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REVIEW

Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy

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Abstract Construction and demolition (C&D) waste is a pressing issue not only in Malaysia, but it is also a worldwide concern including the developed countries as well. C&D waste should be managed throughout the construction cycle. The concept of circular economy (CE) is an emerging notion that has the potential to be utilized as waste minimization approach. This paper aims to assess the potentials of incorporating the CE concept as an approach to minimizing C&D wastes, by developing a CE-based theoretical framework for C&D waste management in Malaysia. In line with this objective, a systematic review has been conducted to determine how CE can be operationalised as a strategy to minimize wastes, while considering it as a key factor for mitigating the environmental impacts. Based on the literature review, a CE-based theoretical framework has been proposed using Malaysia as a case study. The framework has been developed following a three-layer approach namely micro-, meso-, and macro-levels. Waste minimization strategies have been identified for each level taking into account the main stages in the construction industry, i.e., planning, designing, procurement, construction, and demolition. The different stakeholders involved at each stage and their interactions in the stages have also been identified.

Keywords Circular economy · Systematic review · C&D waste minimization · Theoretical framework · Malaysia

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Introduction

The world's urban population is expected to surpass 6 billion by 2045, with cities in Asia and Africa registering the largest growth [1]. The growing urban population has become a catalyst for economic growth, making substantial impact particularly on the construction industry. The increasing amount of construction and demolition (C&D) wastes is a pressing issue in many countries due to rapid economic development and growing populations. For example, in India, 14.5 million tonnes of C&D wastes are being generated annually. This puts a lot of pressure on the already severely limited spaces at landfills [2]. Similarly, 26,000 tonnes of C&D wastes were generated daily in Malaysia [3]. Furthermore, 40 % of industrial wastes in the world come from the construction industry [4]. Hence, the rapid growth of construction activities has influenced the waste generations and pressurized the already over-stretched landfills, especially in urban areas [5]. The inefficient waste management process has led to too much waste being directed to landfills, including the waste that could be recycled [6]. Evaluating the amount of waste generated and developing strategies to minimize waste are, thus, imperative to achieve a sustainable future.

C&D wastes are constantly being generated throughout the construction cycle. C&D wastes are generated even at the planning and design stages due to lack of considerations in minimizing wastes. The construction stage contributes to the largest portion of wastes when the construction activities are not efficiently managed [7, 8].

The large volume of generated wastes is partly due to how the construction industry continues to encourage the linear-based practices of "take-make-consume-dispose". Also, the variety of organizations involved [e.g., project developers, contractors, subcontractors, consultants, general workers, government department staff, the general public, and related non-governmental organizations (NGOs)] have made it difficult to ensure that waste management becomes a priority [9]. Many researchers have asserted on how waste generations from construction activities have substantial impacts on the environment [7, 10–12], and a number of authors agreed that the linear economy needs to be transformed toward a circular approach to achieve a sustainable future [13–15]. However, most of the studies present in the literature, such as Coelho and de Brito [16] and de Guzman Baez et al. [17], have focused on the waste minimization strategies after the waste had been generated. There are also studies highlighting the importance of selecting suitable materials in reducing wastes [18].

In this paper, we introduce the concept of circular economy (CE) as an approach for waste minimization throughout the overall construction cycle. The concept of CE is a prominent example approach to sustainably manage the resources as well as minimize wastes; hence, this concept can be considered as a waste minimization strategy, which can be incorporated throughout the construction cycle [19]. In particular, in this study, the suitability of CE as waste minimization strategy is applied in the context of Malaysian construction industry.

After the introduction, an explanation on the method used in conducting this study will be provided. Next, a review on the current strategies in C&D waste management will be presented, including the definition of C&D waste and the hierarchy of construction waste management. This is based on the 3R principles of reduce, reuse, and recycle, but the elements of reimagine and redesign will also be explored to ensure the efficiencies of waste minimization. Studies that focused on C&D waste minimization strategies were specifically analyzed in this section. After that, the utilization of CE in C&D waste management will be elaborated in detail. Finally, based on the literature review conducted, a theoretical framework for C&D waste management using the concept of CE is developed.

Methodology

A systematic review is an essential feature of any research activity. It provides the foundation for enhancing the knowledge of the research area by summarizing the previous studies and looking for a gap in prior published studies [20, 21]. Petticrew [20] emphasized that it does not intend to be just a large literature review effort, but aims to answer a specific question, to reduce bias in the selection and inclusion of studies, to appraise the quality of the included studies, and to summarize them objectively. Creswell [22] argues that the main objective of carrying out a literature review is to expose the researcher to the previous studies and serve as a basis for future studies. The research questions that guided this review were: what are the main principles of circular economy and how those principles can be used as waste minimization strategy?

