National College of Ireland

Project Submission Sheet

Student Name:	Uvabala Gopalakrishnan Packiriswamy		
Student ID:	23191970		
Programme:	Msc.Management	**Year:**	2025
Module:	Dissertation		
Lecturer:	Dr Amit K Chattopadhyay		
Submission Due Date:	15.08.2025		
Project Title:	Study of sustainable strategies of waste management in real estate construction sector in Delhi – India		
Word Count:	14831		

I hereby certify that the information contained in this (my submission) is information pertaining to research I conducted for this project. All information other than my own contribution will be fully referenced and listed in the relevant bibliography section at the rear of the project.
ALL internet material must be referenced in the references section. Students are encouraged to use the Harvard Referencing Standard supplied by the Library. To use other author's written or electronic work is illegal (plagiarism) and may result in disciplinary action. Students may be required to undergo a viva (oral examination) if there is suspicion about the validity of their submitted work.

Signature:	Uvabala Gopalakrishnan Packiriswamy
Date:	12.08.2025

PLEASE READ THE FOLLOWING INSTRUCTIONS:

1. Please attach a completed copy of this sheet to each project (including multiple copies).
2. Projects should be submitted to your Programme Coordinator.
3. **You must ensure that you retain a HARD COPY of ALL projects**, both for your own reference and in case a project is lost or mislaid. It is not sufficient to keep a copy on computer. Please do not bind projects or place in covers unless specifically requested.
4. You must ensure that all projects are submitted to your Programme Coordinator on or before the required submission date. **Late submissions will incur penalties.**
5. All projects must be submitted and passed in order to successfully complete the year. **Any project/assignment not submitted will be marked as a fail.**

Office Use Only	
Signature:	
Date:	
Penalty Applied (if applicable):	

AI Acknowledgement Supplement

Dissertation

Study of sustainable strategies of waste management in real estate construction sector in Delhi – India

Your Name/Student Number	Course	Date
Uvabala Gopalakrishnan Packiriswamy - 23191970	Msc.Management	12.08.2025

This section is a supplement to the main assignment, to be used if AI was used in any capacity in the creation of your assignment; if you have queries about how to do this, please contact your lecturer. For an example of how to fill these sections out, please click here.

AI Acknowledgment

This section acknowledges the AI tools that were utilized in the process of completing this assignment.

Tool Name	Brief Description	Link to tool

Description of AI Usage

This section provides a more detailed description of how the AI tools were used in the assignment. It includes information about the prompts given to the AI tool, the responses received, and how these responses were utilized or modified in the assignment. **One table should be used for each tool used**.

[Insert Tool Name]	
[Insert Description of use]	
[Insert Sample prompt]	[Insert Sample response]

Evidence of AI Usage

This section includes evidence of significant prompts and responses used or generated through the AI tool. It should provide a clear understanding of the extent to which the AI tool was used in the assignment. Evidence may be attached via screenshots or text.

Additional Evidence:

[Place evidence here]

Additional Evidence:

[Place evidence here]

Study of sustainable strategies of waste management in real estate construction sector in Delhi – India

Abstract

This study focuses on the real estate business in Delhi, aiming at gathering insights on the current techniques, stakeholders, and the way GIS is utilized to manage C&D waste, because it is in these pertinent areas that the areas of high concentration can be established. The survey of 60 industry professionals used in this research targeted policy experts, project managers, and contractors, and all of their answers were taken as the main source of data. Statistical analyses (ANOVA, correlation, and Chi-square tests) have revealed substantial correlations, linkages, and associations between stakeholder roles, regulatory efficacy, and waste severity. Mapping through the geographic information system showed places where the concentration of garbage was high, which signaled the inefficiency in the infrastructure and space. Based on the results, it is clear that a lack of adequate enforcement, inadequate recycling facilities, and insufficient coordination between the stakeholders are undermining the overall sustainability of waste management activities in the country. The suggestions include the use of improved enforcement, more decentralized recycling infrastructure, GIS-based monitoring, enhanced training of the stakeholders, and the encouragement of sustainable behavior. The analysis of this case indicates that the building industry in Delhi could take advantage of a more effective, transparent, and sustainable system of waste management when the quantitative analytics and coverage mapping are merged to provide location-specific answers.

Keywords: C&D waste management, Delhi, GIS mapping, stakeholder roles, sustainable construction, statistical analysis, waste hotspots

Acknowledgement

I would like to express my sincere gratitude to all those who contributed to the completion of this research study. My heartfelt thanks go to the participants from the real estate sector of Delhi, including contractors, project managers, site engineers, and developers, for their valuable time and insights that greatly enriched the findings. I also extend my appreciation to my supervisor Dr .Amit K Chattopadhyay for his constant guidance, constructive feedback, and encouragement throughout the research process. Special thanks to my peers and colleagues who provided support in data collection, analysis, and the application of GIS mapping tools. Finally, I am grateful to my family and friends for their unwavering moral support and understanding during the course of this study.

Declaration

I hereby declare that this dissertation entitled “Study of sustainable strategies of waste management in real estate construction sector in Delhi – India” is my own original work and has not been submitted, in whole or in part, for the award of any degree or diploma at any other institution. All sources of information, data, and ideas from other authors have been properly acknowledged and referenced in accordance with academic standards. The findings, interpretations, and conclusions presented in this study are the result of my own independent research and analysis.

