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An Overview of Construction Waste Management

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ABSTRACT. *The need of construction projects is increasing day by day in developing countries to improve and build new infrastructures. Due to massive procurement of materials on these projects, significant amount of waste is generated. This waste has substantial impacts not only on project cost but also on the environment. So waste measurement and its source of generation would be the first initiative to control these wastes. In this regard, around sixty (60) papers were reviewed to determine the most wasteful materials based on past papers literature. Further, to determine the barriers in waste management, frequency analysis was performed. Based on these analysis it was found that design changes, procurement problems, theft and vandalism, etc. are major sources of waste generation. Further, out of twenty five (25) materials, most wasteful were wood, steel, bricks, concrete, tiles, sand, cement and ceiling boards. Moreover, major barriers in waste management are inappropriate regulations, financial issues, lack of standards and lack of awareness programs. So to promote suitable construction, waste management practices must be followed, in this regard more studies are required to focus in developing a comprehensive waste management framework.*

Keywords: construction waste, building industry, sustainability, causes, barriers in waste management

1. INTRODUCTION

Construction industry is best known for contributing to the economic growth of any country. On average it is accounted for 5-15% towards GDP of a country [1, 2]. But such significant output does not come cheap. Construction industry is one of the largest resource consumers. [3] states that approximately 40% of the materials are used in building construction. With such massive consumption and production of equally massive waste, construction processes are infamous for their lower efficiency [4]. Thus construction industry has negative impact on the environment due to generation of onsite waste and production material [5]. A staggering 40% of total global waste is due to the building industry, closely followed by household waste (36.73%), and market and commercial waste (21.54%) [6]. About 1-10% of purchased material by weight are left on site as a waste in construction industry [5]. According to a report of Eurostat, almost two billion tonnes of waste is generated by construction industry and its contribution to the total waste is 31% [7]. Material waste is generated at different stages of the project including design, estimation, planning and construction.

Some of the major sources of construction waste are design, procurement, material handling, operation, residual and others [8]. So, construction waste minimization techniques have substantial impacts on waste reduction [9]. [10] used BIM for planning of tiles algorithm to design out the waste through proper selection of cutting and reduced the waste by around 14% in comparison to traditional methods. But studies have shown that there are barriers which significantly the hinder the adaptation of waste management methods. In this context, major barriers that are identified are poor supervision, lack of communication, lack of awareness, lack of commitment, ineffective management, lack of national vision, insufficient funding, and the lack of legal arrangements [11]. Similarly, poor implementation of rules and regulation of waste management, lack of commitment from industry and lack of awareness about sustainability also contributes towards waste generation [12]. So, overcoming these barriers will promote the waste management culture, reduce environmental impacts and encourage sustainable constructions worldwide.

For a comprehensive literature review on the state of material waste throughout a period from 1996 to early 2023, a proper retrieval process of research papers was used. A total of 15 different journals were searched, the most important journals among them were "Journal of Construction Engineering and Management", "Automation in Construction", "Waste Management", "Resources, Conservation and Recycling", and "Building and Environment". Initially more than 100 papers were retrieved by searching keywords in the title and abstract, then a filtering process was adopted as some of these papers were related to other waste. This research finally draws up around sixty (60)

research papers that were closely related to the sources of waste generation and its quantification. Results of this study are presented in following sections.

2. SOURCES OF WASTE GENERATION

Substantial sources of waste generation which are reported in different research studies are presented in Table 1. These sources have other root causes such as procurement on construction sites without proper planning always an issue of multiple problems. Issues of over ordering and under ordering cause waste, since more material reached on site and then when it is not used it is wasted. Similarly, when less material is ordered then number of trips increased to fulfil the requirement of quantities. In this way more number of times or chances of material waste during loading and unloading of materials.

Similarly, design changes occur in most of the projects when detailed design drawings are not prepared at start. When design changes during currency of project, it causes rework and ultimately cause waste generation. Another scenario of it is, change in design may change the materials type and if material is already purchased as per previous design then it will also cause waste generation. Further, workforce attitude vary country to country and industry to industry.

Other factors which affect the behavior of workforce are their knowledge, skills, experience, age and moral values. All these are important in waste control or generation. Moreover, material storage of those materials which are chemically active such as cement, paints, etc. is very important on construction sites. Because if these kind of materials are not stored properly then there are chances of these materials to be wasted completely. Sites with no or few security protections are more prone to this cause of material lost. Theft is considered one of the factors of waste generation since the material is lost as result of this action.