A systematic review is conducted using large databases that contain a large set of related publications along with effective search tools, which allow relevant keywords to be used. After an initial run of results, a set of specific high impact journals related to the topic were recognized. Literature was taken from the databases gathered from highly recognized publishers including *ABI Inform Global* (*Proquest Direct*), *ScienceDirect* (*Elsevier*), *Emerald Insight, Scopus, Springer Link, and Wiley Online Library* (*Wiley*). The limitation of search tools in databases was that only one keyword could be used at a time which is time-consuming. Some other keywords were selected to reflect the selected topic as some keywords are used differently between countries, for example, some countries used the term construction waste and other countries used the term construction debris. Varieties of folder with an appropriate name were created initially. Then, after several refinements throughout all folders, 55 papers were selected to be included in the citation manager. Table 1 summarizes the method used in conducting the systematic review and Fig. 1 illustrates the sequence adopted in this study in finalizing the systematic review.

A review on the current strategies in construction and demolition waste management

Definition of construction and demolition (C&D) waste

C&D waste is the waste generated throughout all the construction cycle. Skoyles and Skoyles [23] define this waste as a material "which needed to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project due to damage, excess or non-use or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process". Ekanayake and Ofori [24] further classified C&D waste into three categories: material, workforce, and machinery; material is the most critical category of waste generation. Also, Poon [25] defines C&D waste as a combination of inert and non-inert materials. The inert

Table 1 Summary of research method

Area	Relevant books, peer-reviewed papers, government documentation and reports published that are related to the area of C&D waste management and frequently cited in the literature. Dissertation, unpublished publications, and conference proceedings were excluded
Period of analysis	2000–2015 (15 years)
Databases	ABI Inform Global (Proquest Direct), ScienceDirect (Elsevier), Emerald Insight, Scopus, SpringerLink, and Wiley Online Library (Wiley)
Keyword used	Circular economy (CE), definition of CE, principles of CE, close-loop system, CE and construction waste, sustainable construction, construction waste management, construction and demolition waste
Targeted journals	Journal of Waste Management, Waste Management and Research, Material Cycles and Waste Management, Building Research and Information, Construction Innovation, Construction Engineering and Management, Resources, Conservation and Recycling, Industrial Ecology, Clean Technologies and Environmental Policy, Cleaner Production, Environmental Management, International Journal of Life Cycle Assessment, Environmental Policy and Planning, Environmental Impact Assessment Review, Energy and Environmental Science, Chinese Journal of Population Resources and Environment
Selective methods	Theoretical information about CE is the main criterion in selecting the suitable papers. The introduction of selected papers was read to initially identify the definition and principles of CE. Additionally, the conclusion section of selected papers was also reviewed to enhance the fundamental knowledge of CE. Furthermore, the scenarios of construction waste management were studied to imitate on accomplishing the sustainable construction
Total number of selected articles	55

