Towards the Adoption of Zero Waste Concept in the Construction Industry : A Review of Existing Strategies

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Abstract
The construction industry, being the largest industry, generates massive quantities of Construction and Demolition (C&D) waste. Generation of C&D waste leads to issues related to environmental pollution, adverse health issues, economic issues, social issues, and undesirable landfill creations. Strategies such as the 3R concept (Reduce, Reuse, Recycle), and waste hierarchy are followed in the construction industry for C&D waste management. Although such strategies are applied to manage the C&D waste, C&D waste management is still in a primary stage. In order to eliminate C&D waste, the Zero waste concept emerged as a potential solution. Zero waste means the elimination of waste through redesigning the product lifecycle. Strategies such as eco-design, industrial symbiosis, closed-loop supply chain management, innovative technology, product stewardship, life-cycle assessment, and environmental management system (EMS) are employed to implement the zero waste concept in the construction industry. Although adopting zero waste concept in the construction industry has several benefits, only limited studies could be found on zero waste management in the construction industry. Therefore, this paper aims to review the available strategies to implement zero waste concept in the construction industry by critically reviewing the secondary data on waste management studies performed in the construction industry.

Keywords :
Construction Industry, Construction and Demolition Waste, Zero Waste, Strategies

1.0. Introduction

The construction industry is considered a key economic driver in an economy with its considerable contribution to the gross national product along with employment and business opportunities (Sapuay 2016). However, the construction industry is also one of the largest polluters and faces the challenges regarding the reducing of construction waste generation (Banihashemi et al. 2018; Elgizawy et al.2016). As defined by Kofoworola and Gheewala (2008), Construction and Demolition (C&D) waste mean the waste generated through new construction, demolition, and renovation activities of structures and buildings. C&D waste comprise of concrete, bricks, tiles, ceramics, and gypsum-based materials, wood, glass, plastic, electrical wiring, asphalt, tar and tarred products, metals soil and dredged soil, insulation materials, mixed C&D, and hazardous components (Elgizawy et al. 2016, Ghosh and Ghosh 2016; Hsiao et al. 2002). Although many researchers have attempted to manage C&D waste since the 1980s, still, it remains in a primary stage (Hao et al. 2007).

As depicted in literature, the lack of interest of contractors, poor knowledge in the designing stage, use of low-quality products and lack of expertise in material handling, and issues related to the delivery of materials has led to the generation of C&D waste (Kofoworola and Gheewala 2008). Poor C&D waste management has led to environmental impacts, health issues, land depletion, soil and water pollution, and economic impacts (Coelho and Brito 2012; Elgizawy et al. 2016; Lingard et al. 2000; Nitivattananon and Borongan 2007; Wahi et al. 2016; Wang et al. 2010; Yeheyis et al. 2013). In order to manage the C&D waste, various strategies, i.e., 3R (Reduce, Reuse, Recycle), waste hierarchy, client awareness, and zero waste concept are being followed (Ling and Nguyen 2013; Nitivattananon and Borongan, 2007; Zaman 2015). As Zaman (2015) mentioned, the Zero waste is a perfectionistic concept to address the critical waste issue in the society.

By challenging the traditional waste management method, zero waste concept converts waste into useful resources (Curran and Williams 2012; Ksiazek et al. 2016; Pietzsch et al. 2017). Further, Curran and Williams (2012) define Zero Waste as the redesigning of resources to reduce the harmful impacts to the environment through the emissions and to minimize resource wastage through a whole system approach. Thus, the implementation of zero waste concept offers benefits such as the optimum use of natural resources, reduction in environmental issues, improvement in the quality of life, and the use of renewable sources (Curran and Williams 2012; Kofoworola and Gheewala 2009; Osmani 2012; Zaman 2014). Strategies, for instance, eco-design, industrial symbiosis, innovative technology, product stewardship, life-cycle assessment, and environmental management system could be followed to implement the zero waste concept (Curran and Williams 2012; Song et al. 2015). Thus, the paper aims to review available strategies to implement zero waste concept in the construction industry.

2.0. Research Method

A literature review helps to identify the knowledge gap (Webster and Watson 2002); hence, a systematic literature review is performed as the initial research process. Here, the required information is gathered by referring to journal articles, books, published and unpublished bibliographies, conference proceedings, industry reports, and documents that are specifically related to the construction industry, C&D waste, zero waste, and zero waste strategies.

3.0. 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). Different authors have given different definitions for C&D waste and Table 1 shows the different definitions of C&D waste.