Signature: Uvabala Gopalakrishnan Packiriswamy

Date: 11.08.2025

\Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Introduction

Delhi, India and other cities which are going through the process of urbanization depend on the construction industry as a major contributor to their economy and infrastructure development. Unfortunately, construction is also a major generator of waste which adds to the pollution, reduction of resources, and degradation of the environment. The poor handling of construction and demolition (C&D) waste which includes concrete, wood, metals, bricks, and plastics poses significant challenges to managing urban life in a sustainable manner (Sharma *et al.*, 2022). As a country with booming urbanization, India faces these challenges in managing waste in real estate development projects.

As India's capital region, Delhi is an active marketplace for all construction and commercial activities such as erecting new structures or expanding/renovating existing ones. The construction and demolition waste, commonly referred to as C&D waste, has rapidly escalated because of the metropolitan area's population boom and demand for new developed regions (Sharma *et al.*, 2022). Today, due to the need for environmental protection, limited land space, and reduction of carbon emissions from construction activities, open dumping and landfilling as conventional waste management practices are no longer feasible.

There is a recent increase in attention to the important problem of sustainable approaches to waste recycling, material reuse, decomposition, and construction preservation. These practices help reduce the per capita and environmental footprint. In addition to conserving the natural environment and reducing its impact, these approaches also have socio-economic impact by saving funds for material and waste disposal. Also, the 2016 Construction and Demolition Waste Management Rules, along with other legal instruments, have increased the responsibility of the effect of construction activities on the environment in India at the level of the whole country (archive.pib.gov.in, 2020).

Inconsistent and hindered by issues including ignorance, poor infrastructure, and ineffective enforcement mechanisms, sustainable waste management solutions continue to be implemented despite these advancements. The purpose of this research is to examine the present condition of

sustainable waste management techniques in Delhi's real estate building industry, as well as the obstacles, possibilities, and existing practices in this area (Singhal *et al.*, 2022).

1.2 Background

Immediate urban expansion within India is considered one of the primary factors due to which the real estate sector has vastly developed and serves as a key contributor to the country's GDP. During the phase when advancements in technology became widely available and dominantly adopted, there was tremendous attention given to upgrading and harnessing the potential of infrastructural facilities alongside available workforce. Development of new metropolitan areas has generated unparalleled opportunities onto economic growth and form an attractive prospect for accommodating incoming populations (Singhal *et al.*, 2022). Unfortunately, the practice of civil waste management within most Indian cities is severely lacking or nonexistent and this is a concern severely harming the Indian Economy itself. Most regions have an outrageously higher number of pollutants and toxins compared to places that are even considered most unpolluted in the world.

One example of informal waste management of the construction industry in India is unlawful dumping in open spaces and on riverbanks. Policy and business dialogue about holistic waste management have recently shifted from these practices to greater consideration for the impact on nature, public concern, and laws. The biggest shift came with the Construction and Demolition Waste Management Rules of 2016 that mandated segregation, recycling, and proper disposal of waste (archive.pib.gov.in, 2020). Despite all these initiatives, principles of sustainability are not fully integrated into general construction processes, and there is a gap between proposed solutions and real-world implementation.

Real estate developers might be more inclined to integrate green practices into their projects if they consider the pollution and space constraints in Delhi. Other than financial resources, weak regulations, little demand to market recycled materials, limited raw materials, insufficient technical knowledge, and little effort in promoting sustainable practices through legislation or policy stifling the creation of infrastructure regarding waste management and the ecology economy associated with modular building, IGBC and GRIHA certification systems (Jain, 2021). The real estate expansion in Delhi requires an evaluation of building sustainability at multicriteria levels (like construction waste management) if conservation-minded approaches to development are to be successfully implemented in Delhi.

1.3 Research Aim and Objectives

1.3.1 Aim

The aim of this study is to explore and evaluate sustainable strategies for construction and demolition (C&D) waste management in the real estate sector of Delhi, India, with a specific focus on understanding the roles of key stakeholders and identifying effective collaborative frameworks for improving environmental performance and resource efficiency.

1.3.2 Objectives

- To examine the current practices of construction and demolition waste management adopted by real estate construction firms in Delhi.
- To identify the key stakeholders involved in the management and regulation of construction waste, including policymakers, construction firms, and municipal bodies.
- To evaluate the challenges and barriers faced in implementing sustainable waste management strategies within the real estate construction sector.
- To analyze the role of policymakers and construction firms in developing and implementing integrated stakeholder management frameworks for sustainable C&D waste management.
- To incorporate Geographic Information Systems (GIS) mapping to visualize waste generation hotspots and assess spatial inefficiencies in waste disposal practices in Delhi.
- To propose actionable recommendations for enhancing sustainable construction waste management practices through collaborative stakeholder engagement and technological innovations.

1.4 Research Question

- What are the current practices and strategies adopted for construction and demolition (C&D) waste management in the real estate sector of Delhi?
- Who are the key stakeholders involved in the management and regulation of construction waste, and what are their roles and responsibilities?
- How can Geographic Information Systems (GIS) mapping be utilized to identify waste generation hotspots and spatial inefficiencies in Delhi's waste management system?

1.5 Definition of Sustainability

In this study, sustainability is defined as the principle of responsible and efficient resource use in the building industry with the goals of reducing waste, minimizing environmental deterioration, and promoting long-term ecological balance. It includes strategies for managing waste and reusing materials in order to lessen the environmental effect of building projects over their entire lifespan. When it comes to the research questions, sustainability is key for three things: first, assessing the present C&D waste management methods (RQ1), second, learning how stakeholders may enforce sustainable activities (RQ2), and third, using GIS mapping to make sure trash is handled in an educated and efficient way (RQ3). Rather than viewing sustainability just as an environmental issue, this research uses it as a framework to improve waste management systems in the real estate industry of Delhi by influencing stakeholder behavior, policy execution, and technology integration.

