Optimizing Waste Management in Construction: A Policy Development Approach for Sustainable Practices

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Abstract

The construction industry is pivotal in advancing infrastructure but also contributes significantly to environmental degradation through waste generation. This research investigates waste management practices in three construction projects in Chittagong, Bangladesh, aiming to develop a feasible waste management policy. Through a rigorous analysis of site-specific data, the study identifies the types and quantities of waste generated and evaluates existing waste management practices. The paper proposes a policy focused on reducing waste through strategic planning, efficient resource utilization, and enhanced recycling efforts. While the study provides a foundational policy framework and contributes to sustainable construction practices, it also acknowledges its limitations due to the sample size and geographical focus. Future research directions include broader application and longitudinal studies to assess the policy's impact, integration of advanced technological tools for waste tracking, and a more in-depth stakeholder analysis to foster inclusive and comprehensive waste management solutions. This work serves as a stepping stone towards more sustainable construction practices, with implications for environmental, economic, and regulatory aspects of construction waste management.

1 Introduction

Construction waste management is essential in today's building industry. It involves handling, recycling, and disposing of materials left over from construction (Ginga et al., 2020). This process is crucial for environmental and economic reasons. Waste in construction can be materials, debris, or by-products (Panizza et al., 2020). The aim is to minimize waste and its impact. This includes reusing materials and reducing waste at the source (Lamba et al., 2022). Effective waste management can lead to cost savings and sustainability in construction (Daoud et al., 2023). It also aligns with global efforts to reduce environmental harm (Shahid et al., 2023). The importance of waste management in construction is multifaceted. It plays a key role in environmental conservation by reducing landfill waste (Saeed & Yas, 2023). Managing construction waste effectively reduces the industry's ecological footprint, promoting sustainability (Shahid et al., 2023). It also enhances resource efficiency by recycling and reusing materials (Lamba et al., 2022). Economically, efficient waste management can lower project costs through reduced material consumption and disposal fees (Rosli et al., 2023). Moreover, it aids in compliance with legal and environmental regulations, preventing penalties (Shahid et al., 2023). These factors underscore the critical role of waste management in the construction industry's future. The research aims to optimize construction waste management. It seeks to identify efficient waste reduction strategies, focusing on sustainability and cost-effectiveness. The objectives include analyzing current waste levels, evaluating the effectiveness of existing waste management practices, and proposing innovative solutions. The research contributes to the field by providing a detailed analysis of waste in construction, including interior waste, and a comprehensive waste management policy tailored to real-world scenarios. These contributions will aid in reducing environmental impact and promoting sustainable practices in the construction industry. This study is significant for practitioners and policymakers, offering insights for improving waste management in construction projects.

2 Literature Review

The literature review on existing waste management practices in construction reveals a multifaceted approach. Research highlights the significant role of waste hierarchy – reduce, reuse, recycle – in managing construction waste (Küpfer et al., 2023). Studies emphasize reducing waste at the source, advocating for sustainable design and material selection (Nawaz et al., 2023). Reuse and recycling practices are also widely discussed, with a focus on repurposing materials and waste-to-energy conversion (Rezania et al., 2023). Furthermore, technological advancements, such as Building Information Modeling (BIM), have been identified as key in improving waste management efficiency (Ismaeel et al., 2023). Policy and regulatory frameworks also play a critical role, enforcing guidelines and encouraging sustainable practices (Daoud et al., 2023). These diverse practices underline the evolving nature of waste management in the construction industry. The challenges in construction waste management are diverse and complex. One primary issue is the lack of awareness and understanding of waste management's importance among stakeholders (Ramos et al., 2023). This often leads to inadequate planning and implementation of waste management strategies. Another challenge is the varying nature of construction waste, which requires different handling and disposal methods (Ismaeel et al., 2023). Financial constraints also pose a significant barrier, as waste management can incur additional costs (Rosli et al., 2023). Regulatory challenges, including varying local and national waste management regulations, complicate standardization and enforcement (Rondinel-Oviedo, 2023). Additionally, technological limitations, such as the lack of advanced tools for waste tracking and sorting, hinder efficient waste management (Peng et al., 2023). Resistance to change, particularly in adopting new and sustainable waste management practices, is also a notable challenge (Rondinel-Oviedo, 2023). Furthermore, the construction industry's project-based nature makes consistent waste management practices difficult to maintain (Peng et al., 2023). Lastly, logistical issues, such as transportation and storage of waste materials, add to the complexity of waste management in construction (Ramos et al., 2023). The literature review highlights the complexities and challenges in construction waste management, indicating a need for improved implementation and technological progress. This gap underscores the necessity for creative and hands-on solutions. Our proposed work aims to create a waste management policy that is specifically designed to address the current challenges. We will use real-world data and practices to ensure that the policy is effective in reducing waste and promoting sustainable construction methods.