Table 1 : C&D waste definitions

Source	**Definition**
Hsiao et al. (2002)	All wastes generated in construction works
Wang et al. (2014)	Waste of valuable natural resources.
Yuan and Shen (2011)	Solid waste generated in the construction sector is defined as the C&D waste.
Shen et al. (2004)	Construction wastes are mixtures of inert and organic materials arising from all construction related activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork and building renovation along all stages in implementing a construction project.
Christensen and Andersen (2011)	Waste generated during the building, repair, remodeling or removal of constructions
Ghosh and Ghosh (2016)	Waste arising from the construction, repair, maintenance and demolition of buildings, structures and roadways
Kofoworola and Gheewala (2008)	The waste produced during new construction, renovation, and demolition of buildings and structures
Fatta et al. (2003)	The waste generated from various activities such as clearing of sites, and the building of new structures or infrastructure
Hsiao et al. (2002)	Construction waste is defined as legal and illegal construction activities encompassing new construction, addition, renovation, rebuilding, and repair as well as the associated demolition. Demolition waste is defined as legal reported demolition, demolition of structures under government requisition, demolition of structures destroyed by natural force, demolition of illegal structures, and illegal demolition.
Statistics Canada (2003)	Waste materials from the construction and demolition of roads, bridges and buildings

Osmani (2012) stated that attention is paid to waste minimization in the construction industry to enjoy the cost-saving benefits and overcome the environmental issues. Massive quantities of waste generate, starting from the raw material extraction up to the demolition and waste disposal, and the heavy use of raw materials for the construction industry results in unsustainability of the industry (Elgizawy et al. 2016). A considerable amount of C&D waste generates due to the rapid development in the construction industry (Osmani et al. 2008), and the 3R (Reduce, Reuse, Recycle) concept is being practiced to manage C&D waste management (Nitivattananon and Borongan 2007; Wang 2015). Ling and Nguyen (2013) identified training and supervision, management of subcontractors and workforce, material handling and control, procurement, communication, and documentation promotes C&D waste management.

3.1. C&D Waste Generation in Construction Industry

Based on how C&D waste is defined in each country, the amount of C&D waste generated vary among states (Kofoworola and Gheewala 2008). According to Elgizawy et al. (2016), most countries face real threats due to the large quantities of C&D waste generation, and developing countries pay high attention to C&D waste management (Yuan and Shen 2011). In Asian countries, C&D waste management is difficult as they are heavy, bulky, and a majority is unsuitable for disposal through composting or incineration (Nitivattananon and Borongan, 2007; Sapuay 2016).

3.1.1. C&D Waste Management in Developing Countries

The regional and national policies and laws and regulations available in Asia are inadequate for C&D waste management (Nitivattananon and Borongan 2007). In Indonesia, it is identified the involvement of stakeholders such as clients, suppliers, construction managers, foremen, and laborers are necessary for waste minimization (Nitivattananon and Borongan 2007). Similarly, Malaysia produces a large amount of C&D wastes due to the development of major infrastructure projects, commercial buildings, and housing programs (Begum et al. 2010), and the authors have stated a compelling necessity to reduce C&D waste in the Malaysian construction industry. Moreover, Nitivattananon and Borongan (2007) report countries such as China, India, Sri Lanka, Thailand, and Vietnam lack specific C&D waste regulations to manage waste. However, as per Ghosh and Ghosh (2016), cities such as Chennai, Mumbai, Kolkata, and Bangalore in India have initiated C&D waste management through the introduction of C&D waste handling rules.

Although information related to C&D waste in the entire country is unavailable in Brazil, specific cities such as Sao Paulo, Rio de Janeiro, and Salvador generates an average of 0.49 kg per inhabitant/day (Nunes et al. 2006). The authors have stated that out of the generated C&D waste in Brazil, a larger portion is not recycled due to the lack of recycling centers. According to Kofoworola and Gheewala (2008), C&D waste is considered a part of Municipal Solid Waste in Thailand, and the rapid urbanization generates a huge amount of C&D waste. Subsequently, as per Ghosh and Ghosh (2016), nearly 600 million tons of C&D waste get made annually in China, and it is considered as 30 to 40 percent of the total urban waste. Authors have further stated that 500 to 600 tons of waste get generated through the construction of a 10,000 m^2 building, whereas the destruction of a 10,000 m^2 old building produces 7,000 to 12,000 tons of demolition waste.

3.1.2. C&D Waste Management in Developed Countries

Since 1994, Austria and Denmark have reported average recycling of 76% and 90% respectively (Agamuthu 2008). Christensen and Andersen (2011) have stated that in Denmark, building waste comprises of concrete, mortar, and tiles, which are nearly 62-93%, and during the renovation, almost 26% of waste generated from wood and other combustibles. In Germany, C&D waste management practices are being followed and starting in 2002, with proper legislative instruments and treatment methods, disposal of C&D waste into landfills was banned (Agamuthu 2008). Ghosh and Ghosh (2016) have further stated that in 2002 and 2003, C&D waste generated in Germany is 63.2% and 61.0% respectively. Italy, in 2001, disposed 67.1% of the generated waste to landfills, incinerated 8.7%, and recycled the remaining portion (Marchettini et al. 2007).

