ENABLING ZERO WASTE CONCEPT IN THE CONSTRUCTION INDUSTRY: A LITERATURE REVIEW

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ABSTRACT

The construction industry is one of the leading economic players in any region. However, the continuous construction and demolition activities have resulted in the generation of Construction and Demolition (C&D) waste. C&D waste management in the construction industry is still at an adolescent stage where effective reduction of C&D waste is considered as a challenging issue confronted by many economies in the world. Improper waste management has led to several issues related to environmental, economic, and social over the past years. Thus, C&D waste management is considered as a persuasive issue to be addressed. The "Zero Waste" concept has emerged as a solution to eliminate the C&D waste, which eradicates waste at the source and throughout the period of the construction activity. Many researchers have mentioned that efficient material management or waste minimisation plan is an essential process in zero waste. In this process, it is pertinent to consider the potential of which materials may generate less waste, re-useable, or recyclable, i.e., diverting materials from disposal to reuse or recycling during the construction. However, limited studies are available on zero waste management in construction industry. Therefore, this paper aims to review the importance of zero waste concept to the construction industry by critically reviewing the secondary data on waste management studies conducted in the construction industry. The paper further discusses the types of C&D waste, impacts of C&D waste, origins and causes of waste, the zero-waste concept, and the importance and its application in the construction industry. Strategies, enablers, and barriers to implementing zero waste are discussed, and finally, a conceptual framework is developed to achieve Zero Waste in the construction industry.

Keywords: *Construction and Demolition (C&D) Waste; Construction Industry; Enablers; Zero Waste.*

1. INTRODUCTION

Any material which is a by-product of human and industrial activity that has no residual value is defined as waste (Teo & Loosemore, 2001). The construction industry is considered as a main field, in which the rapid development has resulted in a massive increase of construction and demolition waste causing a significant burden to the environment (Banias et al., 2010). In construction waste, solid waste generated during new construction, renovation, and demolition of structures are identified as Construction and Demolition (C&D) waste (Wang et al., 2010). Esin and Cosgun (2007) identified that solid construction waste is comprised of asbestos, heavy metals, persistent organic compounds, and Volatile Organic Compounds (VOCs) that end up in landfills resulting environmental pollution. According to Wang et al. (2008), cement, timber, brick, concrete, aluminium, tile, and steel are the main types of construction waste materials, and C&D waste accounts for 10-30% of solid wastes at many landfills globally (Wang et al., 2010). Mhaske et al. (2017) mentioned that C&D waste contributes negative impacts on cost, time, environment, and productivity of a country, while Osmani et al. (2008) emphasised on a compelling need to reduce waste in all stages of construction by considering the long-term impacts.

Li et al. (2015) found that 33% of the waste materials are produced due to designer failures, and construction waste generation can be reduced during designing and construction by dimension coordination, using prefabricated components, employing standard dimensions and units, detail designing and avoiding design

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modifications. As per Wang et al. (2015), to reduce the adverse effect of construction waste on human health and sustainable development, a 3R principle (Reduce, Reuse, and Recycle) is used to manage the construction waste. Moreover, Osmani (2012) mentioned that the involvement and commitment of the stakeholders to reduce waste generation at source and efficient waste management strategies could lead the industry to achieve zero waste targets.

Zero waste is a whole system approach that focuses on the elimination of waste at source and during all points of the supply chain (Curran & Williams, 2012). Zero waste concept motivates optimum recycling and resource recovery, sustainable production and consumption, and restricts mass incineration and landfilling (Zaman, 2015). According to Connett (2006), the zero waste concept binds community and industry together, and hence it is certain that zero waste is a precise solution for the C&D waste management in the construction industry. Thus, this paper presents the key literature findings on the importance of zero waste concept to the construction industry, as a part of a research study in investigating the adoptability of zero waste concept to the Sri Lankan construction industry.

2. RESEARCH METHOD

As mentioned by Uyangoda (2010), a literature review is a critical assessment by the researcher on the existing body of knowledge of the theme or problem under investigation. It enables the researcher to identify essential gaps in the existing knowledge with evidence. Thus, as in any research work, conducting a systematic literature review enriches and reinforces the research process initially. Therefore, findings of comprehensive literature review presented the consequences of C&D waste in the construction industry, origin, causes of waste generation, zero waste concept and its importance to the construction industry, and enablers to implementing zero waste in the construction industry. Literature evidence was collected by referring journal articles, books, published and unpublished bibliographies, conference proceedings, industry reports, and documents that are specifically related to the construction industry, C&D waste, C&D waste management procedures, and zero waste. The literature survey was facilitated by the use of key terms such as construction and demolition waste, zero waste, enablers, and construction industry.