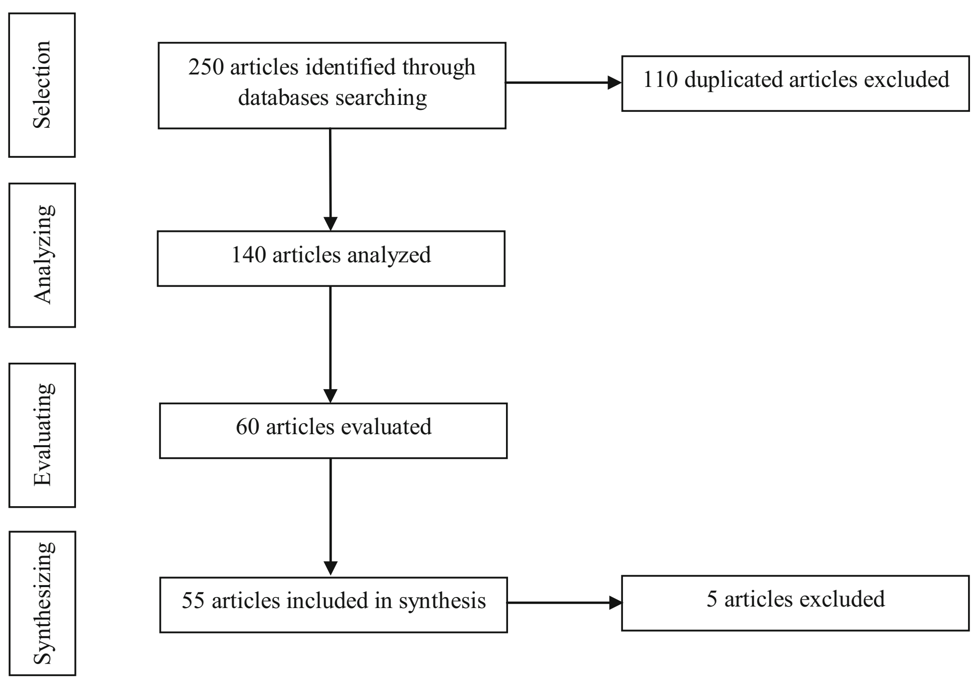

Fig. 1 Flow of literature review

materials comprise soft inert materials, such as soil, earth, and slurry, and hard inert materials as rocks and broken concrete. The non-inert materials include wastes, such as metals, timber, plastics and packaging waste. Besides that, Nagapan. et al. [26] have divided C&D waste into two groups: physical and non-physical forms of waste. For example, physical forms of waste are concrete, timber, steel, and packaging, while non-physical wastes are cost overruns and time delays. Wastes generated from the construction activities are, in fact, not only about the materials, but the inefficiencies in the use of equipment, labor, and money could also contribute to the waste generation in the form of non-physical wastes. Cost overruns due to the design errors and over-ordering could happen in any construction projects. Meanwhile, time delays due to the shortage of materials and faulty of the equipment could also contribute to the non-physical generation of wastes.

The EPA [27] defined C&D waste materials to be consisted of debris generated during the construction, renovation, and demolition of buildings, roads, bridges and all other works related to civil engineering. C&D waste materials often contain bulky, heavy materials that include concrete, wood, asphalt (from roads and roofing shingles), gypsum (the main component of drywall), metals, bricks, glass, plastics, polyvinylchloride (PVC), trees, stumps, earth, and rock from clearing sites. Normally, C&D waste may contain hazardous material which may affect humans and the environment. The common hazardous wastes include paints, solvents, adhesives, caulks, pesticides, wood preservatives, oil, or stored materials (such as solvents or pesticides) that have exceeded their shelf life. Other common examples of hazardous C&D wastes are asbestos, polychlorinated biphenyls (PCBs), and heavy metals that can be released during the demolition or renovation of existing structures [27].

Several reasons, such as damage, over-ordering, design, and management fault influence the waste generation by creating a difference on the values of materials delivered on-site and used appropriately according to specification [28]. Different authors have agreed that waste can be generated throughout the construction lifecycle including planning, designing, procurement, transportation, and on-site management processes [4, 24, 29]. According to Kofoworola and Gheewala [30], waste that is being generated from construction processes is often disposed into landfill.

The hierarchy of waste management

The hierarchy of waste management states that waste should be treated according to its suitability to be reduced, reused, and recycled before the last mechanism, which is waste disposal into landfill. Also, Wolsink [31] enhanced the hierarchy by adding one more step which is known as "avoiding the production of waste". Lu and Yuan [32] identified the 3R principles of reduce, reuse and recycle as the common practice used to minimize waste. However, according to Esty and Winston [33], the 3R principles is not enough towards mitigating the environmental impacts of the waste generation. The elements of reimagine and redesign should be explored to ensure the process and design of construction activities will be more innovative by prioritizing the environmental aspect. Figure 2 illustrates the waste management hierarchy which gives great emphasis toward environmental management [33]. Nowadays, 3R principles of reduce, reuse, and recycle are not enough to mitigate the environmental impacts of waste generation. The descriptions of Fig. 2 are as follows:

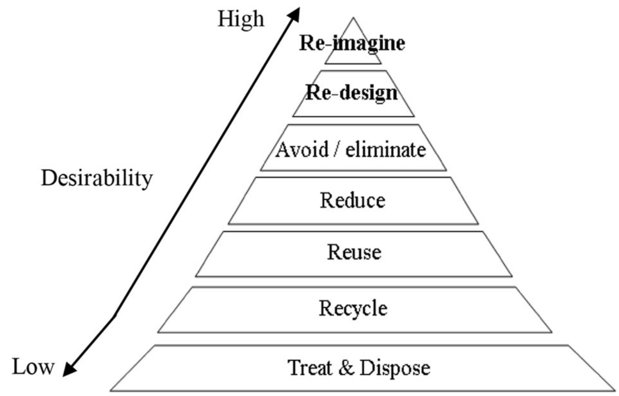

Fig. 2 Strategic hierarchy of environmental management [43]

1. Reimagine	Revising the traditional way of producing building by focusing on the environmental impacts of the end-products rather than profitability alone.
2. Redesign	A consideration is given on how can we design building that could minimize the waste generations rather than esthetic value alone.
3. Avoid/ eliminate	Unnecessary waste can be avoided by encouraging the implementation of advanced materials and technologies.
4. Reduce	the design, manufacture, purchase, or use of materials to reduce their quantity or toxicity before they reach the waste stream.
5. Reuse	Waste materials can sometimes be used again for the same intended purpose or for a different purpose.
6. Recycle	Series of activities that include the collection of used, reused, or unused items that would otherwise be considered as wastes, and then, these items are sorted and processed into raw materials or remanufactured into new products.
7. Treat and dispose	Waste can be treated by achieving the microbiological degradation to produce an organic product that can be used in agriculture industry while waste that cannot be treated, reused or recycled, it will go to the landfill for disposal.

