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An insight about the enablers for waste management culture in construction sector †

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Abstract: Construction industry is growing day by day due to the immense need of infrastructure and development projects in developed as well as developing countries. At the same time, it is generating millions of tons of waste during execution of these projects. In total construction waste, half of the waste comes from building projects. So, the importance of waste control on construction and especially on building projects can be imagined. In this regard, a comprehensive literature was conducted based on fifty shortlisted and most relevant papers from prestigious journals of construction management. Then frequency analysis was conducted. Based on the results, significant enablers at macro as well as micro levels in the construction industry were identified.

Keywords: Enablers, Waste generation, Construction waste control practices, Circular economy

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1. Introduction

The massive urbanization and development projects over the course of past ten years, have significantly increased the number of construction activities throughout the world [1]. On average, construction industry contributes around 10% of the economic growth of a country and also provides employment [2]. Since construction industry consumes natural resources, so, it significantly affects the reserves of these resources [3]. It was estimated that around 200 million tons waste was generated in the UK, where 59% of that waste was of construction waste [4]. Likewise, around 2 billion tons of construction waste was generated in China on yearly basis [5] and around 40% of the construction waste comes from building sector. All this because of linear economy practices in construction industry. Therefore, construction industry required to put some efforts to reduce the waste and bring systematic changes in order to adopt circular economy practices. Circular economy allows the materials to be utilized up to their maximum capacity through 3 R's principle (reduce, reuse and recycle).

So, a comprehensive literature review was conducted to identify the major enablers of circular economy practices and construction waste management. For this review process, fifteen different journals were consulted. Some of the most important journals among them were "Waste Management", "Automation in Construction", "Resources, Conservation and Recycling", "Journal of Cleaner Production" and "Journal of Waste Management and Research". Initially, ninety (90) different research papers were retrieved for a period of 2000 to early 2023. Among these publications, approximately fifty (50) journal articles were closely related to the current study. Findings of this research are presented in following sections.

2. Enablers for Construction Waste Minimization

Major principles of waste minimization in this study mean 5 R's (reduce, reuse, recycling, repurpose and recover), while circular economy (CE) are based on 10R's (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover) [32]. So, it can be said that concept of waste minimization in this study, is just a part of broader concept of CE. Circular economy is the ultimate objective of waste minimization efforts which are being adopted on construction projects. There are number of approaches which have been used to reach out the goal of waste control. Among those approaches, zero waste approach is one of the most practiced approaches worldwide. It prohibits incineration and landfills in general, zero waste aspires to use waste-to-energy technologies. However, the zero waste concept still needs to be broadened to reach its widespread applicability. Similarly, other approaches include lean construction, site waste management and green grading systems [33].

So, in continuation to these approaches number of waste control strategies which are being reported in past literature, can be categorized into two major sections. One is the external strategies and other is internal ones. Internal strategies mean the practices which will be followed at micro (project) level during design, construction and post construction phases of a project. Here, the use of modern tools such as building information modelling, geo-informatic system and radio frequency identification had shown some significant results for waste control in past studies. While external mean those practices which are enforced at macro level like national, governmental and industrial levels. It is considered that enablers at macro level will be in form of policies, rules and regulations. So, these policies will force the local stakeholders to adopt waste control strategies at project level for compliance purpose [31]. Detailed discussions have been made on each of these categories based on the analysis of past literature. So, macro and micro level efforts can be categorized as external and internal strategies respectively.

3. External Strategies

External strategies mean which will be implemented at national and industrial levels. These strategies are important because, it forced the local stakeholders to follow the waste control plans on their projects. External strategies exist at macro level. For this, a frequency analysis of past literature was conducted and significant enablers for waste management practices are given in Table 1. More frequency means, more important that factor will be for waste minimization on a construction project. In this table frequency of factors lies within the range of 4-11. Since these studies considered the literature from different countries around the globe. So, it can be established that these factors are considered as important enablers for waste control at global level.