3. CONSTRUCTION AND DEMOLITION OF (C&D) WASTE IN THE CONSTRUCTION INDUSTRY

In most countries, C&D waste may count for a bigger portion of solid waste generation (Elgizawy et al., 2016). Hence, the construction industry is under pressure as to reduce the sizable quantities of construction waste generated during construction operations (Banihashemi et al., 2018). Although researchers have paid attention to the effective and efficient C&D waste management since the 1980s, C&D waste management is still at an adolescent stage (Hao et al., 2007).

Effective C&D waste management is a challenging issue for many countries, as they make an adverse impact on the environment (Wang et al., 2010). C&D waste can be defined as the waste generated through new construction, renovation, and demolition of buildings and structures (Kofoworola & Gheewala, 2009). According to Wang et al. (2014), C&D waste means the waste of valuable natural resources and disposal of those C&D waste to landfills leads to the scarcity in the land resource. Starting from the raw material extraction up to the demolition and waste disposal, massive quantities of waste generates from the construction industry, and the heavy use of raw materials for the construction industry has resulted in unsustainability in the industry (Elgizawy et al., 2016). Osmani et al. (2008) stated that a considerable amount of waste generates, starting from the pre-construction stage up to the completion of the construction, and according to Kofoworola and Gheewala (2009), the landfill is the favoured method for C&D waste disposal.

3.1. TYPES OF C&D WASTE

In a construction project, design and construction stages are significant as they are inter-related, and systematic waste management in one stage makes a direct impact over the next stage (Ding et al., 2018). The C&D waste composition differs according to the construction technique, building type, and country (Elgizawy et al., 2016). The authors have identified some major waste streams in construction projects such as wood, concrete, masonry, metal ferrous, metal non-ferrous, plastic, glass, insulation materials, gypsum boards, ceramic tiles, paper and cardboard, marble, and granite. As per Wang et al. (2008), construction activities generate waste types such as sludge, soil, timber and steel, from which, 95% can be recycled while remaining 5% is

unrecyclable. Moreover, Hao et al. (2007) have explained that C&D waste is divided into materials, machinery, energy, and labour. According to Kofoworola and Gheewala (2009), a sizable proportion of the generated C&D waste consist of paper and plastic waste from the usage of packaging materials, formwork, and wood waste from scaffoldings. Further, Wang et al. (2008) disclose that concrete waste generation is higher in C&D waste, i.e., approximately 80%- 90%, due to the concrete demolition, plastering flow, excess ordering, and template leakage. The authors have also explained that block wastage happens due to the damages and cutover, whereas timber and brittle material wastage generates due to cutover and transportation issues. Before recycling of C&D waste, the waste generator should perform waste sorting (Wahi et al., 2016). According to Jaillon et al. (2009), C&D waste is a mixture of inert and non-inert materials, and out of the C&D waste, 70% of the construction waste is from the inert materials that can be reused for reclamation and earth-filling works. The authors have also stated that, from the C&D waste, non-inert waste account for 15% - 18% and they are either recycled or disposed to landfills. Out of the generated C&D waste, a certain percentage of waste is reduced and recycled while the remaining C&D waste is incinerated or sent into landfills, as presented in Table 1.

Table 1: C&D Waste Generation and Management in Various Countries

Country	**Waste generation**	**Waste Management**		**Source of Reference**		
	C&D waste (MT)	% Reduced/ recycled	% Incinerated/ land filled	(Jaillon et al., 2009)	(Symonds Group Limited, 1999)	(Franklin Associate, 1998)
Germany	59	17	83	√		
UK	30	45	55	√		
France	24	15	85	√		
Italy	20	9	91	√		
Spain	13	<5	>95	√		
Netherlands	11	90	10	√		
Belgium	7	87	13	√		
Austria	5	41	59	√		
Portugal	3	<5	>95	√		
Denmark	3	81	19	√		
Greece	2	<5	>95	√		
Sweden	2	21	79	√		
Finland	1	45	55	√		
Ireland	1	<5	>95	√		
Luxemburg	0	n/a	n/a	√		
Europe-15	180	28	72		√	
US in 1996	136	30	70			√
Hong Kong in 1999	13.55	79	21	√		
Hong Kong in 2005	21.45	89	11	√		
Singapore in 1999	0.41	70	30	√		
Singapore in 2005	0.49	94	6	√		

