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Barriers and Way Forward to Construction Waste Minimization Practices: A Step towards Circular Economy

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Abstract

Construction industry is expanding rapidly to address the immense need of infrastructure and development projects. However, this expansion generates millions of tons of waste throughout the execution of these projects, with half of this waste originating from building projects. These high waste generation rates demand a detailed investigation into the root causes and way forward to overcome it. Therefore, this study focuses on identifying the barriers to waste minimization (WM) practices and providing strategies to mitigate them to promote circular economy (CE) culture. In this regard, a detailed review process determined forty (40) barriers from previous studies and frequency analysis subsequently shortlisted top thirteen (13) barriers. After a pilot survey from field experts, a questionnaire was formulated and data was collected from thirty (30) field experts. Then severity index identified the root cause barriers. It is found that non-availability of rules & regulations (B1), financial issues (B2), lack of legal enforcement (B4), and poor construction practices (B8) are major barriers in adoption of WM and CE culture. Subsequently, a theoretical way forward was provided which mainly include efforts at macro as well as micro levels. Findings of current study will be helpful for policy makers.

Keywords: waste minimization, circular economy, severity Index, barriers, way forward

1. Introduction

Over the past ten years, there has been a huge growth in construction activities worldwide due to massive urbanization and development projects [1]. The construction industry provides about 10% of a country's economic growth while also creating number of jobs. [2]. The reserves of natural resource are greatly impacted by the consumption of these resources in construction sector [3]. As a result, this sector is regarded as one of the most waste-producing sectors [4]. An estimated 200 million tons of rubbish were produced in the UK, with construction waste accounting for 59% of that total [5]. Similarly, China produced almost 2 billion tons of construction garbage annually [6] and the construction industry was responsible for almost 40% of the generated waste. So, importance to control construction waste on construction projects can be imagined. Therefore, construction industry required to put some efforts to reduce the waste and bring systematic changes in the execution of activities. Major causes of waste in construction industry were construction methods, design changes, labors attitude, material handling and procurement methods [7]. Therefore, the concept of linear economy where materials were produced, used and thrown away, is being discouraged and construction industry is moving towards the new concept of circular economy, where resources are used up to their maximum efficiency by reusing and recycling again and again [8].

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In order to promote waste minimization culture for sustainable constructions of constructions, commitment from all stakeholders is required at all levels such as macro (governmental, industrial) as well as micro (project) levels. This commitment comes in the form of real time formulation and implementation of strategies. Past studies showed that number of steps were required, to promote the culture of waste minimization such as governmental policies, environmental management system, standard operating procedures, supporting business models for recycled materials, funding by governments, charging schemes on landfill wastes, educating and training of local actors to change their behaviors [9–11].

Since the policy guidelines for construction waste minimization on construction projects, is the basic necessity of every country. So, the concept of construction waste control has been adopted by developed countries to ultimately achieve the goals of circular economy, not only in construction sector but also in other sectors. But such concepts are very rare in developing countries. So, there is an urgent need to identify the challenges which hinder the adoption of waste minimization and circular cultures in developing countries.

2. Methods

At start of this study, forty (40) barriers to WM on construction projects were identified through a detailed literature. After detailed literature, a frequency analysis was conducted to shortlist the top thirteen (13) significant barriers as presented in Table 1. The criteria of selection was, more the frequency more important that factor would be. Based on this criteria, factors having more frequency were selected. Then a questionnaire was formulated and a pilot survey was conducted from four (04) different experts to validate the questions asked in the questionnaire. After validation and modification, questionnaire was sent out to all the stakeholders of construction industry such as clients, consultants, contractors and regulators as shown in Figure 1. A total of fifty (50) people were targeted out of which thirty five (35) people responded which is a healthy response. Out of 35 responses, 30 were considered valid Respondents were of different categories. Out of a total of 35 responses, 27% were contractors, 30% were consultants, 20% were regulators and 23%% were clients. Respondents have different education levels including BS and MS degrees and minimum experience of 10years. Because experts with minimum 10 years of experience can make informed decisions.

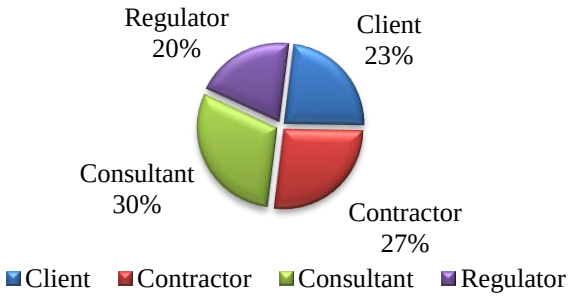

Figure 1. Profile of respondents

2.1 Severity Index Analysis

Significance index was calculated by using the five-point Likert scale where responses are normalized at a 100-point scale. Asilian-Mahabadi et al.,[27] proposed a simplified method for converting the Likert scale to a significance index in the form of a 100-point scale, as shown in Equation (1).

$$\text{Significance index} = \frac{R_{i1}\times 20+R_{i2}\times 40+R_{i3}\times 60+R_{i4}\times 80+R_{i5}\times 100}{R_{i1}+R_{i2}+R_{i3}+R_{i4}+R_{i5}} \quad (1)$$

Here R_{i1} for the number of responses as "1", R_{i2} for the number of responses as "2", R_{i3} for the number of responses as "3", R_{i4} for the number of responses as "4", R_{i5} for the number of responses as "5" for ith barriers.