In Taiwan, C&D waste generation accounts for 1.2 to 1.9 million tons per year, and reuse 64% to 80% of waste (Lai et al. 2016). The C&D waste accounts for 33-65% in landfills of the USA, Canada, UK, and Hong Kong and they follow 3R initiatives within their countries (Agamuthu 2008). In the UK, more than 50% of the C&D waste is landfilled (Ghosh and Ghosh 2016). Here, 51.2% (27.4 million tons) of C&D waste is directly disposed to landfills, and 39.6% (21.2 million tons) exempted from licensed disposal and applied to land modeling of the construction projects (Lawson et al. 2001). Further, the authors have mentioned that 9.2% (5 million tons) of C&D waste produces graded products.

In the USA, C&D waste ranges from 20 to 30 kg/m^2, which is approximately 500 kg/person/year on a per capita basis (Peng et al. 1997). The authors have further stated that nearly 31.5 million construction waste is produced, and the demolition waste is almost equal to the double amount of the generated construction waste in the USA. According to Ghosh and Ghosh (2016), the USA produces 170 million tons of waste per year, from which, 48% is recovered. In the

USA, recycling the C&D waste is a challenging issue since the secondary market for recycled materials is still in an adolescent stage (Peng et al. 1997).

According to Yeheyis et al. (2013), C&D waste accounts for one-third of the solid waste stream in Canada, where nearly 9 million tons of C&D waste get generated, and 27% of the total municipal solid waste disposed to landfills are from the C&D waste. The authors have further stated that Canadian C&D waste recycling rate is low, and an integrated and comprehensive C&D waste management plan needs to be implemented within the country. The recycled or reused C&D waste in Canada is comparatively lower than other developed countries (Ghosh and Ghosh, 2016), and according to the findings, concrete is the largest C&D waste generated in the construction industry in Canada, which is nearly 52%.

The construction industry has developed in Greece over the past decades, and with the C&D waste generation, materials such as wires, glass, and frames of doors and windows are being reused while some quantities of waste ended up in landfills (Fatta et al. 2003). Out of 13,458 tons of Municipal Solid Waste (MSW) in Hong Kong, C&D waste accounts for a quarter of the MSW in 2011 (Ghosh and Ghosh 2016), and hence construction waste management policies are introduced to handle the C&D waste issue. Moreover, the authors highlighted that nearly 7890 tons of C&D waste was landfilled in 1999, and after introducing two off-site waste sorting facilities from the off-site Construction Waste Sorting (CWS) program, nearly 5.11 tons of C&D waste is handled in the two off-site CWS facilities during 2006 to 2012. Also, Nitivattananon and Borongan (2007) report that infrastructure projects in Hong Kong have caused a significant increase in C&D waste generation over the past decades. Australia generates nearly 5 million tons of C&D waste within a year (Nitivattananon and Borongan 2007) and C&D waste management practices are followed in Victoria, Queensland, South Australia, Western Australia, Tasmania, and Australian Capital Territory (Ghosh and Ghosh 2016). In the European Union (EU), C&D waste accounts for 855 million tons per year which are 33.3% of the total EU waste; and out of the generated C&D waste, nearly 75% of the waste gets landfilled (Ghosh and Ghosh 2016).

In order to manage the generated C&D waste in the construction industry, strategies such as 3R (Reduce, Reuse, Recycle), waste reduction at source, Waste Minimization Design (WMD), client awareness, use of Building Information Modelling (BIM) tools along with Revit, Archi CAD, training and supervision, material handling, and communication are used (Akinade et al. 2016; Baldwin et al. 2009; Bossink and Brouwers 1996; Ling and Nguyen 2013; Pitt et al. 2009; Nitivattananon and Borongan 2007). The strategy of Zero waste concept is identified as the correct solution to eliminate C&D waste in the construction industry (Song et al. 2015; Zaman 2015).

3.2. The Concept of Zero Waste

"Zero Waste" is an idealistic concept to address the critical waste issue in society. It is an ambitious goal to handle waste and is considered an innovative waste management approach (Zaman 2014, 2015). With the application of the zero waste concept, products are redesigned in a manner in which they can be reused, and the zero waste concept challenges the traditional waste management views (Curran and Williams 2012; Song et al. 2015). Furthermore, zero waste concept ensures waste is managed through reuse, recovery, or recycling in an eco-friendly manner (Zaman 2014).