3.2. ORIGINS OF WASTE AND CAUSES FOR WASTE GENERATION

As per Osmani (2012), C&D waste generates due to the design changes, poor communication between design and construction team, extended project duration, and lack of design information. Further, Jaillon et al. (2009) stated that design and requirement changes of clients generate vast amounts of waste. According to Kofoworola and Gheewala (2009), C&D waste generates due to contractor's lack of interest, lack of knowledge in the designing stage, use of poor-quality products, and poor material handling. Furthermore, the authors have identified causes for concrete waste creation as, dimension deviation in structural elements and ordering of

surplus of concrete to carry out the work. Moreover, the authors explained that material delivery issues and poor handling of materials cause brick and block waste and tile waste.

Insufficient environmental awareness and structural selection, lack of management skills, lack of training to manage waste, and the use of outdated technology for construction are the reasons for the generation of C&D waste (Wang et al., 2008), and these authors highlight that landfilling is the method used by the contractors to dump C&D waste. Magalhaes et al. (2017) explained that construction planning and designing decisions also lead to the C&D waste generation. Table 2 presents a review of the C&D waste origins.

Table 2: Review of C&D Waste Origins

Origins of waste	Osmani et al. (2008)	Gavilan and Bernold (1994)	Osmani et al. (2006)	Formoso et al. (1999)	Begum et al. (2006)	Poon et al. (2004)	Li et al. (2015)	Osmani (2012)	Kulatunga et al., (2006)
Contractual issues	√					√			
Design issues	√	√	√	√	√		√	√	√
Procurement issues	√	√		√				√	√
Transportation issues	√			√					√
On-site management and planning issues	√				√	√	√	√	
Material storage issues	√								
Material handling issues	√	√							√
Site operation issues	√	√	√				√	√	
Residual issues	√	√			√	√			
Other issues (Weather, Vandalism)	√			√					√

3.3. IMPACTS OF C&D WASTE AND SOLUTIONS FOR PREVENTION

Sapuay (2016) states that the improper management of C&D waste leads to adverse environmental impacts and health issues of humans. The author further indicates that although the development takes place in the society, waste issues can lead to an environmental catastrophe. The current practice of C&D waste dumping in landfills results in environmental issues and natural resource depletion (Elgizawyet al., 2016). Similarly, Wang et al. (2010) specified, in the current global context, C&D waste creates numerous environmental issues, and as per Coelho and Brito (2012), C&D waste damage the ecological environment, consume the land resource, and leads to soil and water pollution. Correct management of C&D waste reduce the adverse environmental impacts, undesirable landfill site creation, and health risks related to construction waste (Lingard et al., 2000).According to Sapuay (2016), construction waste is heavy, bulky, and occasionally, toxic. Magalhaes et al. (2017) have pointed out that designing strategies should focus on the environmental impacts of the construction stages. For sustainable construction activities, policies and regulations are introduced by governments to reduce the negative impacts of C&D waste (Oluwole & Olaniran, 2013). Furthermore, Elgizawy et al. (2016) reports, once the building is demolished, waste get ended up in landfills, and this creates the need to consider alternative methods for waste recycling. The authors further explained that a recycling process and profitability aspects should be available to make a sustainable environment, where recycling products of C&D waste are provided with a good market. The government involvement is necessary to provide incentives and create new regulations. As stated by Zaman (2015), to address the critical waste issue in the society, zero waste is an idealistic concept, which is an ambitious goal to handle waste.

4. ZERO WASTE CONCEPT

Zero Waste is defined as the 'redesigning of resources to reduce the harmful impacts to the environment through the emissions and to minimise resource wastage through a whole system approach' (Curran &

Williams, 2012). Critical innovations have been taking place in the development history of waste management (Zaman & Lehmann, 2011). Figure 1 illustrates the historical development of waste management.