Waste minimization strategies

The amount of waste generated will increase if there is no effort given to adopt waste minimization strategies during the design and planning stages. Currently, most of the construction actors are only concerned about the level of profitability, without consideration to the waste management [34]. When there is a lack of attention given at the design and planning stages, waste generated during these stages would be hard to control, and this will affect the cost and time to manage the wastes. Table 2 summarizes the suitable minimization strategies that can be adopted during the different stages of the construction process as suggested in the existent literature [11, 35–47].

As we can see in Table 2, various waste management strategies have been suggested in the literature, however, limited studies were conducted in focusing on how the waste is being managed throughout the construction cycle. For example, many researchers realized the importance of having waste minimization strategies at source, starting at the design and planning stage. Even though the waste is being managed at source, it is necessary to include waste minimization strategies at the procurement and construction and demolition stage as the occurrence of unavoidable waste that could be generated at those stages.

This summary is useful in guiding the authors to develop a theoretical framework for C&D waste management using the circular economy concept.

Table 2 Summary of waste minimization strategies

Authors	Country	Waste minimization strategy	Stages
Gangolells et al. [38]	Spain	On-site sorting technique	Procurement
		Suitable plants such as mobile crusher available on-site	Construction/demolition
		Standardization	Design and planning
		Teamwork among the stakeholders	Design and planning
		Reusable elements by considering the future dismantling of components	Design and planning
Low et al. [11]	Singapore	Encourage the usage of eco-labeling products to support the idea of sustainable development	Design and planning
Yean Yng Ling and Song Anh Nguyen [46]	Vietnam	Employ subcontractor with the ability to manage the waste efficiently	Procurement
		Conduct training and allocate time for auditing	Design and planning
		Close monitoring of the workers	Construction/demolition
		Set target of allowable wastage	Design and planning
		Give reward to those effectively applied C&D waste management and provide punishment for those who failed to apply C&D waste management	Post-Construction
Yu et al. [47]	Hong Kong	Construction waste disposal charging scheme (CWDCS), which is introduced to encourage the construction actors to consider the 3R principles before disposal	Design and planning Post-construction
Li et al. [41]	China	Adoption of C&D waste generation index to estimate the amount of waste	Procurement
Ordoñez and Rahe [42]	Sweden	Improvement in collaborating and communicating among the stakeholders especially the designers	Design and planning Procurement Construction
Huang et al. [39] Urio and Brent [45] Poon et al. [43]	China Botswana Hong Kong	Proper material selection in which prioritization should be given to the materials that could prolong the conservation of raw materials and mitigate CO_2 emissions	Design and planning
Lachimpadi et al. [40]	Malaysia	Improvement in the construction methods, e.g., Industrialized Building System (IBS)	Design and planning
Arif et al. [35]	India	Revised and enforced waste management related laws	Procurement
		Avoid confusion among multiple contractors on the construction site to manage the wastes	Construction
		Proper storage location for materials	Construction
Tam and Tam [44]	Hong Kong	Stepwise incentive system (SIS), which is an award given to those who are producing lower waste levels	Design and planning
Begum et al. [37]	Malaysia	Contractor's willingness to pay (WTP) for an improved C&D waste management	Construction
Barlaz et al. [36]	United States	Pay-as-you-throw (PAYT) scheme, which requires the construction actors to pay for the amount of waste that they are going to produce	Procurement/construction

Circular economy (CE) in C&D waste management

Definition and key concepts of the circular economy

According to Preston [48], the CE is a concept that is designed based on the aspect of regeneration, i.e., based on reducing the consumption of raw materials. CE is a concept that is practically in line with the elements of sustainability in the social, economic, and environmental aspects.

Most of the definitions of CE given in the literature (see the Supplementary Material) have pointed out the importance of shifting from the traditional linear methods to circular methods. Moreover, CE and close-loop systems have been stated to be interrelated as both approaches focus on preserving the resources toward creating sustainable development. CE is, thus, an emerging notion that could be used to transform the linear-based economy toward a circular approach by maximizing the resources. CE is not only developed based on the 3R principles of Reduce, Reuse, and Recycle, but also including the elements of Reimagine and Redesign to maximize the resource efficiencies by reconsidering the processes and the designing-out of the wastes.