Among the many articles on C&D waste management, none published from 1995 to 2014 focuses on the C&D waste documentation for zero waste (Zaman 2015). As per Osmani (2012), achievement of the zero waste target in the construction is highly challenging. However, with the maximum use of raw materials and renewable resource usage through the implementation of zero waste concept, the construction industry can achieve sustainability (Curran and Williams 2012). Thus, zero waste could be identified as the key strategy to eliminate C&D waste from the construction industry.

In a linear economy, recyclable materials are not directed into the production process, and it causes long-run issues from the perspective of sustainability (Curran and Williams 2012). Hence, authors have declared, zero waste can be implemented with the rejection of one-way linear method and using a circular closed-loop system. Elgizawy et al. (2016) have further elaborated that the cradle-to-cradle approach should be used for the efficient use of materials. Figure 1 presents the linear and circular resource flow.

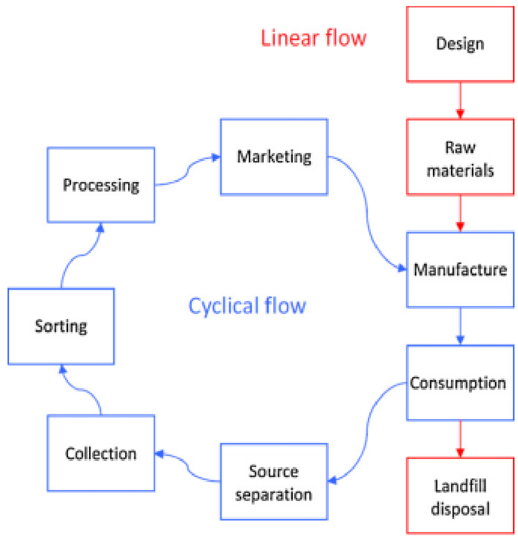

Figure 1 : Linear and circular resource flow
Source : Curran and Williams (2012)

Curran and Williams (2012) have defined zero waste as a whole-system approach that aims to 'eliminate' rather than 'manage' waste. Further, all discarded materials that are designed to become resources for others to use are also defined as zero waste (ZWIA 2015). Zaman and Lehmann (2011) defined zero waste as the recovery of all resources from waste materials, and the zero waste challenges the traditional waste management system within which, at the end of the product life, is considered as waste (Zaman 2014). The author states waste is transformed into a resource through zero waste and redirected to the production process holistic zero waste management systems. Further, the author explained zero waste management get created as a result of design integration and waste management philosophies. The implementation of zero waste promotes high recycling levels, valuation of resources that are generated from waste, prevention of waste, and changes in behaviors (Pietzsch et al. 2017). Table 2 shows the development of the zero waste concept over the past years.

Table 2. : Key milestones of zero waste concept development
Source : Zaman (2015)

Year	Country	Milestones/Events
1970	USA	The term "Zero Waste" was coined by Paul Palmer
1986	USA	The National Coalition against Mass Burn Incineration was formed
1988	USA	Seattle introduced the Pay-As-You-Throw (PAYT) system
1989	USA	The California Integrated Waste Management Act was passed to achieve 25% waste diversion from landfills by 1995 and 50% by 2000
1990	Sweden	Thomas Lindhqvist introduced "Extended Producer Responsibility"
1995	Australia	Canberra passed the "No Waste by 2010" bill
1997	New Zealand USA	• The Zero Waste New Zealand Trust was established • The California Resource Recovery Association (CRRA) organized conference on zero waste
1998	USA	Zero waste was included as guiding principles in North Carolina, Seattle, Washington, and DC

1999	USA	The CRRA organized zero waste conferences in San Francisco
2000	USA	The Global Alliance for Incinerator Alternatives were formed
2001	USA	Grass Roots Recycling Network published "A Citizen's Agenda for Zero Waste"
2002	New Zealand USA	• The book Cradle to Cradle was published • Zero Waste International Alliance was established • The first ZW summit was held in NEW Zealand
2004	Australia USA	• ZWIA gives a working definition for zero waste • GRRN adopts ZW business principles • Zero Waste SA was established in South Australia
2008	USA	The Sierra Club adopted a zero waste producer responsibility policy
2012	USA	• The documentary film Trashed premiered at the Cannes Film Festival • The Zero Waste Business Council was established in the USA

To remove the environmental threats caused as a result of human consumption and unsustainable behaviors, product design, and waste management principles are considered within the zero waste philosophy (Zaman 2014). The authors emphasized, to extend the lifecycle of the product in a zero waste product design, products are designed in a way they can either be reused or repaired. The authors also stated that pollution of the natural environment is avoided through the zero waste management process, as waste is recycled and recovered. Moreover, zero waste encourages the diversion of waste from incineration and landfills (Curran and Williams 2012). Figure 2 illustrates the historical development of waste management up to zero waste system.