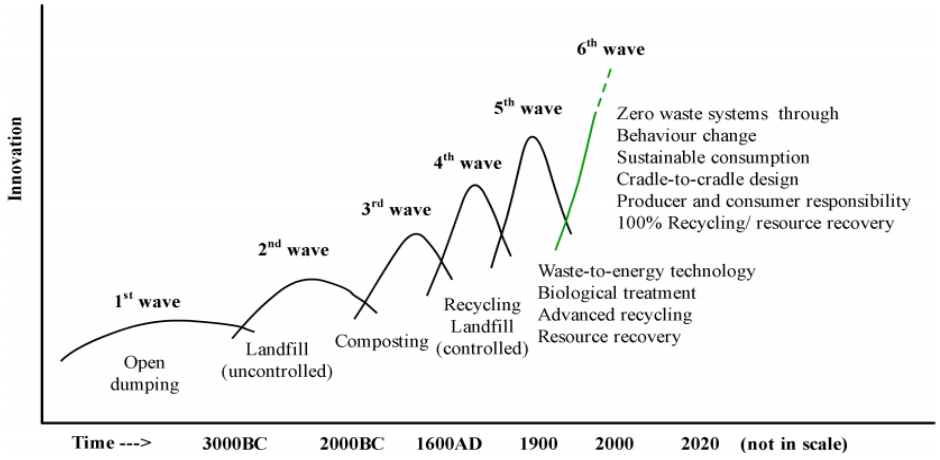

Figure 1: Historical development of waste management

Source: Zaman and Lehmann (2011)

According to Curran and Williams (2012), Zero waste concept is a unifying concept for a range of measures aimed at eliminating waste and challenging old ways of thinking. In a single framework, zero waste includes producer responsibility, eco-design, waste reduction, reuse, and recycle (Murray, 2002). Zaman (2014) defines zero waste management as the combination of waste management philosophies and integrated design. Moreover, Curran and Williams (2012) mentioned that zero waste concept could be implemented by eliminating waste at the source and throughout the supply chain, and encouraging waste diversion from incineration and landfills.

4.1. THE IMPORTANCE OF ZERO WASTE AND ITS APPLICATION TO THE CONSTRUCTION INDUSTRY

In the recent years, waste minimisation in the construction industry has drawn attention with the understanding of the waste minimisation benefits, cost-saving benefits, and environmental issues due to C&D waste (Osmani, 2012). Thus, to protect the environment and to conserve the natural resources, waste management in the construction industry is needed as it helps to reduce cost and the adverse waste disposal impacts (Akinade et al., 2018).

According to Zaman (2015), none of the articles published from 1995 to 2014 has focussed on the C&D waste documentation for zero waste. The implementation of Zero waste concept helps to achieve the optimum use of natural resources and reduce environmental issues (Zaman, 2014). According to Curran and Williams (2012), with the waste elimination through zero-waste concept, pollution issues affecting the ecosystem can be sorted, and the optimum use of raw materials and the use of renewable sources will bring the sustainability in the construction industry. Osmani (2012) reports that zero waste achievement is a highly challenging target for the construction industry. The author has further elaborated, in order to bring the construction industry closer to the Zero waste, waste reduction at source and material, and component reuse and recycle can be performed. When the construction industry focuses on waste minimisation, construction material flows through a closed loop system to preserve natural resources and to reduce waste landfilling (Akinade et al., 2018). As stated by Kofoworola and Gheewala (2009), reduce, reuse, and recovery of construction waste helps to realise employment opportunities and cost savings. The authors have further explained that environmental protection and improvement in the quality of life is achievable via C&D waste management.

4.2. STRATEGIES TO ACHIEVE ZERO WASTE IN THE CONSTRUCTION INDUSTRY

For the C&D waste management in the construction industry, 3R (Reduce, Reuse, Recycle) concept is being practised (Nitivattananon and Borongan, 2007; Wang, 2015). According to Yuan et al. (2011), the 3R concept is comprised of waste management strategies to manage C&D waste. Tam and Tam (2006) have proposed strategies such aswaste reduction at source, reusing and recycling of waste, and landfilling for C&D waste management. Moreover, Baldwin et al. (2009) indicate that Waste Minimisation Design (WMD) is a

crucialstrategy for effective C&D waste management, while Bossink and Brouwers (1996) propose to manage C&D wastethrough strategies such aswaste prevention at the site and to consider environmental impacts from the designing stage. Client awareness, adhering to building regulations, and checking client demand can be other useful schemes in the construction industry (Pitt, Tucker and Riley, 2009).

According to Akinade et al. (2016), Building Information Modelling (BIM) tools can be applied along with platforms such as Revit, Micro station, Archi CAD, and Teklato manage C&D waste. Further, Ajayi et al. (2017) have stated that C&D waste can be managed through the use of minimisation and prevention strategies. Moreover, Ling and Nguyen (2013) have identified that training and supervision, management of subcontractors and workforce, material handling and control, procurement, communication, and documentation promotes C&D waste management. According to Curran and Williams (2012), to implement zero waste in the construction industry, strategies that can be followed are elaborated in Figure 2 along with the external influences and constraints. Out of the identified strategies, the authors have selected Eco design, Industrial Symbiosis, Closed loop supply chain management, Innovative technology, Product stewardship, Life cycle assessment, and Environmental Management System (EMS) as leading strategies to implement the zero waste concept.