However, there is a lack of research on the integration of the CE concept into the construction industry. Cahalane [49] explained that there is a need to integrate CE into the construction industry to ensure a reduction of wastes generation and to create a sustainable future. CE can be successfully implemented at three different levels, i.e., micro-, meso-, and macro-levels [50–52]. Geng and Doberstein [50] stated that the CE will be successfully implemented through “three-circles” approaches, while Yuan et al. [51] named it as a “three-layers” approach. The three different levels involved are:

1. Micro — Focusing on the production area, this level requires the adoption of a cleaner production process and more eco-friendly design;
2. Meso — Environmentally friendly design that encourages the introduction of waste trading system; and
3. Macro — A more advanced collaborative network among industries which encourages the element of *Reuse, Reduce*, and *Recycle*.

Adoption of circular economy in the construction industry

UK and the Netherlands are among the countries that have considered CE in their construction practices. For instance, CE has been used as a foundation to guide the construction actors across the UK to reduce waste generations and carbon emission; an approach known as *Resource Efficient Construction* has been established in the UK to encourage the construction actors to redesign wastes, develop products from efficient resources, minimize waste, and maximize the reuse [53]. This approach has successfully led to divert 5 million tonnes of waste annually from going into landfills. *Ellen MacArthur Foundation* is one of the inspirational examples of organization in the UK that synthesized the idea of CE as a framework to regenerate a positive future. In the context of CE, Ellen MacArthur Foundation [54] has introduced a framework known as *ReSOLVE*. The *ReSOLVE* framework is there to assist businesses and countries in developing circular strategies. This framework consists of six (6) action areas which are:-

1. Regenerate — Shifting toward renewable energy and materials; protecting the ecosystems;
2. Share — Encouragement towards sharing assets and reusable elements; design for durability by prolonging the lifespan through effective maintenance system;
3. Optimize — Increasing the efficiency of products, removing unnecessary wastes throughout the supply chain;
4. Loop — Provide technology to remanufacture and recycle the products;
5. Virtualise — Dematerialize directly and indirectly; and
6. Exchange — Encourage innovative materials, apply new technologies.

A pilot study has been carried out in Denmark to seek the potential of integrating CE in the construction and real estate sector based on the *ReSOLVE* framework. Based on the framework, the level of prioritization (*high, medium* and *low*) of each area to be implemented in the construction and real estate is being studied. From the study, there are high possibilities to *share*, *optimize*, and *loop* the construction process in Denmark.

Furthermore, the Netherlands has also outlined the direction to accomplish the integrations of CE into the construction industry by unleashing a blueprint that designates the potentials of CE as a new economic approach that will create products to the future generations. International Management Search Association (IMSA) is the example of organization in Netherlands that is very keen to support the implementation of CE with the aim of addressing resource scarcity and environmental impacts [15].

A theoretical framework for waste minimization using the circular economy concept: case of Malaysia

In this section, a theoretical framework based on the concept of CE for construction waste management is proposed for the Malaysian construction industry. The theoretical framework is developed based on the literature review presented in previous sections. The scenario of construction waste management in Malaysia is discussed below before the theoretical framework is tackled.

Construction and demolition (C&D) waste management in Malaysia

In the first quarter of 2015, the construction industry in Malaysia has contributed 15.1 % of the country's Gross Domestic Products (GDP) and provided employments to about 10 % (1.4 million) of the total workforce in Malaysia [55]. During the presentation of the 10th Malaysia Plan (10MP), the Prime Minister of the country has allocated a budget of USD 18 billion to improve infrastructure facilities and to cater to the pressing demand for housing [56]. The government has targeted building 78,000 affordable houses by 2015. Furthermore, the government of Malaysia also announced an additional USD 5.5 billion budget under the 10 MP for the purpose of accelerating the sustainability awareness among construction actors. The aspect of sustainability has been emphasized by considering its ability to protect the environment. This is evident through the introduction of the "Strategic thrust 5: building an environment that enhances quality of life". Prior to this, the main regulating body for the Malaysian construction industry, which is the Construction Industry Development Board (CIDB) has introduced the "Strategic recommendation for improving environmental practices in the construction industry" to encourage the construction actors to consider the environmental impacts of construction activities [57]. Hence, the procurement of the 10 MP is a continuous government effort to create a sustainable future for Malaysia.

