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Research Article

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Are we ready for circular economy? Towards zero waste in construction

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Abstract. Over the past decade, the concept of circular economy (CE) has emerged encouraging a rethinking of the way products are designed so that they can be "made to be made again", turning the conveyor belt of consumerism into a circle (a closed-loop supply chain) and hence eliminate waste. The construction sector, especially, is known to be one of the main contributors of material waste-to-landfill. This paper investigates (i) the causes of construction waste and (ii) the readiness of the construction sector in Malaysia to embrace CE. Based on the relative importance index (RII), the five main causes of construction waste in Malaysia identified include frequent design changes (RII = 0.853) by owner or agent during construction followed by poor site management and supervision (RII = 0.835), changes in material specification and type (RII = 0.803), rework (RII = 0.719) and lack of coordination between parties (RII = 0.680). Survey findings also show that a majority (75%) of stakeholders within the Malaysian construction industry is unfamiliar with the concept of CE while 90% of the respondents claim that they are not ready to implement such practices within the next 5 years. It is anticipated that the findings from this paper will be of interest to construction practitioners.

Keywords: sustainability / circular economy / sustainable construction / waste / Malaysia

1 Introduction

In September 2015, 193 member countries agreed to champion the 17 Sustainable Development Goals (SDGs) consisting of 169 targets [1], encompassing a broad range of issues from the need to end poverty, promote gender equality, intensify climate action and protect biodiversity among others. Specifically, Goal 12 focuses on responsible consumption and production [2]. This goal depicts the challenge of decoupling economic growth from resource use as one of the most critical challenges facing humanity today requiring effective policies, changes to social and physical infrastructure as well as business practices along the supply chain. The "material footprint" per capita of developing countries grew from 5 metric tons in 2000 to 9 metric tons in 2017. While this represents a significant improvement in the material standard of living, most of the increase is attributed to a rise in the use of non-metallic minerals, pointing to growth in the areas of infrastructure and construction [3].

Waste management issues in the construction industry have been widely discussed in the construction management literature. The rapid development of houses and major infrastructure projects at an unprecedented rate are increasing the amount of construction waste generated and if not handled properly could result in negative impacts to the environment, society and finally the economy. Illegal dumping of construction waste due to the irresponsible practice of certain parties to save cost is another issue commonly encountered in the construction industry [4]. This has spurred a handful of researchers [5–9] to explore ways to minimise waste at construction project sites and better understand the factors behind high waste generation in this sector. For example, Garas et al. [10] while quantifying waste generation rates in the Egyptian construction industry find that "late information" and "changes to design" are fundamental causes of material waste. Teo and Loosemore [11] propose a theory of waste management behaviour for the construction industry and make recommendations to help managers improve their operative's attitude towards waste. Lu and Yuan [12] work on a comprehensive framework for understanding waste management studies from the construction and demolition process.

In 2018, more than 108 countries implemented policies and initiatives relating to sustainable consumption and production. According to KPMG, 93% of the world's 250 largest organisations by revenue are reporting on their sustainability practices. The concept of the circular

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economy (CE) which encourages rethinking of the way products is designed so that they can be "made to be made again", turning the conveyor belt of consumerism into a circle (a closed-loop supply chain) has emerged as an answer to address Goal 12 of the SDGs. As it is, construction waste is still recognised as a pressing issue in Malaysia [13,14]. And not much is known about the progress made in this area over the past decade.

This paper fills the void accordingly by investigating the status of Malaysian construction industry in particular the causes of construction waste and the readiness of the industry to embrace the CE concept. The findings from this paper would be of interest to construction practitioners and policymakers.

2 Literature review

The construction industry has a varied reputation for coping with waste. Some countries appear to be more ahead than others. Nitivattananon and Borongan [15] identify variations in waste management practices across Asia both in terms of strategies and technologies adopted as well as policies implemented. Kartam et al. [16] report that the amount of effort put into recycling by the Kuwait construction industry is very minimal. Al-Hajj and Hamani [17] argue that the United Arab Emirates (UAE) faces challenges in achieving sustainability due to increasing amounts of construction waste dumped in landfills.