1.6 Research Significance

The construction and demolition (C&D) waste generated in Delhi has reached a new peak record due to the rapid growth in the real estate industry. This waste adds to the already existing problems with infrastructure, pollution, degradation of land, and loss of resources. This problem is further aggravated by inefficient legislation for sustainable waste management (Nithya and Ramasamy, 2021). Sustainable solutions tailored to the specific needs of Delhi's real estate sector have been lacking, and this research addresses that gap.

This research places emphasis on stakeholder collaboration, thus drawing attention to the gap in governance that combines politicians, builders, and local government. Enhanced compliance, resource recovery, and minimization of waste can be achieved by implementing integrated systems based on understanding stakeholder relationships. Other than that, this research employs GIS mapping, yielding a spatial perspective to problem identification by revealing the inadequacies and hot spots of waste generation. This geographical inquiry strengthens the empirical foundation of the research while offering targeted insights for strategic planning.

Numerous stakeholders can benefit from the study's salient features. Policymakers can use the practical recommendations in the report for improving regulations and enforcement. Also, the construction industry will be highlighted in practices that add to productivity and result in less cost associated with waste disposal through enhanced resource utilization (Nithya and Ramasamy,

2021). Indian cities can use this information for improving local governance in waste management, recycling infrastructure, and planning of sustainable cities.

The advances made in strategic planning for eco-friendly cities in India have been increased with this research. To support the environmental sustainability goals in Delhi, it offers constructive and collaborative strategies for managing C&D waste. This design is applicable for other urbanizing cities with similar problems (Nithya and Ramasamy, 2021).

1.7 Research Rationale

The rapid urbanization of Delhi has enhanced construction activities, thereby magnifying the issue of C&D waste. The sector is regulated by the 2016 Construction and Demolition Waste Management Rules, which has, to date, been implemented in an inconsistent and piecemeal manner. The wasteful practices of open dumping and improper disposal coupled with the lack of regulation lead to further and deeper environmental damage, resource depletion, and greater pressure on already limited landfills (archive.pib.gov.in, 2020). Within this context, developing adequate policies towards sustainable waste reduction is necessary to foster responsible urbanization and ameliorate the ecological footprint of such activities.

This quantitative study has Delhi specific data driven remedies to the actual real estate market. The research gap in literature on city level issues like the participation of stakeholders and trends in the field creates an immediate need on the part of the policymakers to come up with comprehensive strategies of waste management. It is in an attempt to address this gap that this study aims to give evidence-based understanding of the commercial real estate building business in Delhi. To enable policy makers and stakeholders in the industry to make informed decisions, the findings will be oriented to offer workable, location specific recommendations that will promote viable waste management practices.

The increasing awareness of the C&D waste problem has brought attention to the issue that no single organization can address this issue alone. A holistic approach involving politicians, construction companies, and municipal organizations is needed to take control over the management of reduction, recycling, and reusing. The incorporation of GIS mapping technologies allows for analyzing the spatial patterns of waste generation, enabling targeted and evidence-based interventions.

Locally, this study is relevant and timely since it supports the national initiatives like the Swachh Bharat Mission, Smart City Mission, and Government of India's targets towards greener urban regions. Moreover, it aligns with the international SDG framework, particularly those relating to responsible consumption and production (Goal 12) and sustainable cities and communities (Goal 11) (Viswalekshmi *et al.*, 2024).

1.8 Problem Statement

The real estate market in Delhi is expanding, but with this development comes a huge problem with Construction and Demolition (C&D) waste management that is troubling not only for the city's administration, but for the environment as well. The Construction and Demolition Waste Management Rules, 2016, along with other legal frameworks, have failed to encourage the adoption of eco-friendly waste management policies. C&D waste, like nature's waste, is the most prevalent and is the most widely discarded through open landfilling and dumping, which results in further land pollution along with deteriorating resource efficiency. There is a serious problem with the lack of collaboration between other main actors like policymakers, building contractors, and local government authorities with regards to developing integrated waste management solutions. Furthermore, Geographic Information Systems (GIS), as well as other technological aids or tools for sculpting the landscape of waste generation and supporting the decision process, are vastly underused. The need for tailor-made approaches to stakeholder collaboration to close the gap between C&D waste policy making and implementation work in C&D waste policy in Delhi's real estate sector is crucial.

Chapter 2: Literature Review

2.1 Introduction

Focusing on management of C&D waste, this chapter offers an expedition evaluation of the existing body of literature regarding sound practices of waste management in real estate construction sector. In an effort to provide the theoretical and empirical basis of the present study, the review summarizes the opinions of the various world regions, various regions, and in the United States. The key subjects covered include the sustainable structures used in buildings, construction and demolition waste management challenges and issues, the regulatory system, stakeholder duties, and the application of new approaches to be incorporated such as the Circular Economy and Life Cycle Sustainability Assessment. Other countries exhibit case studies and comparative analysis which is also carried out in this chapter in order to point out the gaps in the policies and the best practices provided. This area has contributed by reviewing the literature to identify gaps in knowledge, especially as pertains to Delhi where there is no data-driven researches that is relevant to the city. The findings assure that the study is contributing to what is already known as the study approach focuses the research strategy and the analytical approach of the subsequent chapters.

2.2 Overview

According to Sharma, (2018), green building research, motivations, and challenges have received considerable attention. Very little effort has been made in designing a holistic framework to encourage the uptake of green buildings. This study seeks to address that gap. Following a comprehensive literature review, we developed a 'Green Building Sustainability Model' and tested it with structural equation modeling. They require that societal green performance intentions at any level should try to maintain green performance and perform green practices. Issues, challenges, government, corporate, developers, buyers, private actors, strategic-mix and sustainable development are postulated to be related in the conceptual model which results in twelve assumptions. Data is collected through a questionnaire. The empirical data demonstrates that government together with other stakeholders (corporate, developers, buyers, and private actors) form a strategic-mix which results in sustainable development, but the government as an authoritative body provides the most considerable influence toward a sustainable resource-efficient society.