Environmental protection is becoming a major concern as construction waste is now considered one of the main contributors to environmental degradation in the country [58]. In recent years, the construction industry has caused the depletion of natural resources in Malaysia, which heightened the problem of environmental degradation. In 1991, the former Malaysian Prime Minister, Tun Mahathir Mohamad, introduced the Vision 2020 to mark the beginning of Malaysia's strive to become a fully developed country by 2020, and one of the significant factors for achieving this vision is environmental protection.

For the past 10 years, there were studies conducted that reflected on situation of construction wastes in Malaysia, but only a few of these have focused on the specific aspect of C&D wastes. For instance, Begum et al. [59] studied the potentials in adopting the 'reuse and recycle' strategies to manage wastes in institutional buildings in Bangi, Malaysia. Many researchers have also identified the dependency on the labor-intensive methods as the main contributor of waste generation in Malaysia, and how this could result in a lower level of productivity and quality of construction works [7, 60–62]. Furthermore, there is an urgency to adopt a more modern method of construction like 'Industrialised Building System' (IBS) in Malaysia to reduce the dependency on labor as well as reducing the waste generation. For instance, Abdullah et al. [63] argued that the construction industry must evolve from the traditional wet construction methods to a more environmental friendly, energy efficient, and productive method of IBS. A similar study by Lachimpadi et al. [40] reported that IBS has the ability to reduce the amount of wastes dumped into landfills. Also, according to Esa. et al. [64], it is important to identify the issues and challenges that reflect the current scenario of construction waste management in Malaysia. The authors identified the four (4) key issues that need to be addressed to develop an effective construction waste management, i.e., the increasing amount of waste, environmental impacts, illegal dumping issue, and lack of support from the top management. Besides those, three (3) challenges were identified that need to be overcome in pursuing the implementation of construction waste management, i.e., the regulations enhancement, a shift of awareness and mindset, and provision of tools to collect relevant information regarding construction waste (such as source of waste and waste composition). However, there is still a lack of study on waste minimization throughout the construction cycle in Malaysia. This covers from the planning, designing, procurement, construction and demolition stages. Hence, circular approach is required to ensure the control of wastes starting from the planning stage of the construction, rather than emphasizing on the end-of-pipe strategies where wastes are managed after they are generated.

The development of a theoretical framework based on circular economy concept: case of Malaysia

In this section, a theoretical framework of waste minimization using the concept of CE is proposed. To develop the framework, key elements have been chosen to ensure the practicality in employing the framework in real-life situations. First, the authors have decided to select five (5) common stages that are universally practiced in the construction industry, these stages are *planning, designing, procurement, construction*, and *demolition* stages. Different stakeholders who are involved at each stage and their interactions in the stages are then identified, and the key principles of CE (*reduce, reuse*, and *recycle*) are used as strategy to minimize construction wastes. To successfully adopt the concept of CE in waste minimization, the three-layer approach of micro, meso, and macro explained in the previous section is used [50–52]. Previous studies have used this approach to comprehensively transform the economy of a country as whole by focusing at the individual firm, regional, and national level [50, 52, 65]. However, in this research, the authors anticipated a smaller scope of study by focusing on utilizing the CE as an approach to minimize the wastes throughout the construction cycle. The theoretical framework must be developed carefully as various stages in the construction cycle will be included accordingly at the three-layer approach. Finally, waste minimization strategies will be included at each level of the framework based on the literature obtained in Table 2. Figure 3 illustrates the proposed theoretical framework of waste minimization using CE.

At the micro level, the authors were looking at the early stages of construction processes, specifically the planning and designing stage. The main stakeholders involved at these stages are basically the products' designers and their clients, as well as contractors who can also be involved depending on the procurement method that is adopted by the project. By implementing waste minimization strategies at this stage, where a lot of decisions have been made by the stakeholders involved, wastes generation can be controlled. For example, the decision will be made on the type of construction methods to be used during the construction stage. Transforming the traditional construction methods is necessary to materialize waste reduction strategy at its source, and IBS is a clear option for designers and clients in Malaysia. Its adoption into the management of C&D wastes can reduce waste generation. The production of IBS components (e.g., wall, column, beams) is made off-site; therefore, the construction activities related to wet construction on-site can be reduced, and, indirectly, the quality and productivity of the construction activities can be improved. According to Gangolells et al. [38], standardization could reduce the wastage generated from cutting and modifying of building elements. In Malaysia, modular coordination (MC) is a new dimensional system used in drawing the building specifications and can be incorporated into IBS, resulting in the reduction and elimination of wastes or at least prevent the occurrence of wastage. MC is essentially based on the use of modules (basic module and multi-modules) and a reference system to define coordinating spaces and zones for building elements and for the components which form them [66]. Based on this, CIDB has enforced the implementation of MC in the Uniform Building By-Laws (UBBL) in 2004. MC complements the IBS implementation in facilitating greater productivity in the building industry through its ability to create discipline on the dimensional and spatial coordination of buildings and their components, thus allowing a more flexible and open industrial system to take shape. Meanwhile, giving awards such as stepwise incentive system (SIS) and construction waste disposal charging scheme (CWDCS) to construction actors can be useful in reducing the wastes generation at the planning and designing stages. Furthermore, the selection of materials will be also decided in ensuring the suitability of the materials that will be used for the projects. Hence, selection

