economy holistic vision has been inhibited by overemphasis on recycle and underuse of reuse and reduce. This is essentially important when recycling cost exceeds recyclable value and consequently, recycling generates negative value. Yuan (2017) studied barriers to and countermeasures for C&D waste management in Shenzhen, an economically developed region in southern China. Based on reviewed literature, group discussions, and semi-structured interviews with experts and governmental staff, following grievous local problems in Shenzhen C&D waste management were identified: “*Lack of mature regulatory environment for managing C&D waste, separate involvement of multiple government departments in different C&D waste management processes without a leading department, lack of fundamental data in C&D waste, Insufficient attention*

paid to waste management in construction projects, slow pace of C&D waste recycling factories toward growth”. Accordingly, five measures along with various supporting methods were suggested to improve the situation. Hossain et al. (2017) assessed environmental contribution of off-site sorting, on-site sorting, and direct disposing of construction waste in Hong Kong. They resulted that tendency to off-site sorting and direct landfilling was a barrier contributing to significant environmental impacts, however, on-site sorting provoked net environmental benefits. They believed that space and budget limitations, tight schedules, and additional labor and managerial efforts make construction participants reluctant to do on-site sorting with respect to current dominant cradle-to-grave approach. Mangla et al. (2017) prioritized 30 barriers to achieving sustainable consumption and production trends in supply chains using fuzzy AHP followed by a sensitivity analysis to monitor the prioritization and to determine its small variations in case of changes in the barriers relative weights. They asserted that the trends minimize natural resources use as well as waste generation over their lifecycle. Among the barriers, lack of appropriate methods, tools, techniques, and indicators to cleaner production practices was ranked first. Esa et al. (2016) conducted a systematic review of 55 papers within the field of C & D waste management and circular economy. It resulted that in-depth C&D waste management related studies are wanting and structuring a C & D waste management regime in developing countries and particularly in Malaysia is necessary. So they developed a theoretical framework for C&D waste minimization in Malaysia based on concept of circular economy at micro, meso, and macro levels which introduced waste reduction strategies as well as stakeholders during planning and designing, procurement, and C&D stages. Pomponi and Moncaster (2017) contended that built environment negatively impacts on natural environment making its transition to circular economy imperative. However current circular economy researches incline to ignore effects and potential barriers of buildings at meso level. They framed a research framework based on a critical literature review to plug this gap. To test its ability to overcome barriers of embedding circular economy principles in the built environment, they applied it to circular economy-themed events in C&D sector. The application proved that it includes pivotal initiatives of producing circular buildings. Smol et al. (2015) identified waste generation not only as a major negative impact of construction sector but also as a barrier to construction industry transitioning to circular economy. So they indicated that the sector requires innovative ways of converting C&D wastes to resources. After suggesting possible uses of major wastes in construction materials production, they narrowed down their study to sewage sludge ash proposing its usefulness in cement, brick, ceramic, glass, pavement, and road embankments production. Singh and Ordonez (2016) analyzed 58 products developed from discards to understand resource circulation in practice and barriers to implement a circular economy. Identified barriers after interviewing waste management professionals and designers were handling products at use and end of life stages differently, recovered materials bad quality, product composition complexity, and material ownership. They also proposed a model manifesting possible materials flow through society and resource recovery routes. Lee et al. (2014) presented downside of a zero waste society transitioning to circular resource flows through advancing recycle rates. They concluded that current focus on increasing recycle rates will lead to an unintended continuous risk cycle. They exemplified three toxic anti-androgenic phthalates cycle in paper and plastic frequent recirculation. They also warned that full implementation of European waste legislation will increase recycle rate of C&D wastes from 21.8% in 2012 to 70.0% in 2020 which will increase unwanted micro-pollutants recycling. As a remedial solution, they proposed upcycling by guaranteeing clean resource flows instead of recycling. Mittal and Sangwan (2014) believed that manufacturing firms' unsustainable energy

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