According to Devaki and Shanmugapriya, (2023), the growing issue of construction and demolition waste (C&D), as its management has a negative impact on the environment, economy, and society. At the same time though, increased demand for construction materials derives from consuming more natural resources. Thus, the need for effective C&D waste management (CDWM) planning that is environmentally friendly is essential. In this regard, advancements that inhibit realization should be explored. This aims to identify the barriers to achieving sustainable CDWM, investigate their interrelationships from an Indian perspective, and develop a conceptual model. The literature review revealed 48 barriers pertaining to People (PE), Top Management (TM), Procedures (PR), Legislation (LE), Strategies and Technologies (ST), and Sustainable CDWM (SM) are identified. DMATEL was applied to analyze relationships among barrier groups. TM and LE were identified as cause groups, and the other three groups, PE and PR and ST, were identified as effect groups. A conceptual model was verified using PLS-SEM.

2.3 Construction and Demolition (C&D) Waste Management

Construction and demolition (C&D) waste contributes about 30–40% of the total trash generated across the world. This waste stems from the numerous development projects which are currently being implemented for the improvement and expansion of urban infrastructure facilities (Islam *et al.*, 2024). Many scholars are striving to find reasonable solutions to these enormous volumes of C&D waste that optimally balance negative environmental and human health impacts with positive socio-economic influences. Even with all this effort, there is a lack of integrated C&D waste sustainable management systems analyses research. Therefore, the general objective of this study is to carry out literature evaluation to identify gaps in sustainable C&D waste management strategies and provide direction for further work on effective C&D waste management (Islam *et al.*, 2024). To accomplish the research objectives, a two-step systematic approach was employed. The first step involved conducting a bibliometric analysis of the available literature from 2002 to 2022. Then, guided by the bibliometric results, the most relevant articles were analyzed.

The mounting quantity of construction waste is becoming more concerning, affecting the ecosystem as well as the profits of contractors. This chapter examines various dimensions of construction and demolition waste which include its concepts, features, management strategies, policies, regulations, laws about disposal, and even the productivity of workers (Hassan *et al.*, 2022). This chapter also outlines the hierarchy of waste management. The authors have studied

not only the causes of garbage and the methods of disposal but also the design features and technologies of waste management and the corresponding laws. In this chapter, we will analyze some of the statistics and the C&D waste management disposal processes and its purposes in Malaysia, which is not unfamiliar on a global scale (Hassan *et al.*, 2022).

The construction and demolition activities generate substantial amounts of waste which contribute considerably to the environmental issue. This is a literature review on how Australian construction and demolition activities manage the associated waste. The study conducted a search using the Scopus search engine with relevant keywords and were able to find journal papers pertaining to waste management of construction and demolition activities in Australia (Zhao *et al.*, 2022). The study selected 26 articles for further examination. Additional analyses included a set of government documents such as legislation, policy regulations, and strategy documents. It was noted that the inter-jurisdictional transfer of waste was made easier by the variation in state and territorial landfill pricing and associated legislation. From a stakeholder and project life cycle perspective, this study concluded that designers are critical and that the design phase is the most optimal in terms of minimizing waste (Zhao *et al.*, 2022). This is a useful review for Australian academics and practitioners as it provides the most recent information on construction and demolition waste management and recommends further research.

2.4 Sustainable Waste Management Practices in the Real Estate Construction Sector

Building construction remains one of the biggest contributors to a country's GDP. There are folks in the sector who lament the industry's contribution to the waste problem and its efforts towards achieving sustainability development goals (SDGs). As a market form, Circular Economy (CE) seeks to minimize waste by reusing and recycling goods and services (Matemilola and Muraina, 2023). This paradigm is capturing attention as a feasible approach to sustainable development. In response to the growing waste problem in construction, the authors advocate explaining how to implement CE in relation to the UN Agenda 2030 SDGs for advancing sustainable development policies. This article elucidates the relationships among the SDGs, CE, and construction waste management to propose a blueprint for advancing sustainable development policy frameworks (Matemilola and Muraina, 2023).

According to Backes and Traverso, (2021), states Life Cycle Sustainability Assessment (LCSA) has evolved, particularly in the construction industry, this article reviews actual case studies of

sustainability assessments within this sector. This region of the economy simultaneously acts as a major contributor to job creation and economic expansion. It also consumes disproportionately high amounts of energy (33%), raw materials (40%), and produces solid waste (40%). The LCSA technique integrates financial, societal, and environmental impacts of goods and services throughout their entire lifespan. This study was not balanced between the number of impact assessments with LCSAs done in comparison to sectoral emissions. Only eleven percent of the assessed papers applied all three aspects of sustainability. Social, and more so, economic components were ignored. While every Life Cycle Assessment (LCA) included GWP, only thirty percent of them went beyond five indicators. Life Cycle Costing (LCC) was far more encompassing. Lifetime and depreciation were mostly disregarded.

The Russian investment and construction complex suffers severely on the micro and macro levels due to an ongoing economic crisis, which jeopardizes the ability to provide housing through federally and municipally funded investment programs (Avilova *et al.*, 2020). One path toward sustainable replicating real estate assets under modern socioeconomic conditions involves optimal material selection and design employing novel recycling technologies. The amount of waste generated by the construction industry shows no signs of plateauing, and the rate at which retiring regions are replaced is alarmingly low. The primary focus of this strategy are both the economic benefits of resource utilization and elimination of environmental pollution (Avilova *et al.*, 2020). The proposed algorithms perform the analysis of the property manager's activity evaluation and their implementation in a management console and offer practical decision control systems for automated management.