Table 1. Frequently occurring barriers to waste control on building projects

ID	Barrier's Name	Details of Barrier	References
B1	Non availability of rules	Effect of Absence of waste control policies at national levels on waste generation.	[12–14]
B2	Financial issues	High upfront cost, lack of subsidize	[15]
B3	Poor awareness of stakeholders	Lack of training and education	[16]
B4	Lack of legal enforcement	Poor implementation of waste control rules and regulations in the field	[17]
B5	Shortage of resources	Non-availability of infrastructure i.e. waste sorting, storage, recycling plants and disposal facilities.	[18]
B6	Lack of collaboration	Poor communication among departments to deal with the generated waste	[15, 17]
B7	Low fines for illegal waste disposal	Fines for waste dumping are very low	[19]
B8	Poor construction practices	Poor onsite supervision for waste control, inadequate construction methods	[20, 21]
B9	Illogical Design	Drafting errors, clashes and discrepancies in drawings due to which rework required	[22, 23]
B10	Lack of innovation in product design	No practice of considering alternate design options with less waste generation	[24]
B11	Poor behavior of stakeholder	Stakeholders attitude to save materials is very poor due to non-availability of contractual binding	[25]
B12	Unclear specifications	Unclear specifications at the time of project initiation, later rework may be required	[13]
B13	Lack of use of modern tools	Such as use of BIM, RFID, GPS-GIS	[26]

3. Results and Discussion

This section will explain major barriers in adaptation of waste minimization and circular economy practices on construction projects. As a result of severity index significant barriers as per its rankings are provided in Table 2. These barriers can be divided into two major categories such as macro level barriers and micro level barriers. Macro level barriers exist at national or industrial levels while the micro barriers exist at project level such as design, construction and post construction phases.

At macro level major barriers with highest SI score found as non-availability of rules and regulations, financial issues and lack of legal enforcement. These challenges exist due to weak political will to implement waste minimization techniques in construction industry [28]. It also

emphasize on the importance of development of policy guidelines for construction sector. Further, construction industry culture matters a lot to promote the circular economy practices [29]. Therefore, poor awareness and behavior of stakeholders mattes. These barriers are ranked at number 6th and 7th. It can be synthesized that controlling these barriers can have significant impact on improving the waste control practices at macro as well as micro levels.

At micro level, barriers exist at project level such as barriers which can occur during design, execution and post construction phases of a project. From Table 2, it can be found that poor construction practices and shortage of resources are ranked at number 5th and 6th. Further, in terms of design phase, major barriers include; illogical design, design and detailing errors, unclear speculations and lack of innovation in product design are found as important barriers. So, controlling these barriers can cut of the waste from its source. Because design is that phase of project where vigilant decision can reduce or prevent significant amount of waste from its generation. These findings are line with other study [30]. Further, use of modern tools can also save significant amount of waste from generating. Building information modelling (BIM) is one of the modern tools which has been used to reduce waste during design phases of a project.

Table 2. Ranking of Barriers to Waste Minimization Practices

ID	Barrier Name	SI Score (%)	Rank
B1	Non availability of rules	84.7	1
B2	Financial issues	80.6	2
B4	Lack of legal enforcement	77.4	3
B8	Poor construction practices	77.4	4
B5	Shortage of resources	76.0	5
B3	Poor awareness of stakeholders	74.0	6
B11	Poor behavior of stakeholder	74.0	7
B7	Low fines for illegal waste disposal	72.6	8
B9	Illogical Design	69.3	9
B10	Lack of innovation in product design	66.6	10
B13	Lack of use of modern tools	66.6	11
B6	Lack of collaboration	66.0	12
B12	Unclear specifications	61.4	13

4. Theoretical Way Forward to Overcome Identified Barriers

In the light of previous studies, number of mitigation measures to overcome the identified barriers are discussed here. Barriers to adopt waste minimization practices need to be addressed at macro as well as micro levels. In order to encourage sustainable construction practices, governments must create environmental legislation, allocate funds for environmental initiatives, and subsidize projects with appropriate waste management strategies [33]. Further, supportive business

models for wasted materials, building recycling plants are also required [34]. Education and training of local stakeholders is also compulsory to improve the awareness about waste control practices [35].

On construction sites, industry must abide by these rules and guidelines. Utilize bonuses and incentives to influence employees' behavior. Every project must have a waste management plan, which clients must make sure that contractors are adhering to on the job site. Industry stakeholders will feel more committed to sustainable construction as a result of these kinds of activities. Moreover, other mitigation measures include modular design, prefabricated structures, following waste management plans and reuse of materials [36]. Latest tools such as BIM can be an effective tool to control waste on construction sites [37]. So, efforts at macro as well as micro levels are equally important to develop a waste management and circular economy culture in construction sector.

5. Conclusions

This paper attempts to explore the factors causing waste generation in the construction industry. In pursuit of this objective, a thorough literature review has been conducted to explore major barriers to poor waste control practices, and based on the most frequent barriers, a questionnaire was prepared. On the collected data, SI was performed to identify significant barriers. It is found that:

- At macro level barriers include non-availability of environmental bylaws, lack of financial support from governments, and lack of awareness among industry stakeholders are significant barriers. Further, at micro level barriers for waste control are illogical design, poor construction practices, and shortage of resources.
- In order to overcome the barriers, significant strategies to control waste are development of policies, awareness among stakeholders, business models to support recycled materials and governmental support in the form of providing subsidize.

The findings of current study will not only highlight the major barriers to waste control culture in local industry but also provide a way forward for local stakeholders about how to overcome these barriers. Further, this study will also add more value to the efforts of country in achieving the sustainable development goals as well. The study has few limitations. The study focuses on 40 barriers which may not address all issues in large-scale projects. The severity index, while successful, might be supplemented with advanced analytical approaches such as regression analysis or multi-criteria decision-making procedures to provide more exact rankings and deeper insights.

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Abbreviations

The following abbreviations are used in this manuscript:

WM	Waste minimization
CE	Circular economy
SI	Severity Index
BIM	Building information modelling

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