Table 1: Sources of Material Waste Generations

Sr. No.	Sources of waste generations	Root causes	References
1	Poor handling of materials	loading and unloading, improper handling during transportation, negligence of labours	[13-16]
2	Procurement Issues	issues of over ordering and under ordering, improper planning of procurement	[17]
3	Design Changes	absence of detailed design drawings at start	[18]
4	Behaviour of Workforce	workforce attitude, lack of ownership, moral values	[19]
5	Issues of Material Storage	rains, heat, fog	[14, 16, 20]
6	Theft	non-availability of security personnel and fencing	[14, 16].

3. MATERIAL WASTE GENERATION IN PAST YEARS

There are number of quantitative studies which measure material waste generated in building industry during execution. Some of these studies measure waste as percent of purchased material as shown in Table 2. These studies include the research from developing and developed countries.

Materials wastes are measured by different methods such as waste percent as purchased or designed material, material lost per unit area and material waste per unit volume. It is synthesized that maximum variation in waste generation among these studies are found in sand (28.8-7.0 = 21.8%), wood (36.2 – 6.41 = 29.79%) and reinforcement (19.03 – 4.5 = 14.53%). This much variation in waste generation can be due to the change of methodology in waste measurements, different construction practices and workers behaviour and non-availability of skilled labour. All these factors could be the difference for such variation of waste generations around the globe.

Further, it can also be observed that waste generation rates of tiles, reinforcement, concrete blocks and ceiling boards and bricks are relatively lower in Pakistan as compare to other construction industries over the globe. The major reason is that these materials are constructed by using labour with materials (L-M) subcontracting arrangement [24]. While the other materials such as sand and mortar are normally follow the direct labour (D-L) subcontracting arrangement, due to which more materials is wasted. Also these materials are relatively cheap so contractors do not bother about their waste [24]. In addition, use of prefabricated elements, use of modern tools such building information modelling to design out waste, online waste share, wide application of digitalization through geo-informatics system (GIS) are some of the major methodologies which are adopted over times which affected the waste generation rates significantly [30-32]. Moreover, the concept of circular economy, zero waste generation, lean constructions and green buildings emerged in 20th century to eliminate the waste out of construction process.

Table 2: Material Waste as a Percent of Purchased/Designed Material

Material	**[21]**	**[22]**	**[23]**	**[24]**	**[25]**	**[26]**	**[27]**	**[28]**	**[29]**
Stone Tablets	15.14%	-	-	-	-	-	-	-	-
Concrete	16.76%	-	5.00%	-	8.99%	4.10%	5.61%	14.13%	-
Sand	20.98%	-	-	28.8%	-	-	-	-	7.00%
Tiles	15.57%	-	8.00%	13.5%	15.58%	7.40%	6.68%	21.38%	6.00%
Mortar	-	-	3.00%	-	-	-	6.63%	14.91%	7.00%
Packaging	-	-	-	-	-	16.30%	-	-	-
Bricks	-	-	3.00%	13.7%	8.90%	11.30%	6.82%	14.15%	8.00%
Metal	-	17.1%	-	-	-	3.90%	3.61%	-	-
Wood	19.49%	51.2%	-	36.2%	20.00%	13.90%	6.41%	-	-
Reinforcement	16.91%	-	5.00%	4.5%	7.70%	-	4.76%	19.03%	8.00%
Cement	18.34%	-	-	-	-	7.80%	-	-	6.00%
Blocks	17.05%	-	-	14.5%	-	-	-	-	-
Paint	-	-	-	-	-	-	6.00%	12.95%	5.00%
Plastic pipes	-	8.1%	-	-	-	-	4.95%	15.70%	-
Ceiling Boards	20.70%	-	-	13.6%	-	-	4.32%	15.70%	-

4. BARRIERS IN WASTE MANAGEMENT

In the past, construction waste quantification and measurement remained an area of research for a long time but with the increase of environmental issues day by day, waste management is considered a potential area of study in developing as well as developed countries. Number of studies have been conducted to identify the major barriers in implementing waste management strategies as shown in Table III. It can be synthesized that most of these barriers are related to lack of awareness, non-availability of standards for waste management, financial issues and lack of support from governments. So comprehensive framework and policies are required to overcome these barriers and promote sustainable constructions.