Europe generates most of its waste from construction and demolition activities. Even though European regulations tend to focus on this waste stream because of its large volume and resource consumption—primarily due to its relatively small impact, this problem is often overlooked due to its marginal effect (Gálvez-Martos *et al.*, 2018). Member States' diverse practices in waste management create a greater need for a new approach that considers the entire value chain of the construction industry, including the Circular Economy package which sets new objectives and targets for this waste. This paper aims to address the entire construction value chain by compiling all pertinent strategic documents and analyses to guide effective management of demolition and construction waste (Gálvez-Martos *et al.*, 2018). Through implementation of these best practices,

efficiency and reduction of negative environmental impacts could be achieved. This would involve reducing the amount of waste generated, the impact of transport, increasing reuse and recycling, and optimizing environmental outcomes of treatment methods.

2.5 Regulatory Frameworks Governing C&D Waste Management in India

Due to a predicted growth in the Indian construction sector, there will be an imbalance between the supply and demand of aggregates, limestone, and sand. Large amounts of raw construction and demolition (C&D) debris are problematic in development hotspots spanning residential, institutional, industrial, and commercial sectors (Faruqi and Siddiqui, 2020). Although there are several methods for measuring trash, India has been grappling with calculating the amount of waste produced. A lack of defined control structure, uniform C&D waste estimating method, and multi-faceted expertise in C&D waste treatment creates gaps across generators, collectors, operators, regulators, and the public. In India, C&D Waste Management Rules 2016 outlines the processes of collecting, storage, transportation, treating/processing, and disposal of C&D waste and defines the responsibilities of each stakeholder (Faruqi and Siddiqui, 2020). This comprehensive research evaluates C&D waste policies and regulations and proposes a design for systematic collection, storage, treatment/processing, and disposal. Emphasis of this design is placed on C&D waste processing alongside restrictions and favorable policies in India.

Most of the construction and demolition (C&D) waste is either stored in landfills or dumped in uncontrolled sites which is detrimental to the environment in India. It has been pointed out that poor policies, lack of incentive, knowledge about recycling processes, and absence of regulations have minimal recycling policy impeded the construction of facilities in India (Ramanathan and Ram, 2020). Although faced with challenges, some cities in India have opened some recycling facilities. A comprehensive account of the narratives enables us to trace the evolution of recycling in India. Active support from the Ministry of Urban Development, the Proactive Urban Local Bodies, private partners who acted as recycler and innovator, the Central Road Research Institute and other consider numerous professional bodies created frameworks of rules and standards alongside guidelines to collaboratively built and operated India's C&D waste recycling facility (Ramanathan and Ram, 2020).

Due to adverse effects stemming from climate change and rapid resource depletion, there is an adoption of circular approaches in the environmental management field, which is gaining attention

globally (Priyadarshini and Abhilash, 2020). Therefore, this research aimed to investigate the possible relationships between circular economy (CE) and sustainable development (SD) by studying the contribution of waste management (WM) and renewable energy (RE) industries to CE, as well as the policy frameworks and conducive policies that advocate circularity concepts within the Indian context. It was found that an Indian study on energy recovery from waste (ERW) lacked integration with sustainable development. The findings also indicated that while India seems to be highly devoted to fulfilling the SDGs, there is considerable effort needed regarding incorporating CE principles into governance, especially since there WM regulations for municipal, plastic, and e-waste are not aligned with CE specifications (Priyadarshini and Abhilash, 2020). The Indian economy might gain in its pursuit of circularity and SD if there were an integration of WM and RE policies based on a CE policy framework.

2.6 Role of Stakeholders in Sustainable Waste Management

As one of the developing countries, Nigeria's municipal waste management systems are lacking. This can further be attributed to the expanding population which also increases the production and consumption of goods and services. This puts additional strain on the already stressed systems. Inefficient solid waste management leads to contamination of air, water, and land, which surmounts health risks for the people (Ikhuoso, 2018). The municipal authorities have made little to no effort to try solving this problem, which motivates other stakeholders to intervene. In this study, local government insufficiencies are analyzed alongside the potential usefulness of integrating policy-altering educational campaigns. The research's goal was to design a radiographic questionnaire to analyze the waste management literacy levels of secondary school students and identify the gaps that need to be addressed (Ikhuoso, 2018). The results show that an alarming number of households employ burning as a means of waste disposal, while only 16% of secondary school students receive any form of environmental education.

Some attempts have been made in recent years to manage the global waste problem. These days, active community participation in waste management is given priority. Community participation in both developed and developing countries has mobilized local and national governments to address the issue of waste management (Kalra, 2019). The attitudes of society toward waste and their understanding of the consequences of it motivate waste management. Community participation in waste management is important and is the focus of this paper. The research is

framed by two theories, social capital and integrated waste management models. They both promote community and collective action and therefore public service effectiveness. Then success stories from advanced, transitioning, and developing nations are presented (Kalra, 2019). Successful stories of community participation from Singapore, Japan, Netherlands, Uganda, Philippine, Thailand, and India have been documented.