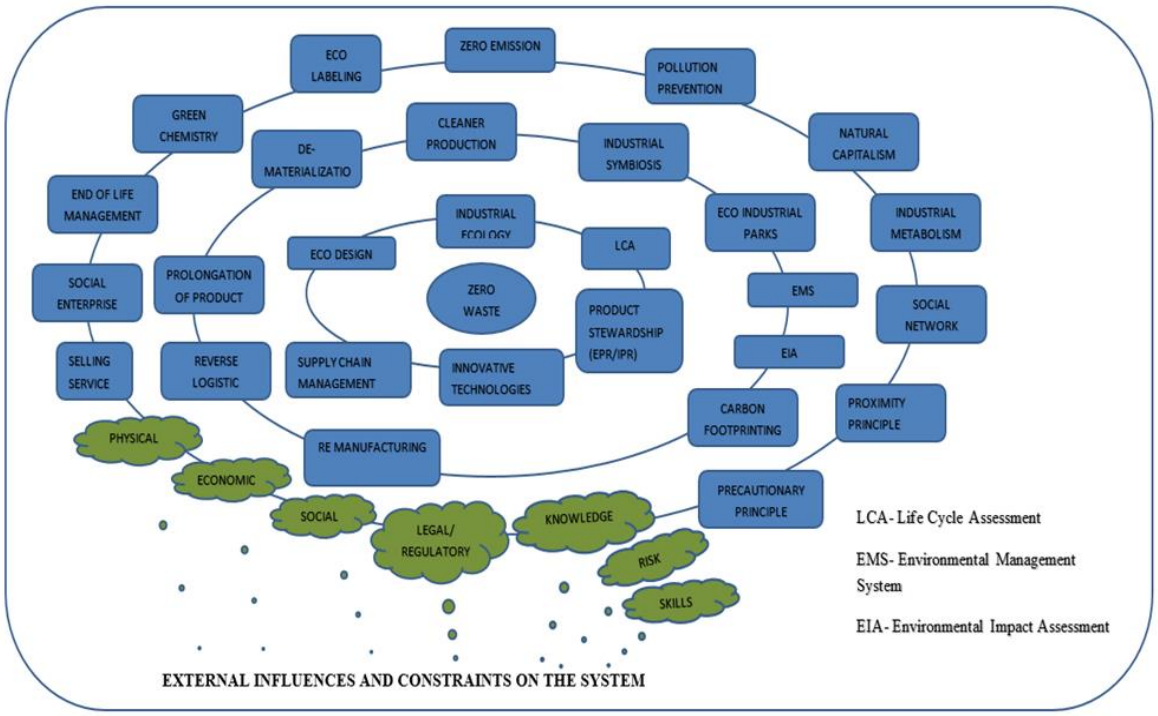

Figure 2: Zero Waste System to Achieve Zero Waste

Source: Curran and Williams (2012)

4.3. ENABLERS TO ACHIEVE ZERO WASTE IN THE CONSTRUCTION INDUSTRY

Appreciating the current possibilities or enablers in the construction industry is important to implement the zero waste concept effectively. According to the key literature reviewed, various enablers can be encountered. Legislation and policy, awareness and understanding, manufacture of construction products, designing and operating buildings, business, recovery of materials and products, and economics were identified as some enablers in the construction industry for waste management. Similarly, Zaman (2013) explained that social, economic, and environmental enablers could facilitate waste management in the construction industry. Further to authors, personal behaviour, local waste management practice, and consumption and generation of waste can be identified as the critical social enablers, while the resource value of waste, economic benefit from waste treatment facilities, and landfill tax are the economic enablers. As Zaman (2013) further elaborated, main enablers such as global climate change, the environmental movement, and awareness can also assist to manage C&D waste. Osmani (2011) have also identified that environmental, legislative, economic, and business enablers can reduce the waste in construction industry. Geo-administrative, socio-cultural, management, economic, environmental, organisational, and policy are the additional enablers identified for the implementation of zero waste concept (Zaman, 2014).

However, several gaps can be existed in the current procedures that need to be enhanced for the effective implementation of zero waste concepts. The barriers encountered in research projects in key literature are described in section 4.4.