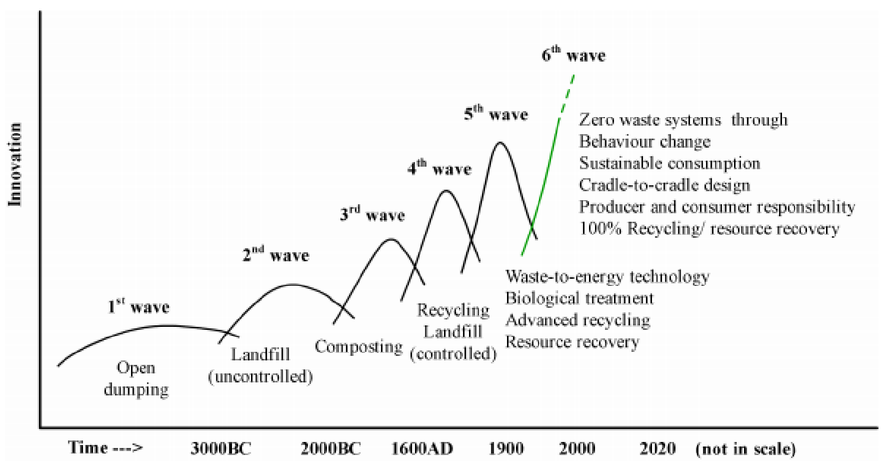

Figure 2 : Schematic waves of innovation management system
Source : Zaman and Lehmann (2011)

In the schematic waves of the innovative waste management system, open dumping is the first wave still practiced in low-income countries; uncontrolled landfills are considered as the second wave while composting is the third wave (Zaman and Lehmann 2011). The authors stated the fourth wave focuses on recycling and controlled landfill, whereas the fifth wave focuses on waste-to-energy technologies such as incineration, pyrolysis-gasification, and plasma arc. Finally, the sixth wave of innovation focuses on sustainable waste management system through zero waste, and include the recovery of resources from waste, sustainable resource consumption, and cradle-to-cradle closed-loop design systems.

3.3. Zero Waste Strategies

Effective strategies are a need for implementing the zero waste concept (Zaman 2014). Zero waste system comprises four levels, i.e., design, manufacturing, application, and recycling and disposal (Song et al. 2015). According to Curran and Williams (2012), different strategies can be followed to implement zero waste in the construction industry. 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 as the key strategies to implement the zero waste concept.

- **Industrial Symbiosis (IS)**

Industrial Symbiosis is identified as a part of industrial ecology concept (Curran and Williams 2012). Yazan et al. (2016) have stated that more attention is paid towards the waste reduction in the production economies. The authors further reported IS has forced to provide waste as a primary resource to other companies, which will ultimately reduce the adverse environmental impacts near industrial areas.

- **Life Cycle Assessment (LCA)**

Measurement of impacts throughout the entire life cycle, starting from the raw material extraction up to end disposal of the product helps to identify the environmental effects of the product, and also to have sustainable production and consumption patterns (Curran and Williams 2012).

- **Eco-Design**

Eco-design could be defined as, starting from the origin of the product, thinking about the entire life cycle and environmental impact reduction, throughout the product life (Vallet et al. 2015). As per Bhamra (2004), Eco-design is defined as the integration and balancing of the existing design practice considering cost, quality, and functionality. In order to manage ecological issues related to the types of C&D waste, the client and design team awareness is needed (Ball 2002). Also, sustainable construction techniques and materials are required for the eco-friendly construction industry (Torgal and Jalali 2012), and in the ecosystem, waste is designed out of the system to achieve real waste reduction (Curran and Williams 2012).

- **Closed-Loop Supply Chain Management**

According to Krikke et al. (2004), closed-loop supply chains comprise of reverse and forward supply chain. Authors elaborate that loops can be closed through reusing the whole product, components, or materials. Moreover, Morana and Seuring (2011) stated that closed-loop supply chain deals throughout the product lifecycle. The supply chain of the construction industry could be explained under four roles as focus on the impacts of the supply chain on on-site activities, focus on the supply chain and to reduce costs in logistics, lead-time, and inventory, focus on transferring activities from the site to earlier stages of the supply chain, and finally, focus on the integrated management and improvement of the supply chain and the site production (Vrijhoef and Koskela 2000).