Modern society relies heavily on plastic because it is encompassing in every industry including packaging, agriculture, vehicle parts, electronics, and even medical equipment. Client shapes and colors can be fabricated into custom plastics to suit specification requirements (Wichai-Utcha and Chavalparit, 2019). In any case, overpopulation and reliance on plastic leads to plastic waste. Most of the increase in ocean plastic waste, including marine waste in Thailand, is due to negligence. Thailand produces industrial and domestic plastic waste, derived from both commercial and residential sectors. Waste management is a problem in Thailand due to the exponential increase in waste from these two sources. Thailand also helps to greatly worsen the problem of plastic waste in oceans, due to poor waste management systems (Wichai-Utcha and Chavalparit, 2019). The use of the 3Rs approach or recovering energy from plastic waste can mitigate some of the challenges posed by plastic waste, though not all.

2.7 Challenges and Barriers in Implementing Sustainable Waste Management Strategies

This research elaborates on a transdisciplinary approach that analyzed the reasons for and implications of Delhi's centralized waste-to-energy (WTE) adoption as a singular approach to solid waste management. It also tried to discuss alternative waste management solutions that address social and environmental justice issues (Randhawa *et al.*, 2020). The authors narrate how a transforming narrative depicting waste as a resource rather than risk enabled and drove socio-technical-eco change in urban development, pertaining public-private participation in waste infrastructure reconfiguration with WTE-scaling enterprise. The authors conduct an empirical analysis of the consequences of the Delhi WTE project through the lens of local inhabitants, waste pickers, NGOs, and government officials. In the absence of other strategies, the WTE-centered approach is likely to shift, but not eliminate, the health burdens across temporal, spatial, and social lines, thereby deepening inequity (Randhawa *et al.*, 2020). The dominant narrative on the objectives of waste management safeguards certain health concerns while masking others.

The construction industry's high energy consumption makes it one of the main contributors to global warming. However, planners and stakeholder ecologists stand to gain from this industry if a profit is made while emitting greenhouse gases less during operational costs (Abraham and Gundimeda, 2018). Also, they offer a lot of value to the customers such as increased property value, water and power conservation, reduction in waste generated, use of green building materials, and protection of flora. While the obstacles to transitioning towards green buildings may be numerous, the advantages they provide to both the environment and economy are phenomenal (Abraham and Gundimeda, 2018). The focus of this article is to apply the Analytic Hierarchy Process (AHP) to identify and prioritize the barriers to the adoption of green building practices.

The use of Sustainable Material Management (SMM) can alleviate the profound negative impacts associated with building processes on society and the environment. Nevertheless, there is scant literature pertaining to SMM in construction or the drivers and barriers to SMM in construction. Also, prior studies did not examine the effect of these drivers and barriers on the adoption of SMM initiatives (Kar & Jha, 2021). This study figured out the fundamental drivers and barriers associated with SMM and the construction industry by analyzing their interaction. The authors crafted this study based on literature review and consultations with three specialists which led us to identify 17 SMM practices, 16 barriers, and 20 drivers. The responses of 102 material management specialists gathered through a survey questionnaire were analyzed (Kar & Jha, 2021). First, variables were collected through exploration factor analysis, and then, the hypothesis that SMM behaviors have significant relations to both enabler and obstacle factors was tested using partial least squares structural equation modeling (PLS-SEM).

2.8 Summary

Author(s) & Year	Title / Focus	Methodology	Key Findings	Relevance to Current Study
Sharma (2018)	Green Building Sustainability Model	Quantitative survey, SEM	Government plays key role in sustainable development; strategic-mix of stakeholders	Highlights stakeholder collaboration for sustainable construction

Devaki and Shanmugapriya (2023)	Barriers to Sustainable C&D Waste Management	DMATEL, PLS-SEM	Identified 48 barriers; TM and LE as cause groups	Reveals key barriers and relationships for CDWM in India
Islam et al. (2024)	Global C&D Waste Management Review	Bibliometric analysis	Lack of integrated sustainable systems analysis	Identifies gaps for future integrated waste management strategies
Hassan et al. (2022)	C&D Waste Management in Malaysia	Literature review	Outlines causes, disposal methods, laws, and hierarchy	Provides comparative global perspective
Zhao et al. (2022)	C&D Waste Management in Australia	Literature & policy review	Design phase most optimal for waste reduction	Emphasizes role of design in waste minimization
Matemilola and Muraina (2023)	Circular Economy in Construction	Policy framework proposal	Links CE with UN SDGs for construction waste	Blueprint for sustainable development policy frameworks
Backes and Traverso (2021)	Life Cycle Sustainability Assessment in Construction	Case study review	Low integration of social/economic aspects in LCSA	Shows gaps in holistic sustainability assessments
Avilova et al. (2020)	Sustainable Real Estate in Russia	Algorithm-based evaluation	Focus on recycling technologies and economic benefits	Applies to resource utilization in construction
GÃ¡lvez-Martos et al. (2018)	EU C&D Waste Management	Policy & strategy review	Proposes value chain approach with CE package	Encourages best practices for efficiency and recycling

Faruqi and Siddiqui (2020)	C&D Waste Regulations in India	Policy analysis	Evaluates C&D Waste Management Rules 2016	Framework for systematic waste processing
Ramanathan & Ram (2020)	Recycling Facilities in India	Case review	Identifies gaps, highlights successful facilities	Documents evolution of recycling in India
Priyadarshini and Abhilash (2020)	Circular Economy & SD in India	Policy framework analysis	Lack of integration of WM and RE with CE	Suggests aligning WM and RE policies with CE
Ikhuoso (2018)	Stakeholder Roles in Nigeria	Survey & policy review	Low environmental education and poor municipal waste systems	Highlights community and educational interventions
Kalra (2019)	Community Participation in Waste Management	Case studies	Shows success stories globally	Promotes collective action and social capital
Wichai-Utcha and Chavalparit (2019)	Plastic Waste in Thailand	Case analysis	Plastic waste exacerbated by poor systems	Advocates 3Rs and energy recovery
Randhawa et al. (2020)	Delhi Waste-to-Energy Analysis	Empirical stakeholder analysis	WTE approach deepens inequity without alternatives	Warns against single-strategy waste management
Abraham and Gundimeda (2018)	Barriers to Green Buildings	AHP	Identifies and prioritizes barriers to adoption	Supports green building transition strategies