Part I of this section seeks to review the main causes of construction waste while Part II explores the definition of the CE and highlights indicators that will be used to assess the readiness of the Malaysian construction industry to embrace this concept.

2.1 Part I: cause of construction waste

According to Periathamby et al. [18], the generation of municipal solid waste (MSW) in Malaysia has increased more than 91% over the past 10 years, due, in particular, to the rapid development of urban areas [19], rural–urban migration, increase in per-capita income, inadequate infrastructure and the change in consumption patterns brought about by development.

Table 1 summarises some of the causes of construction waste found in mainstream construction literature. These will be used as a key construct to understanding the primary causes of construction waste in Malaysia [20].

Table 1. Causes of construction waste.

Causes	Reference
Poor site management and supervision	[21–23]
Lack of experience	[24,25]
Inadequate planning and scheduling	[21,23,24,26]
Mistakes and errors in design	[26–28]
Mistakes during construction	[27,29]
Incompetent subcontractors	[21,22,24,27]
Rework	[24,26,28]
Frequent design changes	[22,23,26]
Labour productivity	[20,21]
Inadequate monitoring and control	[28]
Inaccurate quantity take-off	[30]
Shortage of site workers	[22,31]
Lack of coordination between parties	[26]
Slow information flow between parties	[28]
Shortage of technical personnel (skilled labour)	[24,26]
Changes in material specification and type	[32]
Equipment availability and failure	[23,24,26,27]
Effect of weather	[21,22,26,28]

2.2 Part II: circular economy (CE)

To address the issue of increase in waste generation, the concept of the CE has been proposed as an alternative to our linear economic system where material resources are recirculated for new product development [33].

While the term (CE) has gained traction with academia, industry and policymakers, there is still ambiguity over its meaning, in a similar fashion to the term sustainability [34,35]. Kirchherr et al. [36] examine 114 definitions of CE and warn that the variety of understandings can result in this concept eventually collapsing or ending in "deadlock".

(i) According to the [37], the concept of CE aims to accelerate the transition towards a regenerative circular way of thinking, the idea is "to shift from a linear model of resource consumption that follows a 'take- make- dispose' pattern, to an industrial economy that is 'restorative by intention'; i.e. that replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and aims for the elimination of waste through the superior design of materials, products, systems and, within this, business models".

(ii) The Danube Transnational Programme [38] argues that: "*Waste is a human invention. The current modes of consumption and production are linear. Resources are extracted and processed into products, and when a product is no longer needed, it is discarded and typically ends up in an incinerator or landfill. Thus, valuable resources are lost. In contrast to the traditional, linear, throwaway economy, in the CE, the design and creation of products are easy to share, lease, reuse, repair, refurbish and recycle, while using regenerative resources and renewable energy. The goal is to minimise waste and to keep products and resources in the economy for as long as possible. Ideally, this win–win approach benefits both the economy and the environment*".

(iii) Murray et al. [39] claim that CE represents the most recent attempt to conceptualise the integration of economic and environmental well-being in a sustainable manner. They argue that while this concept has placed emphasis on the redesign of processes and materials, the social dimension appears to be missing. This has led to the

Table 2. CE indicators.

Indicators	Definition
Input in the production process	How much input is coming from virgin and recycled materials and reused components?
Utility during use phase	How long and intensely is the product used compared to the industry average product of similar type?
Destination after use	How much material goes into landfill (or energy recovery), how much is collected for recycling?
Efficiency of recycling	How efficient are the recycling processed used to produce recycled input and to recycle material after use?
Complementary risk indicators	Does the organisation/individual consider potential risk in relation to business priorities? (i.e. material supply chain risks, scarcity, toxicity, energy usage, emissions)

proposed revision of the definition as "*an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximise ecosystem functioning and human well-being*" ([39], p. 369).