- **Product Stewardship / Extended Producer Responsibility (EPR)**

Management of impacts of a product throughout the life cycle of the product until the disposal is identified as the product stewardship (Zaman and Lehmann 2011). Further, authors have elaborated, once the consumer stops using the product, the producer has to take back the product in product stewardship. According to Zaman and Lehmann (2011), EPR is also identified as a product stewardship principle and take-back principle. Authors have stated that in the innovative packaging and product design, EPR is a vital tool to reduce waste generation in the production process, and EPR takes responsibility for each action and work. EPR is a strategy used in the recycling process (Chavan 2014). Accordingly, through the EPR, the manufacturer is responsible for the entire lifecycle of the product, and the manufacturer is liable for the take-back, recycle, and final disposal. EPR model comprises of four responsibilities as informative, physical, financial, and liability (Manomaivibool 2008), and EPR is an important tool to reduce and avoid major waste volumes during the production process of the product (Lindhqvist 2000).

- **Environmental Management System (EMS)**

EMS helps to achieve environmental obligations and performance goals by identifying problems and solving the problem with the systematic management of environmental activities of the organization, and the plans, schedules, implementation, and monitoring of events take place to improve the environmental performance through EMS (Curran and Williams 2012).

4.0. Conclusion

C&D waste is a persuasive issue that needs to be addressed since the construction industry is considered a leading contributor to solid waste generation. C&D waste comprises of rubble, sand, cement, timber, plastic, brick, concrete, tile, aluminum, steel, paper, and cardboard. The generated C&D waste triggers health, environmental, and social and economic issues, and hence, strategies such as the 3R concept, WMD, waste reduction at source, waste hierarchy, and zero waste are being followed.

Zero waste concept is considered one of the idealistic methods to manage the generated C&D waste as a resource. In order to adopt zero waste concept, strategies such as eco-design, innovative technology, product stewardship, life cycle assessment, and industrial symbiosis are being followed. Development of a framework for adopting zero waste in the construction industry will be the final outcome of this research project.

5.0. Acknowledgement

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6.0.References

Agamuthu, P., Challenges in sustainable management of construction and demolition waste. *Waste Management & Research,* vol. 26, pp. 491-492, 2008.

Akinade , O. O. et al., Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment. *Journal of Cleaner Production*, vol. 180, pp. 375-385,2018.

Annual Report, *Annual Report 2017,* Colombo: Central Bank of Sri lanka,2017.

Ball , J., Can ISO 14000 and eco-labelling turn the construction industry green. *Building and Environment ,* vol. 37, pp.421-428,2002.

Banihashemi, S., Tabadkani, A. and Hosseini, M. R.,Integration of parametric design into modular coordination: A construction waste reduction workflow. *Automation in Construction*, vol. 88, pp. 1-12,2018.

Begum, R. A., Satari , S. K. and Pereira , . J. J., Waste Generation and Recycling: Comparison of Conventional and Industrialized Building Systems. *American Journal of Environmental Sciences,* vol. 6, no.4, pp. 383-388,2010.

Begum, R., Siwar, C., Pereira, . J.and Jaafa, A., A benefit-cost analysis on the economic feasibility of construction waste minimization: The case of Malaysia. *Resource Conservation and Recycling,* vol. 48, pp. 86-98,2006.

Bhamra , T., Eco design: the search for new strategies in product development. *Journal of Engineering Manufacture,* vol. 218, no.5, pp. 557-556,2004.

Bossink, B.A.G. and Brouwers, H.J.H.,Construction Waste: Quantification and Source Evaluation. *Journal of Construction Engineering and Management*, pp.55–60,1996.

Burlakovs, J. et al., On the way to 'zero waste' management: Recovery potential of elements, including rare earth elements, from fine fraction of waste. *Journal of Cleaner Production,* vol. 186, pp. 81-90,2018.

Chavan, R., Environmental sustainability through textile recycling. *Textile Science & Engineering, vol.S2*, pp.1-5,2014.

Christensen, T. H., and Andersen, L., Construction and Demolition Waste. In: T. H. Christensen, ed. *Solid Waste Technology & Management.* s.l.:Blackwell Publishing Ltd, pp. 104-109,2011.

Coelho, A. and Brito, J. d., Influence of construction and demolition waste management on the environmental impact of buildings. *Waste Management*, vol. 32, pp. 532–541,2012.

Curran, T., and Williams, I., A zero waste vision for industrial networks in Europe. *Journal of Hazardous Materials*, pp.3–7. doi:10.1016/j.jhazmat.2011.07.122,2012.

Ding, Z. et al.,A system dynamics-based environmental benefit assessment model of construction waste reduction management at the design and construction stages. *Journal of Cleaner Production*, vol. 176, pp.676–692,2018.

Elgizawy, S., Haggar, S., and Nassar, K., Slum development using zero waste concepts: construction waste case study. *International Conference on Sustainable Design, Engineering and Construction*, vol. *145*, pp. 1306-1313,2016.

