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# An Insight into the Enablers for Waste Management Culture in the Construction Sector †

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**Abstract:** The construction industry is growing day by day due to the immense need for infrastructure and development projects in developed as well as developing countries. At the same time, millions of tons of waste are generated during the execution of these projects. In total construction waste, half of the waste comes from building projects. So, the importance of waste control in construction and especially in building projects can be imagined. In this regard, a comprehensive literature review 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 the 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 amount of urbanization and development projects over the course of the past ten years have significantly increased the number of construction activities throughout the world [1]. On average, the construction industry contributes around 10% of the economic growth of a country and also provides employment [2]. Since the construction industry consumes natural resources, it significantly affects the reserves of these resources [3]. It was estimated that around 200 million tons of waste were generated in the UK, where 59% of that waste was construction waste [4]. Likewise, around 2 billion tons of construction waste is generated in China on a yearly basis [5] and around 40% of the construction waste comes from the building sector. All this is because of linear economy practices in the construction industry. Therefore, the construction industry is required to put some effort into reducing waste and bringing systematic changes in order to adopt circular economy practices. A circular economy allows the materials to be utilized up to their maximum capacity through the three R's principle (reduce, reuse, and recycle).

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, 90 different research papers were retrieved from the period from 2000 to early 2023. Among these publications, approximately 50 journal articles were closely related to the current study. The findings of this research are presented in the following sections.

## 2. Enablers for Construction Waste Minimization

The major principles of waste minimization in this study include five R's (reduce, reuse, recycling, repurpose, and recover), while a circular economy (CE) is based on 10 R's (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and

recover) [6]. So, it can be said that the concept of waste minimization in this study is just a part of the broader concept of CE. A circular economy is the ultimate objective of the waste minimization efforts that are being adopted on construction projects. There are a number of approaches that have been used to reach the goal of waste control. Among those approaches, the 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 widespread applicability. Similarly, other approaches include lean construction, site waste management, and green grading systems [7].

So, in the continuation of these approaches, a number of waste control strategies that have been reported in past literature can be categorized into two major sections. One is external strategies and the other is internal strategies. Internal strategies are practices that will be followed at the micro (project) level during the design, construction, and post-construction phases of a project. Here, the use of modern tools such as building information modeling, geo-informatic systems, and radio-frequency identification have shown some significant results for waste control in past studies. External strategies are practices that are enforced at the macro level like national, governmental, and industrial levels. It is considered that enablers at the macro level will be in the form of policies, rules, and regulations. So, these policies will force the local stakeholders to adopt waste control strategies at the project level for compliance purposes [7]. 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 those that will be implemented at national and industrial levels. These strategies are important because they force the local stakeholders to follow the waste control plans on their projects. External strategies exist at the macro level. For this, a frequency analysis of past literature was conducted and significant enablers for waste management practices are given in Table 1. The greater the frequency, the more important that factor will be for waste minimization on a construction project. In this table, the frequency of factors lies within the range of 4–11. These studies considered the literature from different countries around the globe, so it can be established that these factors are considered important enablers for waste control at the global level.

**Table 1.** External strategies for waste control.

| Rank | Enabler Name | Frequency | References |
|---|---|---|---|
| 1 | Financial support | 11 | [8] |
| 2 | Education and training | 9 | [9,10] |
| 3 | Legislation | 8 | [11] |
| 4 | Designated public and landfill areas | 6 | [12] |
| 5 | Business model | 5 | [13,14] |
| 6 | Cultural awareness | 5 | [15] |
| 7 | Recyclable infrastructure | 5 | [16] |
| 8 | Environmental standards | 5 | [17,18] |
| 9 | High cost for waste disposal | 4 | [19] |
| 10 | Information management system | 4 | [20] |

Based on the frequency analysis, the most significant enablers are financial support from governments in the form of subsidies, tax relaxations, and easy loans to set up businesses like building recycled materials markets. The next most important strategy is the education and training of the stakeholders and community of the construction industry to follow waste control guidelines in their organizations. Further, legislation and bylaw formulation and implementation are very important, because they force the local actors of the construction industry to avoid waste generation; otherwise, severe penalties and fines would be imposed on the company. Similarly, business models that encourage

waste management culture are required to be established like recycling plants, markets 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 systems for locating landfill sites and recycling plants.

## 4. Internal Strategies

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

**Table 2.** Internal strategies for waste control.

| Rank | Enabler Name | Frequency | References |
|---|---|---|---|
| 1 | Use of latest tools | 14 | [21,22] |
| 2 | Modular design options | 8 | [23] |
| 3 | Waste auditing | 7 | [24] |
| 4 | Construction practices | 6 | [21] |
| 5 | Waste handling requirements | 5 | [24,25] |
| 6 | Fewer design changes | 5 | [21,26] |
| 7 | Reuse of materials | 5 | [25] |
| 8 | Attitude of workforce | 4 | [23,24] |
| 9 | Site waste management plans | 3 | [12] |
| 10 | Contractual binding | 3 | [25,26] |
| 11 | Avoid irregular ordering issues | 2 | [12] |
| 12 | Storage of materials | 2 | [23] |
| 13 | Incentive Reward Program (IRP) | 2 | [27] |
| 14 | Skilled labor | 2 | [28] |

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

### *Tools and Techniques*

Important strategies at the micro level in the construction industry for waste control include the use of the latest tools such as building information modeling (BIM), geo-informatics systems (GIS), and radio-frequency identification (RFID). By using these tools on a project, a substantial amount of waste was saved in different studies [21,22]. BIM is used to save a substantial amount of construction waste during the design and construction phases of the project [29,30]. Meanwhile, RFID is an effective tool to control waste during the construction phase through record keeping of an inventory of materials [31]. Similarly, GIS is used to manage the waste in post-construction phases. It helps to locate the designated

landfill areas, recycling units, and recycled materials markets [32]. So, by using these latest tools, large amounts of construction waste can be controlled.

## 5. Conclusions

The construction industry is required to move towards a 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 the following:

- The major principle of waste minimization on construction projects includes five R's while CE includes 10 R's. So, it can be established that efforts for waste minimization are part of the 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 that were identified after frequency analysis are financial support, legislation, business models, and education were found to be the most important strategies at macro levels. All these strategies would enforce and motivate the local stakeholders to take the issue of waste control seriously.
- In terms of internal strategies, modular design options, better construction practices, waste auditing and monitoring, and reuse of materials are considered significant strategies that must be followed on a project. Similarly, the use of the latest tools such as BIM, RFID, and GIS can be helpful in reducing and managing waste during the design, construction, and post-construction phases of a project.

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

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