For the purpose of this paper, the definition of CE from the Ellen MacArthur Foundation [37] is adopted. Given the increasing demand for transparency on sustainability issues [40], a number of tools have surfaced in the past decade to track progress [41] and understand how organisations are responding to sustainability [42]. The Ellen MacArthur Foundation [43] has also developed a set of indicators intended for use in product design that could also be used for internal reporting, for procurement and investment decisions. These indicators (Tab. 2) are converted to a questionnaire (on a 5-point Likert scale) to assess the readiness of Malaysia's construction sector for CE, with 1 = Not Ready to 5 = Extremely Ready.

3 Research methodology

Evans and Mathur [44] provide a thorough analysis of the role of the internet in survey research and discuss the strengths and weaknesses compared to other survey methods. Cobanoglu et al. [45] compare between mail, fax and web-based surveys and find that on average, the response rate for web-based surveys is higher while mail surveys have the slowest response rate. Web-based survey is adopted in this research due to its benefit.

The survey method has been widely used in studies within the construction industry. Akintoye [46] analyses the perception of contractor's views on design and build as a procurement route using a structured survey. Siew [47] uses the survey method to gauge occupant's/user's perception on the performance of completed buildings. Lyons and Skitmore [48] use the survey method to investigate the use of risk management techniques among senior management in the construction industry in Queensland.

A survey questionnaire was developed to assess (i) the perception of Malaysian construction practitioners on the relative importance of causes of construction waste determined via an extensive literature review and (ii) assess the readiness of the construction industry in Malaysia to embrace the CE model. The questionnaire was filled out by 124 highly experienced construction professionals including project and site managers, technical office engineers, procurement managers and technical consultants. The data collected for part (i) was analysed using the relative importance index (RII).

3.1 Relative importance index (RII)

The relative importance of the causes of delay in Malaysian construction was quantified using the RII method (see [49,50]). The ranking of the factors was determined according to their importance level on delay [51].

$$\mathrm{RII} = \frac{\Sigma w}{AN} \tag{1}$$

where w is the weighting given to each factor by the respondent, ranging from 1 to 5, A represents the highest weight (i.e. 5 in this study) and N is the total number of respondents. RII ranges from 0 to 1; the higher the RII, the more important was the cause of delays. The RIIs were then ranked accordingly and the results are depicted in Table 2.

4 Discussion

4.1 Part I: cause of construction waste

The causes of construction waste are ranked as shown in Table 3. Frequent design changes (RII = 0.853) by owner or agent during construction is ranked as the number cause of construction waste followed by poor site management and supervision (RII = 0.835), changes in material specification and type (RII = 0.803), rework (RII = 0.719) and lack of coordination between parties (RII = 0.680). Inaccurate quantity take-off is ranked as the factor that least contributes to construction waste in Malaysia (RI = 0.285).

Table 3. RII and causes of waste.

Causes	Frequency of "5" responses	Frequency of "4" responses	Frequency of "3" responses	Frequency of "2" responses	Frequency of "1" responses	RII	Rank
Frequent design changes	64	44	6	5	5	0.853	1
Poor site mgt and supervision	72	20	14	18	0	0.835	2
Changes in material specification and type	60	28	16	18	2	0.803	3
Rework	45	38	8	12	21	0.719	4
Lack of coordination between parties	12	39	67	6	3	0.680	5
Mistakes during construction	15	70	5	16	18	0.677	6
Labor productivity	18	48	21	28	9	0.661	7
Mistakes and errors in design	8	68	15	12	21	0.648	8
Incompetent subcontractors	9	60	22	12	21	0.639	9
Inadequate planning and scheduling	0	40	52	32	0	0.613	10
Inadequate monitoring and control	22	24	27	38	13	0.606	11
Equipment availability and failure	9	27	59	17	12	0.606	12
Lack of experience	21	32	21	25	25	0.598	13
Slow information flow between parties	18	22	13	71	0	0.579	14
Shortage of technical personnel (skilled labour)	13	28	24	17	42	0.524	15
Effect of weather	5	12	36	49	22	0.485	16
Shortage of site workers	2	5	17	2	98	0.295	17
Inaccurate quantity take-off	0	0	14	25	85	0.285	18

Table 4. Survey results on readiness for CE ($n = 124$).