3 Data Collection

To get data for this study, detailed information was gathered from three building projects run by a company in Chittagong, Bangladesh. The data covered different aspects of construction waste produced at these sites. For data collection, we utilised various methods such as conducting on-site observations, gathering waste records, and conducting interviews with project managers and workers. This method allowed for a thorough grasp of waste generation and management practices. Every project site offered valuable insights thanks to differences in size, design, and management, resulting in a comprehensive dataset for analysis. The data was carefully calculated and recorded, serving as the foundation for the waste analysis and policy development that followed. The analysis of collected data involved a detailed examination of the volume and nature of materials wasted, such as concrete, wood, metal, and packaging. The data was analyzed to identify patterns in waste generation, including factors contributing to waste, such as construction methods and material handling. Comparisons were made across the three sites to understand the variability in waste generation and management practices. This analysis provided a comprehensive understanding of the current state of waste in these construction projects, laying the groundwork for developing effective waste management strategies tailored to these specific contexts.

4 Analysis of Construction Waste

The analysis of waste generation data provides a comprehensive overview of construction waste in the three project sites in Chittagong, Bangladesh. The data was meticulously analyzed to understand the types and quantities of waste produced. This included common construction materials like concrete, wood, and metal, as well as other waste forms like packaging materials. By examining the waste generation patterns, it was possible to identify key areas where waste could be minimized. The analysis also highlighted the efficiency of current waste management practices at each site. This detailed examination is crucial for developing targeted strategies to reduce waste and improve overall sustainability in construction projects.

Sl	**Name of Item**	**BoQ Estimate**				**Physical Consumption**				**Wastage Percentage**
		Unit	Q.	Rate	Total (tk)	Q.		Rate	Total (tk)	
1	MS Rod	296,623	kg	95	28,179,185	302,677	kg	95	28,754,315	2
2	RMC	47,751	cft	300	14,325,300	47,992	cft	300	14,397,600	0.5
3	Cement	157094	cft	500	78,547,000	16,030	cft	500	8,015,000	2
4	3/4" stone	22,371	cft	210	4,697,910	22,828	cft	210	4,793,880	2
5	1/2" stone	8,050	cft	200	1,610,000	8,215	cft	200	1,643,000	2
6	Bricks	441,368	nos.	15	6,486,782	445,827	nos.	15	6,687,405	3
7	Medium Sand	43,551	cft	16	696,816	48,391	cft	16	774,256	10
8	Sylhet Sand	89,694	cft	90	8,072,460	11,074		90	996,660	10
9	Floor Tiles	321,584	sft	150	48,237,600	338,510	sft	150	50,776,500	5
10	Wall Tiles	20,905	sft	75	1,567,875	20,914	sft	75	1,568,550	9
Total					**192,420,928**				**118,407,166**	

Budget increased due for Wastage	**(74,013,762)**	**Tk**	**3.84 % Budget increased**

Table 1. Major Materials Wastage Percentage Calculation

The provided data (Table 1) details the waste analysis of a 10-storied residential building project in Chittagong, Bangladesh. The land and construction areas are 10.55 and 50,980 square feet respectively, housing 16 apartments with two apartments per floor. The apartments vary in size between 2980 and 3120 square feet. The waste items analyzed include MS Rod, RMC, Cement, Stones of various sizes, Bricks, Sands from different sources, Floor Tiles, and Wall Tiles. Each item's estimated quantity, rate, and total cost are juxtaposed with actual consumption, highlighting the percentage of wastage. For instance, MS Rod has a wastage percentage of 2%, while Sylhet Sand reaches 10%. The overall budget increased by 3.84% due to wastage, which translates to a financial impact of over 74 million Taka. This meticulous data serves as a foundation for our work, emphasizing the need for optimizing waste management in construction to achieve economic and environmental benefits.