Kar and Jha (2021)	Sustainable Material Management in Construction	Survey, PLS-SEM	Identified drivers/barriers to SMM	Highlights interactions influencing adoption

2.9 Literature Gap

There is still a plethora of unsolved fundamental issues despite the abundance of literature on sustainable building approaches, waste management, and stakeholder participation. Most of the literature that exists does not have a Delhi specific urban analytical framework and poses spatially broad paradigms. Literature highlights the importance of regulations and green construction techniques, but the reality of applying them in dense urban environments tends to be overlooked. While some regulations do exist in India regarding the control of construction and demolition waste, they are not deeply integrated with circular economy principles as well as sustainable development goals. Furthermore, there is a lack of study using GIS to identify high waste generation zones that would aid in planning and intervention efforts. Lastly, there needs to be more emphasis on reasoned and integrated approaches because the proactive role of blended stakeholder participation—developers, legislators, and local authorities—in developing systems for sustainable construction and demolition waste management has been researched too little.

Chapter 3: Research Methodology

3.1 Introduction

The quantitative study examines the sustainable waste management measures in the real estate construction in Delhi. A formal survey in the form of a questionnaire, which was in turn the only source of primary data in the study, was conducted on 60 individuals who had a vested interest in waste management, green law making, and city planning. We selected such individuals since they will have firsthand experience dealing with C&D waste management and can address the merits, demerits, and opinions of those working in the industry. To ensure that the responses of all people were similar and identical, the questions in the survey were standardized and closed-ended. The information may be quantitative in terms of rating, as well as qualitative in terms of checkboxes and geographical data input. To make the process of identifying regional trends in the generation of garbage and its effective management easier, the members were provided with several preselected locations with respect to projects in Delhi. To obtain statistical and geographical information about the obtained data, Python was applied in its processing and analysis. Descriptive statistics were used to summarize the data and pull up key trends. Independent samples t-tests were used to compare the mean responses of various groups, and ANOVA was used to check the significance of deviations among various categories and also Correlation Analysis and Cross-Tabulations with Chi-Square Tests is performed. Moreover, the spatial distribution of waste management techniques was depicted, and the areas with the first priorities to be prevented were identified by GIS mapping with GeoPandas and Folium. Provided that such an approach is taken, the results will be data-driven, objective, and repeatable. The work enhances the presence of sustainable waste management in the construction industry of Delhi by integrating the statistical details with geographical mapping. The conclusions are policy-relevant and can be practically used in terms of operations.

3.2 Research Onion

Saunders created the Research Onion as a framework by grouping different layers, such as philosophical position, approach, strategy, and data collecting procedures (Sinha *et al.*, 2018). In this study, only the Research Onion is used as the source of information. On the first level, the research is practical and accepts both quantitative and qualitative ways of studying. A deductive approach is applied in surveys, but ideas coming from literature and interviews are developed

using an inductive method. The time frame when the data is picked up is referred to as the cross-sectional time horizon. Surveys and interviews of 60 people formed the main part of the study, and additional information was gathered by reading academic journals. Using GIS mapping in the study greatly helps to examine data from a geographical point of view. Each phase of the process promises to properly address waste management strategies that work for different circumstances.

3.3 Research Philosophy

The study follows a quantitative research outlook with objective quantification and statistical analysis used to solve practical problems (real-life) in practical environmental applications in sustainable waste management in the Delhi real estate sector. The research method does not leave room for subjective analysis since it ensures that the conclusions made are based using hard data. Primary data is collected in the form of well-structured surveys in order to appraise existing processes, challenges, and the perceptions of involved stakeholders systematically (Clarke and Visser, 2019). Statistical analysis involving t-tests, ANOVA, geographic information system mapping, and descriptive analysis is used to produce results that are policy- and practice-relevant. GIS relies on practical and workable solutions, and that's why it includes spatial analysis as well. The idea behind this study is to boost the findings by giving the researcher more freedom to choose a design that works best and by adopting research methods that are best for the research aims, in a fast city setting.

3.4 Research Approach

The Delhi real estate and building sector is carefully studied and monitored for its sustainable waste management techniques by combining both logical thinking and deductive methodology of reasoning. In order to ensure that the study is independent and replicable, quantitative methods of research are fully utilized. Groups whose responses will be sought through a structured survey include project managers, contractors, environmental specialists as well and government officials. The survey will be aimed at gathering information about the activities, roles, and challenges of the construction and demolition (C&D) waste management in its current form. Such tools as ANOVA, t-tests, and descriptive statistics help statisticians find trends, patterns, and differences in the data in order to identify various trends. GIS mapping makes the research even more enriched with the graphical representation of geographical patterns of the garbage production and the methods of garbage management all around Delhi. The exclusive application of quantitative methods will

provide an objective study of all factors, which will subsequently allow the obtained results to be repeated and allow the development of sustainable building planning and urban waste management reforms (Kaushik and Walsh, 2019).