Indicators	1 = Not ready	2 = Fairly ready	3 = Moderately ready	4 = Very ready	5 = Extremely ready	Total (n)	Mean
Input	87	33	3	0	1	124	1.35
Utility	90	21	11	1	1	124	1.40
Destination	14	25	68	16	1	124	2.72
Efficiency	87	13	17	7	0	124	1.55
Complementary	75	25	16	6	2	124	1.67

4.2 Part II: circular economy (CE)

When enquired about the familiarity towards CE, 75% of the respondents (93 respondents) claimed they were not familiar with the CE concept while 90% (112 respondents) claimed that they are not ready to implement CE within the next 5 years. Further probing using the indicators (see Tab. 4) – input, utility, destination, efficiency and complementary risks reveal that a large majority of Malaysian construction practitioners are indeed not ready for CE. When asked whether construction organisations are ready to answer: "how much input is coming from virgin and recycled materials and reused components?", the mean score achieved was 1.35 which signifies that a large majority of Malaysian construction practitioners lack clarity when it comes to the supply chain of the materials used. Of all the indicators, "destination" achieved the highest mean score at 2.72 further signifying that construction organisations are slightly more prepared to answer: "how much material goes into landfill (or energy recovery) or how much is collected for recycling?" compared to other indicators. Perhaps, this could be attributed to the newly gazetted Solid Waste and Public Cleansing Management Act as of October 2018, which mandates the following:

- Proper segregation of residual and recyclable waste at construction sites;
- Information on the type of waste generated must be recorded;
- All records to be kept for a period of 7 years from the date of issuance.

Failure of which to comply would result in fines not exceeding RM 10 000.

5 Conclusion

The main causes of construction waste by Malaysian construction practitioners are clearly identified in this paper. The top five causes based on the RII analysis are: frequent design changes (RII = 0.853) by owner or agent during construction followed by poor site management and supervision (RII = 0.835), changes in material specification and type (RII = 0.803), rework (RII = 0.719) and lack of coordination between parties (RII = 0.680). The following recommendations are made to minimise and control waste from construction projects:

– Contractors should pay more attention to preparing effective scheduling. Planning and scheduling may be revised if necessary conditions occur.
– There needs to be more effective site management and frequent supervision to ensure that projects complete within the stipulated time frame less wastage.
– Quality and experience of the labour force is important to ensure that there is lesser rework due to mistakes/ defects.
– Since there are many stakeholders involved, proper communication and coordination channels will need to be set up to ensure that all parties have clarity on the project objectives and goals that have been set earlier. This would also help to minimise problems with communication.

The assessment for readiness was conducted based on a 5-point Likert scale consisting of indicators which covered input, utility, destination, efficiency and complementary risk (see Tab. 2). From the survey, it was found that Malaysian construction organisations are unprepared to implement the CE concept. Of all the indicators, construction organisations appear to be more prepared in explaining how much material goes into landfill or recycled, and a possible explanation for this is attributed to the newly gazzetted Solid Waste and Public Cleansing Management Act as of October 2018. It is recommended that this act is revisited to also include a broader set of requirements to facilitate the implementation of CE for example, the need to identify where materials are sourced from, how intensely are the materials used and an assessment of complementary risks associated with the materials.

Future studies could look into refining the CE indicators and testing the readiness of other construction practitioners to embrace this concept across different countries. It might also be worth estimating the probability of waste generated across the different stages of construction.

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