SL	Materials Name	Materials Quantity	Wastage	Materials Quantity With Wastage	Material rate(Per Unit)	Material cost(TK)	Labor Rate	Labor Cost	Total Amount(TK)
1	Brick	6000 nos	3%	60180 nos	15	92700	18	21600	1,14,300
2	Cement	20 Bag	2%	21 Bag	450	9450			9,450
3	Sand	144 cft	8%	156 cft	40				6,240
4	Wood	421 sft	5%	442 sft	250	110500	80	8840	1,19,340
5	Stair Railing	60 sft	4%	63 sft	400	25200	100	6300	31,500
6	Grill	112 sft	4%	117 sft	160	18720	940	1100	19,820
7	Thai Aluminum	140 sft	4%	146 sft	350	51100	10	3500	54,600
8	Cable	26 coil	5%	28 coil	5000	140000	70	1960	1,41,960
9	Plaster(Cement,Sand)	2400 sft	2%	20 sft	490	9000	15	36000	50,200
10	Plumbing & Sanitary	Job 1	8%	130 cft					1,30,000
11	Paint	144 liter	3%	149 liter	330	49170	7	21000	7,0170
12	Tiles	1520 sft	5%	1596 sft	100	159600	25	39900	1,99,500
13	Granite	75 sft	1%	76 sft	800	60800	50	3800	64,600
14	Marble	300 sft	2%	306s sft	800	244500	70	21420	2,66,220
15	Foam/Aica		6%						20,000
16	Poly/Broom		7%						25,000
	TOTAL								***13,22,900 tk***

Figure 1. Interior Waste Calculation.

The detailed analysis of interior waste (Figure 1) focuses on the specific waste generated during the interior construction phase. This includes a variety of materials like tiles, paints, woodwork, and plumbing items. The data highlights the quantities used, the estimated wastage percentages, and the financial implications of this wastage. By analyzing this data, we can identify patterns and potential areas for waste reduction. This analysis is critical for developing strategies that specifically target interior construction waste, aiming to enhance material efficiency and reduce the overall environmental impact of construction projects.

The comparative analysis of waste across different construction phases in our study reveals varying patterns of waste generation. Initial phases, such as foundation and structural work, predominantly produce concrete and metal waste. Mid-phase activities, like wall construction and roofing, generate brick and wood waste. The finishing phase, which includes interior work, shows significant waste in materials like tiles, paint, and plaster. This phase-wise analysis is crucial to understanding where waste reduction efforts should be concentrated and helps in tailoring specific strategies for each stage of construction to minimize waste effectively.

5 Proposed waste management policy

The proposed waste management policy focuses on sustainable practices to minimize waste during construction. It includes strategies such as encouraging economical design, controlling inventory, and optimizing supply chain management to reduce over-ordering and supplier errors. The policy also emphasizes on reusing materials, proper documentation, and training to avoid construction mistakes. By implementing these practices, it is expected to significantly reduce the generation of waste across various construction phases, thus achieving cost savings and environmental benefits. The policy aims to apply these strategies to control wastage during structural work, finishing work, and rubbish control, ultimately leading to a more sustainable construction process.

Figure 2. Wastage Control Policy Key Points.

5.1 Responsible Person & Reporting System

In the proposed policy, project personnel have clear roles. The Project Manager, Inventory Head, and others are responsible for waste management. They ensure effective execution of waste reduction strategies. A monitoring team, including members from various departments, will report to higher management. Their reports are essential for tracking progress and making improvements. This ensures accountability at every level, from planning to execution.

5.2 System & Process

Wastage can be controlled by controlling different sectors like design, inventory, and procurement, engineering services, contracting etc. that leads to develop a sustainable and authentic growth in the business. These are summarized with the following points.

Controlling during Planning, Design & Development Management (PDDM)

- To encourage architectural design that results economic structural design.

- Structural design should be economic design rather than over design
- Changes in design during construction result in more wastage. So we should be conscious of changes in design.
- Zero error in architectural and structural design and drafting that is delivered on site will reduce wastage

- Encourage design that produces less wastage. For example, the selection of pattern and size of tiles should be such a way that will save wastage of tiles

Inventory Control

- Proper storing of materials reduces wastage. We have to first and foremost, secure our stores and site Proper storing of materials reduces wastage. We have to first and foremost, secure our stores and site to minimize wastage and theft. Limit the chances of materials being damaged by bad storing.
- Organizing our site will help us to minimize wastage. When site is organized and our team knows where everything is, it will cause us to spend less wastage for less unnecessary materials. When the project is organized properly, fewer mistakes are made which results less wastage.
- Properly quantity and quality checking during receiving materials will reduce wastage.
- Lack of onsite material control and wastage management plan increase wastage. We have to establish onsite procedure for receiving materials, plan for storage in advance and an effective procedure for issuing materials.

Controlled by Engineering Service Management (ESM)

- Less modification, less wastage. The modification should be stopped at a certain time, say, 6 months of the handover deadline.
- After receiving materials at the site, taking reselection of that material increases wastage (these materials may be tiles, marble, bath-ware or CP fitting, electric items and so on…).