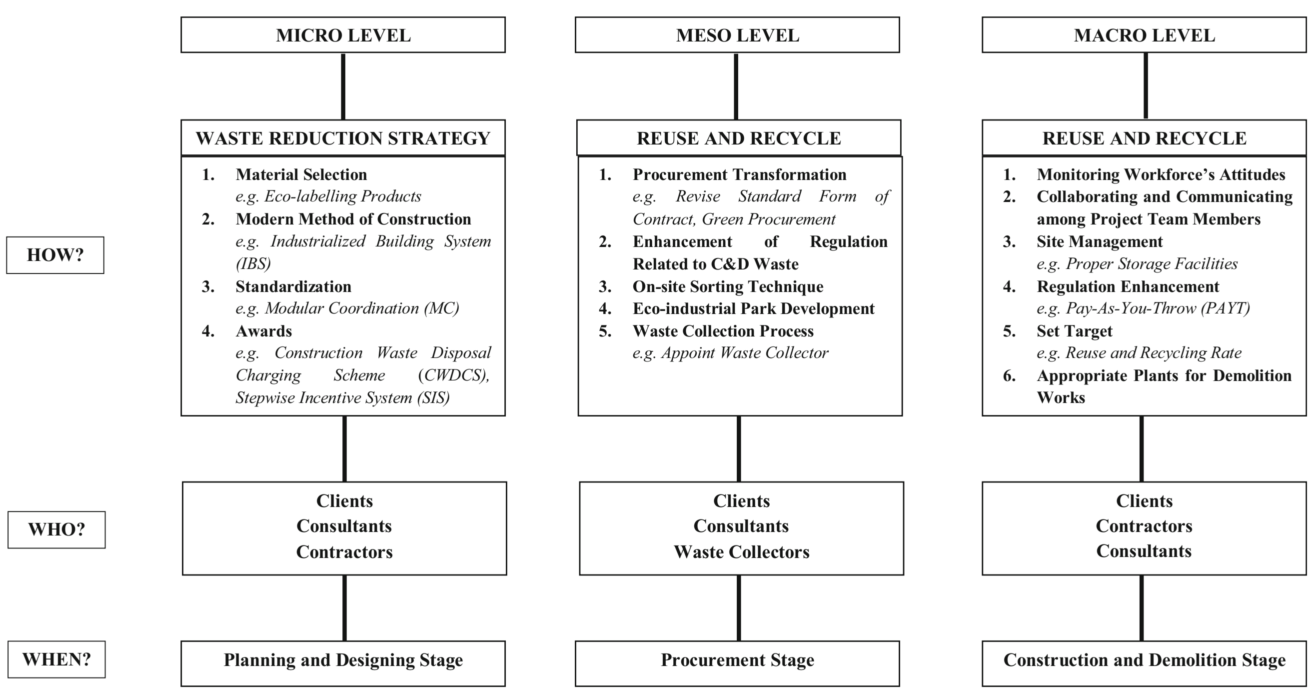

Fig. 3 Theoretical framework for waste minimization using the concept of circular economy

of materials that can prolong the conservations of raw materials, and at the same time, can mitigate CO_2 emissions should be prioritized [39]. It is also important to consider the reusable elements by considering the future dismantling of the components [38]. Low et al. [11] also added the importance of introducing eco-labeling on products which is parallel with the idea of sustainability.