Table 1. External strategies for waste control

Rank	Enabler Name	Frequency	References
1	Financial Support	11	[6]
2	Education and training	9	[7-8]
3	Legislation	8	[9]
4	Designated public and landfill areas	6	[10]
5	Business Model	5	[11, 12]
6	Cultural Awareness	5	[13]
7	Recyclable infrastructure	5	[14]
8	Environmental standards	5	[15,16]
9	High cost for waste disposal	4	[17]
10	Information Management system	4	[18]

Based on the frequency analysis, most significant enablers are financial support from governments in the form of subsidize, tax relaxations and easy loans to setup the businesses like building recycled materials market. Next important strategy is education and training of the stakeholders and community of construction industry to follow waste control guidelines in their organizations. Further, legislation and bylaws formulation and its implementation is very important, because it force the local actors of construction industry to avoid waste generation otherwise, severe penalties and fines would be imposed to the company. Similarly, business models which encourage the waste management culture, required to be established like recycling plants, market for recycled materials, waste collection and sorting units, etc. Other important factors include building environmental standards, imposing heavy fines for waste disposal in open spaces and information management system for locating landfill sites and recycling plants.

4. Internal Strategies

Internal strategies mean which will be implemented at micro (project) level like during planning, construction and post construction phases of a project. Among these phases, most important phase is planning phase, because, this is where waste can be cut off from its source. Once this stage passed, waste which may have controlled through vigilant design, can not be reduced in later stages of the project. Then comes the construction phase where, reduce and reuse techniques are applied simultaneously. At last, recycling of wasted materials is ensured in post construction phase of a project. In this regard, most frequently occurring enablers at micro levels are identified. Details of these enablers are given in Table 2. In this table, frequency values varies within a range of 2-14. More frequency means more important that strategy is.

Table 2. Internal strategies for waste control

Rank	Enabler Name	Frequency	References
1	Use of latest tools	14	[19-20]
2	Modular design options	8	[21]
3	Waste auditing	7	[22]
4	Construction practices	6	[19]
5	Waste handling requirements	5	[22-23]
6	Fewer design changes	5	[19, 24]
7	Reuse of materials	5	[23]
8	Attitude of workforce	4	[21-22]
9	Site waste management plans	3	[10]
10	Contractual binding	3	[23-24]
11	Avoid irregular ordering issues	2	[10]
12	Storage of materials	2	[21]

13	Incentive Reward Program (IRP)	2	[25]
14	Skilled labour	2	[26]

Then use of modular design where standard size materials are referred in design, so less waste is generated on sites due to cutting. Next is the waste auditing, where initial targets are set by organizations about waste control on each project, then it is analyzed how much waste is reduced in comparison to original plan. At fourth position is the construction practices which contractors use on sites during execution of different tasks like use of prefabricated elements, strict supervision on waste generation activities and materials, etc. Similarly, other important strategies on a project are few design changes, so rework is reduced. Then contractual binding of contractors would improve the practices of labour to generate less waste on construction sites. Further, IRP and skilled labour are also considered as significant enablers to achieve circular economy goals through construction waste management.

4.1. Tools and Techniques:

Important strategies at micro level in construction industry for waste control include use of latest tools such as building information modelling (BIM), go-informatics system (GIS) and radio frequency and identification (RFID). By using these tools on a project, substantial amount of waste was saved in different studies [19-20]. BIM used to save substantial amount of construction waste during design and construction phases of the project [27-28]. While, RFID is an effective tool to control waste during construction phase through record keeping of inventory of materials [29}. Similarly, GIS is used to manage the waste at post construction phases. It helps to locate the designated landfill areas, recycling units and recycled materials markets [30]. So, by using these latest tools, large amounts of construction wastes can be controlled.

5. Conclusions

Construction industry required to move towards circular economy by adopting external and internal strategies for waste control. For this, studies across the globe were consulted and frequency analysis was conducted. Major findings include following:

- Major principle of waste minimization on construction projects are 5 R's while CE includes 10 R's. So, it can be established that efforts for waste minimization is a part of

broader concept of CE. Further, enablers for waste minimization can be divided into two major categories such as external and internal strategies.

- Important external strategies which were identified after frequency analysis are financial support, legislation, business models and education are found as most important strategies at macro levels. All these strategies would enforce and motivate the local stakeholders to take serious the issue of waste control.

- In terms of internal strategies, modular design options, better construction practices, waste auditing & monitoring and reuse of materials are considered as significant strategies which must be followed on a project. Similarly, use of latest tools such as BIM, RFID and GIS can be helpful to reduce and manage waste during design, construction and post construction phases of a project.

Considering the above findings, construction industries are required to put some efforts to convert these guidelines into meaningful bylaws and implement these strategies in their respective industries. Therefore, future research must focus on developing the policy frameworks for developing as well developed countries.

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