Controlled by Supply Chain management (SCM)

- Ordering error. Over-ordering or under-ordering increase wastage
- Supplier`s error. Mistakes in supply increase wastage
- Strong negotiation skills reduce wastage
- Choosing the right vendor/Suppliers wisely reduces wastage

Operation Control

- Reduce construction mistakes, reduce wastage.
- Ordering right quantity and right size materials reduce wastage.
- Reuse materials that are in good condition reduces wastage
- Use of cut piece (waste) rod in ancillary works reduce wastage
- Studying drawing properly, finding out errors if any, getting correction before starting any construction can minimize mistakes and thus reduces wastage.
- Deconstruction instead of demolishing can reduce wastage.

- Design effective materials selection and delivery at site can reduce wastage
- Uneconomical shape of materials, Offcut from cutting material to shape increase wastage.
- Over mixing of materials increases wastage
- Documentation keeping properly at site can reduce mistakes, thus reduces wastage.
- Criminal waste like thefts increases wastage.
- Error in construction documentation and incomplete contact documentation may increase wastage.
- Errors by laborers, malfunctioning of equipment, accidents increase wastage
- Use of incorrect material requires replacement which increases wastage
- Materials are used other than specified needs substitution increases wastage
- Materials are used in access which is not mentioned in BOQ increase wastage
- Materials are used in temporary site maintenance works sometimes increase wastage
- Inferior quality materials that are being changed after fixing increase wastage

Wastage control during Structure work

- Have to fill the periphery area of a project by the rubbish generated from construction rather than filling by the filling sand.
- Ensure extra care to minimize wastage of sand during foundation work as there is a chance of wastage of sand by mixing with mud and water.
- Ensure control over the thickness of slab casting, and over size of vertical concrete members due to bulging during construction.
- Increase the lifetime of shutter by taking care. Reuse shutter many times more than the expectation.
- Ensure minimum thickness of scree ding concrete by proper leveling.

Wastage control during finishing work

- Brickwork: Control the breaking of bricks during unloading from truck, soaking and carrying to different floors. Use broken bricks in brickwork instead of breaking new brick that require quarter or half-size bricks. Improve brickwork quality so that the thickness of plaster becomes 1/2".
- Woodwork: Inferior quality wood requires replacement which increases wastage.
- Grill work & railing work: Taking exact measurements of the opening and making as per design perfectly can reduce wastage. The design also should be cost-effective.
- Electrical work: We have control wastage of cable by keeping minimum extra cable in SDB and switchboard.
- Plaster work (internal): Different dimensions materials of different brands (For example, different brand bricks having variable size) results high thick plaster which increases wastage.
- We have to ensure 1/2" thick plaster on ceiling and ¾" plaster on masonry work by improving quality of RCC and brick work and proper leveling (paya) of plaster work.
- Plasterwork (External): We have to ensure possible minimum thickness in exterior plaster by improving RCC work and brick work and by proper alignment of plaster work.
- Paint & polish work: Ensure coverage area of paint as per SOP.
- Aluminum work: Making the opening of window as per standard size (As per window schedule of drawing) can reduce wastage.

- Minor materials: Accurate BOQ of minor materials like Foam, Aica, polythene, Hessian cloth, stick broom, flower broom etc. can reduce wastage.
- Percentage of wastage control: We have to ensure % of wastage that is defined in the sanmar standard by reducing wastage generation.

Rubbish control

- Minimum dismantling and demolishing generates minimum rubbish.
- Leak proof form work minimize rubbish
- Immediate complete reuse of mortar that scattered during plaster and brick reduces rubbish
- Mixing mortar on plain sheet rather than mixing on RCC main floor will reduce rubbish
- Use of rubbish for back filling(periphery of building) may be the reuse of rubbish.

The implementation of the Waste Management Policy is designed to be a collaborative and structured process, involving key project personnel across various departments. The Project Manager leads the initiative, ensuring that the policy is adhered to from the top down. The Inventory Head and Supply Chain Management team work closely to monitor material usage and ordering processes to prevent excess and reduce waste. Engineering and Service Management, along with Planning, Design, and Development, incorporate waste minimization strategies right from the planning stages. Regular audits by a designated monitoring team ensure compliance and continuous improvement. This systematic approach aims to embed waste management into the core of construction practices, fostering a culture of sustainability within the organization.

6 Conclusion

This research has successfully developed a comprehensive waste management policy tailored for construction projects in Chittagong, Bangladesh. Through meticulous data analysis and policy formulation, it presents actionable strategies aimed at reducing construction waste significantly. However, the study has limitations, including the small number of projects analyzed, which may not fully represent the diverse construction environments. Future work should focus on applying the policy across a broader range of projects and evaluating its effectiveness over the long term. Expanding the scope to include technological innovations and a more diverse stakeholder analysis could further enhance waste management practices. The continuous evolution of sustainable construction methods presents an opportunity for ongoing research in this critical area.

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