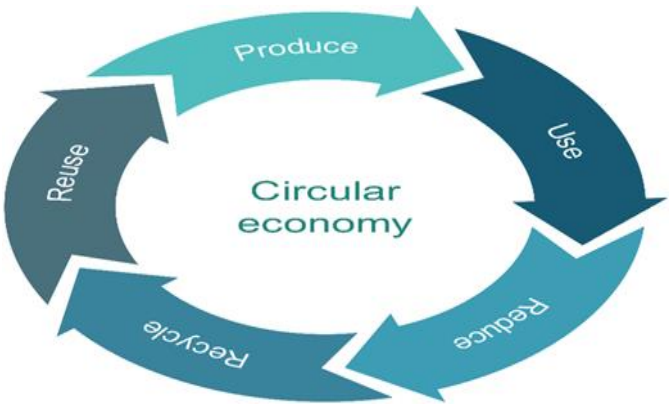

Fig-1: Circular Economy Model

One of the concept of waste control is circular economy which is very much in, these days. It is believed that resource utilization must be ensured throughout its life. In Figure 1 it can be observed that materials are produced at production unit then they are used at construction sites where it is made sure that waste is reduced through vigilant waste minimization methods. Those materials which are wasted on sites are sorted out and brought to the recycling units. When materials are recycled, they become reusable again.

Table 3: Potential Barriers to Implement Construction Waste Management

Sr. No.	Barriers Name	Details of Barrier	References
1	Financial issues	Lack of funding from governments, Insufficient financial support from client	[11], [33-38]
2	Technical difficulties	Non-availability of recycling equipment, Lack of waste collection mechanisms	[33-38]
3	Operational weaknesses	Lack of tracking of dumping sites, deficiency of dumping machines	[33-36], [38]
4	Inappropriate regulations	Non-availability of environmental regulations, Absence of waste management policies	[12], [33, 34], [38-44]
5	Lack of awareness	Lack of trainings and education	[11], [38], [40, 41], [43]
6	Lack of standards	Absence of waste management policies	[33-35], [39, 40], [43]
7	Economic incentives	No mechanism for reward and bonus for waste control	[34], [38], [40], [42] , [44]
8	Lack of collaboration	Poor communication among different departments	[34], [44]
9	Low virgin materials	Virgin material availability is limited	[34, 35], [43]
10	Costly recycled material	Recycled materials are more costly than virgin materials due to operational cost	[35], [39]
11	Lack of education and training	Training and education is limited	[37-39], [42]
12	High upfront cost	Capital cost of investment for recycled materials is very high	[35], [40, 41]
13	Lack of support from Governments	No subsidize from governments for following waste management policies	[36], [45]
14	Lack of environmental standards	Few environmental regulations for waste control	[36], [39], [46]
15	Health and Safety issues	Non-inert materials such as concrete can be harmful for environment through leaching	[42]

5. THERORATICAL WAY FORWARD TO OVERCOME BARRIERS

A way forward to overcome these barriers which construction industries are facing all over the world is only possible if efforts are being made at government as well as at industry level. Governments are required to formulate environmental policies, provide funds to support environmental programs and subsidize the projects having proper waste management plans to promote sustainable constructions. Similarly, industry is required to follow these regulations and policies on construction sites. Change workers behavior through incentives and bonuses. Clients are required to ensure each project has a waste management plan and contractors are also following it on sites. These kind of initiatives will develop a sense of sustainable construction among industry stakeholders.

6. CONCLUSION

In order to move from traditional construction methods to sustainable constructions, there was a need to get an overview of the studies related to waste generation's rates and barriers to waste management strategies over the globe. Therefore, around sixty papers were retrieved from different prestigious journals and based on frequency analysis, results were presented.

Major findings of this study are:

- Sources of waste generation on site are improper handling of materials, change in design, procurement problems, workforce, wrong material storage, theft, and vandalism.
- Wood, mortar, bricks, steel reinforcement, concrete, concrete blocks, tiles, ceiling boards, cement and sand are the most wasteful materials in terms of waste quantity and its impact on cost.
- Key barriers for waste management are found as inappropriate regulations, financial issues, lack of standards and lack of awareness programs in this regard.
- Formulation of policies, regulations and availability of funds to support environmental project by government will help to promote sustainability in construction industry.

Considering the above sources of waste generations, quantities of wasteful materials and barriers to waste management, future researches should focus on the development of frameworks to promote waste management culture for construction industries. Since waste management do not only have significant impact for cost reduction of project but also improves the efficiency of these materials and reduce environmental impacts to encourage sustainability in construction industry.

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