Fatta, D. et al.,Generation and management of construction and demolition waste in Greece - an existing challenge. *Resources, Conservation and Recycling,* vol. 40, pp. 81-91,2003.

Ghosh, S. K. and Ghosh, S. K., Construction and Demolition Waste. In: *Sustainable Solid Waste Management* . New York: ASCE, pp. 511-547,2016.

Hao, J., Hills , M. and Huang, T., A simulation model using system dynamic method for construction and demolition waste management in Hong Kong. *Construction Innovation*, vol.7, no.1, pp. 7-21,2007.

Hsiao , T., Huang, Y., Yu , Y. and Wernick, I., Modeling materials flow of waste concrete from construction and demolition wastes in Taiwan. *Resources Policy,* vol 28, pp. 39-47,2002.

Kofoworola, O., and Gheewala, S., Estimation of construction waste generation and management in Thailand. *Waste Management,* vol.29, pp.731–738. doi:10.1016/j.wasman.2008.07.004,2009.

Krikke, H., Ieke Le Blanc, L. L. and Velde, S. V. D., Product Modularity and the Design of Closed-Loop Supply Chains. *California Management Review*, vol. 46, no.2, pp. 23-39,2004.

Ksiazek, S., Pierpaoli, M., Kulbat, E., and Luczkiewicz, A. A modern solid waste management strategy – the generation of new by-products. *Waste Management,* vol.49, pp.516-529,2016.

Lai, Y.-Y.et al., Management and Recycling of Construction Waste in Taiwan. *Procedia Environmental Sciences*, vol. 35, pp. 723 – 730,2016.

Lawson , N. et al., Recycling construction and demolition wastes – a UK perspective. *Environmental Management and Health,* vol.12, no.2, pp. 146-157,2001.

Lindhqvist, T., Extended producer responsibility in cleaner production: policy principle to promote environmental improvements of product systems. *IIIEE,* Lund University,2000.

Lingard, H., Graham, P. and Smithers, . G., Employee perceptions of the solid waste management system operating in a large Australian contracting organization: implications for company policy implementation. *Construction Management and Economics*, vol. 18, pp. 383–393,2000.

Ling, F.Y.Y., and Nguyen, D.S.A., Strategies for construction waste management in Ho Chi Minh City, Vietnam. *Built Environment Project and Asset Management*,vol.3, no.1, pp.141–156. Available at: http://www.emeraldinsight.com/doi/10.1108/BEPAM-08-2012-0045,2013.

Ling, Y. and Leo, K., Reusing timber formwork: importance of workmen's efficiency and attitude. *Building and Environment,* vol. 35, no.2, pp. 135-143,2000.

Manomaivibool, P., Extended producer responsibility in East Asia: Approaches and lessons learnt from the management of waste electrical and electronic equipment. *5th International Conference on East Asian Studies*, pp. 267-286, Osaka: Asian Research Institute, Osaka University of Economics and Law,2008.

Marchettini , N., Ridolfi, R. and Rustici, M., An environmental analysis for comparing waste management options and strategies. *Waste Management,* vol. 27, pp. 562-571,2007.

Menegaki, M., and Damigos, D., A review on current situation and challenges of construction and demolition waste management. *Current Opinion in Green and Sustainable Chemistry ,* vol.13, pp.8-15,2018.

Morana, R. and Seuring, S., A Three Level Framework for Closed-Loop Supply Chain Management—Linking Society, Chain and Actor Level. *Sustainability,* vol. 3, pp. 678-691,2011.

Nitivattananon , V. and Borongan , . G., *Construction and Demolition Waste Management : Current Practices in Asia.* Chennai, s.n., pp. 97-104,2007.

Nunes , K., Mahler , C., Valle, R. and Neves, C., Evaluation of investments in recycling centres for construction and demolition wastes in Brazilian municipalities. *Waste Management,* pp. 1-10,2006.

Osmani , M., Construction waste minimization in the UK: current pressures for change and approaches. *Procedia - Social and Behavioral Sciences,* vol.40, pp.37 – 40. doi: 10.1016/j.sbspro.2012.03.158,2012.

Osmani , M., Glass, J., and Price, A., Architects' perspectives on construction waste reduction by design. *Waste Management,* vol.*28*, pp.1147–1158. doi:10.1016/j.wasman.2007.05.01,2008.

Osmani, M., Glass, J. and Price, A., Architect and contractor attitudes to waste minimisation. s.l., *Thomas Telford Publishing*, pp. 65-72,2006.

Peng , C.-L., Scorpio, D. E. and Kibert , C. J., Strategies for successful construction and demolition waste recycling operations. *Construction Management and Economics,* vol.15, no.1, pp. 49-58,1997.