At the meso-level, the transformation in the procurement method can be done in Malaysia, as described in Arif et al. [35]. Waste management-related laws need to be revised and enforced to ensure that the generation and management of wastes can be monitored and controlled. Currently, the existing standard form of contracts in Malaysia including the *Public Work Department* (*PWD*) *Form 203* (R*evision 1/2010*), *Persatuan Arkitek Malaysia* (*PAM*) *Contract 2006*, and *Construction Industry Development Board* (*CIDB*) *Contract for Building Works* have not yet included any clause that specifically states the importance of having proper management of C&D wastes. On the other hand, the CIDB Contract for Building Works is the only contract that has indirectly emphasized the elements of C&D waste management. This is shown through Clause 11 under this contract which stated the importance of conserving the environment by complying with the *Environmental Quality Act 1974*. Therefore, the contractors should be obligated to this act to control the pollution that could harm the environment. This shows that the existing standard forms of contracts in Malaysia should be revised by putting more emphasis on the importance of proper C&D waste management, and encouragement should be made to explore the opportunity of introducing green procurement in Malaysian construction industry. Besides that, variety of organizations will be involved in the construction cycle, and this will possibly create confusion among the team members involved on who should be responsible in managing the wastes. Therefore, waste collectors could be assigned to ensure the flow of the waste collection process. Furthermore, the implementation of on-site sorting technique for wastes can be useful for waste collectors when collecting the wastes and for them to take further appropriate actions such as sending the wastes to recycling facilities. The appointment of subcontractors should also include the ability to manage the waste effectively to ensure that the appointed subcontractors are aware about the importance of efficient management of wastes [46]. Furthermore, developing an eco-industrial park can be a great option at the meso-level, as this idea is very helpful in achieving sustainable development by attempting to reduce waste and pollution. Eco-industrial park is a new development trend in which shared resources and facilities are being encouraged among the businesses. This is evident through the growing trend in the development of eco-industrial parks, such as *Setia Eco Park* in Selangor and *Frontier Industrial Park* in Johor Bahru.

Finally, a*t the macro level*, the attention should be given in managing the wastes at the construction and demolition stages. Even though the wastes reduction strategy has been accentuated at the micro-level, the total elimination of wastes is still difficult and might be impossible, hence, it is very helpful if a certain target can be set on the reuse and recycling rates before commencing the process. Having a monitoring mechanism is important in controlling waste generations and at the same time, achieving the target set for the reuse and recycling rates. In addition, the workforces involved during the construction stages should also have the capability to work effectively to reduce the waste generation, this is supported by Kulatunga et al. [4] who identified the attitudes of the workforce to be influencing the rate of waste generation. Having a monitoring mechanism is, thus, also important in controlling the attitudes and perceptions of the workforces toward the minimization of wastes. The collaboration and communication among the stakeholders are also areas that need to be improved [42]. Moreover, regulation enhancement can also be useful to be considered at the construction and demolition stage, for instance, pay-as-you-throw (PAYT) is a good practice whereby the contractors need to pay for the amount of wastes they produced [36]. Furthermore, an effective site management should be employed at the construction and demolition stage. For instance, a proper storage location will help to reduce the probability of waste generations at these stages. Meanwhile, when there are demolition works that need to be done, a suitable plant, such as the mobile crusher, should be used to ensure that the demolished products have the possibility to be reused [38].

Conclusion

This paper proposes a framework based on the concept of CE for minimizing C&D wastes in Malaysia. The systematic review carried out has, in fact, showed that there is a need to develop a strategic and comprehensive C&D waste management regime in developing countries. The review also showed that there are still limited numbers of in-depth studies conducted which focused on C&D waste management practices throughout the construction cycles, particularly in Malaysia. CE has been widely used in developed countries, such as some European countries, but it is a relatively new concept in Malaysia. From the review, it can be concluded that an integrated framework is needed to guide the construction actors in Malaysia to manage wastes effectively and sustainably, and that the implementation of CE is very important in the construction industry to create a sustainable future.

The proposed framework is built following a three-layer approach, namely *micro-*, *meso-*, and m*acro-level*. At the micro-level, the main aspects that need to be highlighted are the transformation of traditional method of construction, in which a more modern method of construction like IBS is needed to ensure that the wastes could be controlled at the source. Reducing wastes at the source translates to a high possibility that the amount of wastes can be reduced throughout the construction cycle. Since wastes are difficult to be totally eliminated, it is also necessary to revise the waste management strategies at the meso- and macro-levels. To ensure that there is a continuous effort in managing wastes, transforming the procurement methods is imperative at the meso-level. This can be done by stating the clauses on the elements of construction waste management clearly in the document contracts so that the construction actors are well aware on the importance of implementing proper C&D wastes management. Finally, at the macro-level, the most important aspects are providing monitoring, coordinating, and communicating mechanisms to ensure the practice of effective construction waste management, which need to be implemented during the construction process.

The proposed theoretical framework provides useful guidance to further exploration on the potential of CE as a waste minimization approach. Further studies on this issue are necessary to enhance the framework and to test its viability to help the construction industry in better waste management. A system dynamic modeling may be useful to quantitatively analyze the interrelations among the different suggested waste minimization strategies. By applying the data simulation process, an integrated framework of C&D waste management applicable to any construction projects could be finalized.

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