4.4. BARRIERS TO ACHIEVE ZERO WASTE IN THE CONSTRUCTION INDUSTRY

Zou et al. (2013) discussed some barriers to manage C&D waste; i.e., lack of knowledge about what can be recycled or recycling opportunities, contamination of recyclables due to lack of separation or lack of space for separation, absence of markets for the recycled materials, technological barriers in terms of conversion of waste materials to useful ends, cost of recycling processes making products more expensive than that from virgin materials, and failure to incorporate design for deconstruction into the building process. Besides, alternatives to recycling are less costly; i.e., landfill gate prices are too low, the government policy is not driving recycling, lack of confidence in recycled materials, lack of communication and industry infrastructure, a dearth of knowledge across industry, and low value/low volume products being landfilled rather than stored for recycling. Further, Guerrero et al. (2017) identified obstacles such as lack of time to develop plans for waste reduction, deficiency of environmental regulations, and lack of available information regarding the requirements of environmental norms.

Accordingly, various strategies, enablers and barriers for implementing zero waste concept in construction industry were identified by reviewing key literature. The key findings were proposed for the next step of the research which is presented subsequently.

5. CONCEPTUAL FRAMEWORK

The major findings derived through key literature are visualised in the developed framework. The major types of C&D waste, causes of waste generation, its impact and most importantly, the strategies, enablers and barriers of implementing zero waste concept were highlighted in the framework. According to the comprehensive literature findings, major types of C&D waste may include cement, timber, brick, concrete, aluminium, tile, steel, plastic, polythene, paper, and cardboard. Figure 3 presents the conceptual framework developed as the main implication of this research paper.

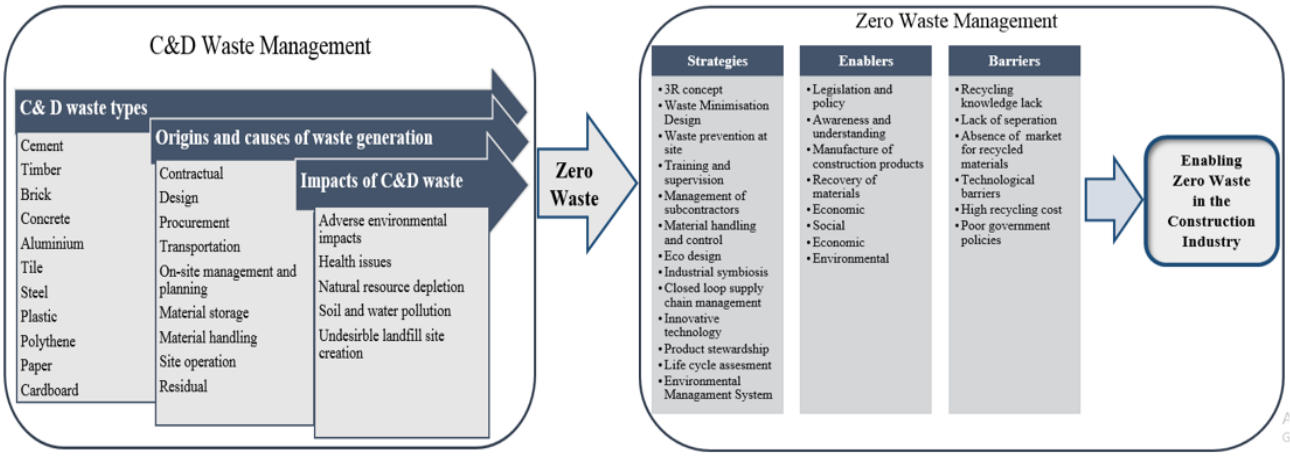

Figure 3: Conceptual Framework for Enabling Zero Waste in Construction

6. CONCLUSIONS

The construction industry, being one of the major economic contributors to the construction activities, generates a considerable amount of C&D waste, which ultimately ends up in the landfills. Therefore, to eliminate the C&D waste, this paper focused on the importance of the zero waste concept to the construction industry and the enablers to implementing zero waste in this industry. The paper discussed common types of C&D waste and the causes for originating waste in construction projects. Adverse environmental impacts, health issues, natural resource depletion, and pollutions in soil and water were identified as some negative impacts of improper C&D waste management. The zero waste concept was identified as a whole system approach to manage issues related with C&D, within which, elimination of waste takes place. Suitable

strategies, enablers, and barriers to implementing zero waste in the construction industry were identified, and finally, a conceptual framework was developed to enable zero waste concept in this trade. Thus, this paper motivates future research on the application of zero waste concept to the construction industry.

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