Pietzsch, N., Ribeiro, J., and Medeiros, J., Benefits, challenges and critical factors of success for Zero Waste:A systematic literature review. *Waste Management*, pp.1-30,2017.

Pitt, M., Tucker, M., and Riley, M. J.L., Article information : *Construction Innovation*, vol.9, no.2, pp.201–224,2009.

Sapuay, S., Construction Waste – Potentials and Constraints. *Procedia Environmental Sciences,* vol.*35*, pp.714 – 722,2016.

Shen, L., Tam, V., Tam, C. and Drew, D., Mapping approach for examining waste management on construction sites. *Journal of Construction Engineering and Management,* vol.130, no.4, pp. 472-481,2004.

Shen, L. and Tam, V. W. Y., Implementation of environmental management in the Hong Kong construction industry. *International Journal of Project Management,* vol. 20, pp. 535-543,2002.

Song, Q., Li, J., and Zeng, X., Minimizing the increasing solid waste through zero waste strategy. *Journal of Cleaner Production*, vol.104, pp.199-210,2015.

Statistics Canada, *Waste Management Industry Survey Business and Government Sectors 2000,* Canada: Authority of the Minister responsible for Statistics Canada,2003.

Torgal, F. P. and Jalali , S.,Earth construction: Lessons from the past for future eco-efficient construction. *Construction and Building Materials,* vol. 29, pp. 512–519,2012.

Vallet, F., Eynard, B. and Millet, D., Proposal of an eco-design framework based on a design education perspective. *21st CIRP Conference on Life Cycle Engineering,* vol. 15, pp. 349 – 354,2015.

Vrijhoef, R. and Koskela, L., The four roles of supply chain management in construction. *European Journal of Purchasing & Supply Management,* vol. 6, pp. 169-178,2000.

Wahi, N., Joseph, C., Tawie, R. and Ikau, R., Critical Review on Construction Waste Control Practices: Legislative and Waste Management Perspective*. Procedia - Social and Behavioural Sciences*, vol. 224, pp. 276 – 283,2016.

Wang , J., Li, Z., and Tam, V. Identifying best design strategies for construction waste minimization. *Journal of Cleaner Production,* vol.92, pp.237-247. doi:10.1016/j.jclepro.2014.12.076,2015.

Wang, J., Li , . Z. and Tam, V. W., Critical factors in effective construction waste minimization at the design stage: A Shenzhen case study, China. Resources, *Conservation and Recycling*, vol. 82, pp. 1–7,2014.

Wang, J., Yuan, H., Kang, X., and Lu, W.,Critical success factors for on-site sorting of construction waste: A china study. *Resources, Conservation and Recycling*, 54, pp.931–936. doi:10.1016/j.resconrec.2010.01.012,2010.

Wang, J.-Y., Kang, X.-P., and Tam, V.-Y. An investigation of construction wastes: an empirical study in Shenzhen. *Journal of Engineering, Design and Technology*,vol.6,no.3,pp.227-236. doi: 10.1108/17260530810918252,2008.

Yazan, D. M., Romano, V. A. and Albino, . V., The design of industrial symbiosis: an inputeoutput approach. *Journal of Cleaner Production,* vol.129, pp. 537-547,2016.

Yeheyis, M. et al., An overview of construction and demolition waste management in Canada: a lifecycle analysis approach to sustainability. *Clean Technologies and Environmental Policy,* vol. 15, pp. 81-91,2013.

Yuan, H., Barriers and countermeasures for managing construction and demolition waste: A case of Shenzhen in China. *Journal of Cleaner Production,* vol.157, pp.84-93,2017.

Yuan , H. and Shen, L., Trend of the research on construction and demolition waste management. *Waste Management,* vol 31, pp. 670-679,2011.

Zaman, A., A comprehensive review of the development of zero waste management: lessons learned and guidelines. *Journal of Cleaner Production,* vol.91, pp.12-25. doi:https://doi.org/10.1016/j.jclepro.2014.12.013,2015.

Zaman, A., Measuring waste management performance using the 'Zero Waste Index': the case of Adelaide, Australia. *Journal of Cleaner Production,* vol.66, pp.407-419,2014.

Zaman, A. and Lehmann, S., Development of demand forecasting tool for natural resources recouping from municipal solid waste. *Waste Management & Research,* vol.31, pp.17-25,2013.

Zaman, A. U. and Lehmann, S., Challenges and Opportunities in Transforming a City into a "Zero Waste City". *Challenges ,* vol. 2, pp. 73-93,2011.

ZWIA, *Zero Waste International Alliance (ZWIA)..* [Online] Available at: http://zwia.org/standards/zw-definition. [Accessed 26 08 2015],2015.

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