3.5 Research Strategy

This paper is conducted in a strictly quantitative methodology that assesses the sustainable waste management procedures in the Delhi real estate industry in an objective manner. A structured survey was issued to developers, site engineers, project managers, and contractors to collect primary data. The survey quantified the information on the awareness of the stakeholders in waste management regulations, the current disposal methods, and the amount of construction and demolition (C&D) waste generation. The measurable measures that can be utilized include accurate statistical analysis, requiring the use of trends and gaps in the current systems. Through GIS mapping, the generation and management of garbage became geographically visible, allowing awareness to be created on areas of concern that need urgent interventions. The best understanding of the issues is acquired through a combination of geographical visualization and such statistical methods as descriptive analysis, t-tests, and ANOVA. The methodology that relies on data contributes to the capacity of the study to facilitate realistic and evidence-based change to bridge the gap in the management of waste and promote sustainable building in Delhi.

3.6 Data Collection and Analysis

The method of data collection was quantitative, and the primary tool used was a structured survey. A pre-designed questionnaire was administered to sixty people who are experts in waste management, environmental policy, and urban planning in the real estate construction business based in Delhi. The closed-ended questions and Likert scales in the survey were designed to measure data on C&D waste amount, recreation facilities, knowledge of the waste management regulations, and participation in the sustainable waste management initiatives.

The level of statistics on the collected data was performed using Python. Descriptive statistics were used to describe the replies. Such statistics include median, standard deviation, frequency distributions, and mean. Inferential statistics, such as ANOVA, as well as independent samples t-tests, were used to investigate whether various stakeholder groups differ in their opinion and methods.

The questionnaire also had an element of geospatial data in which they were asked to show where in Delhi it would be best to use the sustainable forms of construction. Geocoding of those locations in Python produced their exact latitude and longitude data. To observe how trash has been produced and the geographical management, it was applicable to utilize GIS mapping libraries such as Folium and GeoPandas. Waste disposal areas that are otherwise unequipped to handle the garbage were also geography-enabled due to the mapping process that enabled one to identify the position of the hotspot, the buffer zones, as well as the proximity linkages to infrastructure.

The quantitative, data-driven approach to the study provided statistical and geographical insights to come up with policy recommendations which were place-specific. The study suggests robust evidence to promote sustainable waste management in the developing construction industry of Delhi by incorporating a statistical study and GIS mapping.

3.7 Ethical Consideration

The ethical aspects were very important in making this study reliable and honest. Each participant was told about the study's purposes, their part in it, and they could withdraw at any moment without explaining. Only after getting agreement from each participant were surveys and interviews carried out. At all times, this study made sure participants' identities were kept entirely anonymous, and they knew that the information from their answers would be used only for research. To prevent anyone from recognizing the people in the dataset, their names or contact information were never included in it. All the data was saved in encrypted ways so that only the researcher could view it. No actions were taken that could be considered unethical or deceitful, as the study followed both the researcher's university rules and the usual academic practices. Besides, the rules protecting data privacy and intellectual property were followed by using secondary GIS data and government reports.

3.8 Summary

This chapter presented a generalization of the methodology that was used to undertake the investigation. This research drew on a Likert scale survey, which investigated environmentally friendly ways of managing building and demolition waste in Delhi. It followed a quantitative method of research. It contained a logical approach that enabled research on the quantitative, statistical analysis to measure the pre-determined goals that could be tested. A wide range of knowledge that could fit specific industries has been received by pulling the information about

sixty people with expertise in waste management, environmental policymaking, and urban planning. The study employed GIS (geographic information system) mapping and statistical evaluation as methods to identify geographic trends in the creation and efficiency of managing trash in each region. The primary data of the survey would serve as the basis of the studies, and a background would be provided by relevant secondary data through the utilization of literature. The study was performed according to ethics, and this aspect implied the collection of informed consent, the confidentiality of information, and the protection of the participants. The findings are precise, reliable, and applicable to real-life concepts due to the methodological strength in the acquisition of the results. The paper provides practical recommendations for enhancing sustainable waste disposal in the construction sector in Delhi.

Chapter 4: Data Analysis and Result Evaluation

4.1 Introduction

This chapter describes the results of the principal data analysis that was conducted by conducting a structured survey that was carried out among sixty people associated with the real estate construction business in Delhi. Concentrating on the aspect of Construction and Demolition (C&D) waste production, method of disposal, involvement of stakeholders, and knowledge of waste management regulations, the scope of analysis attempts to support the analysis of sustainable waste management exercises. The data was assessed in Python, which provided statistical and geographical results. Although inferential approaches such as t-tests and ANOVA show significant differences between groups, a broad view of significant trends and distributions is offered by descriptive statistics. Geographic information system (GIS) mapping with Folium and GeoPandas also reveals the way the trash is managed in various locations, which can be used to draw the attention of policymakers to the most crucial issues. Chapter 5 discusses and proposes recommendations based on the information and data in this chapter and forms a bridge between the empirical evidence and the greater purpose of increasing the sustainability of building and waste management in Delhi.

4.2 Data Description

The major source of primary data in this study was a structured survey that was conducted with 60 individuals who were working in the real estate construction sector in Delhi. The included respondents held different positions that included those of contractors, project managers, site engineers, developers, and policy officials. The survey questions would be of both unstructured and structured types to obtain quantitative data on issues like quantities of construction and demolition (C&D) waste generated, how it is being disposed of, how well respondents are acquainted with the C&D Waste Management Rules of 2016, and participation in environmentally friendly waste management by stakeholders. Moreover, the respondents identified some regions in Delhi that can be improved through effective garbage management, and this made it possible to apply geospatial analysis. There the category variables in the dataset, such as stakeholder roles, type of organizations, and location. Numerical variables assume the form of evaluation of current sufficiency, effectiveness, and severity (ranging between 1 and 5). Various statistical variations, including t-test, ANOVA, and descriptive statistics, can be performed under this framework, and

geographical visualization under GIS tools can also be done; hence, the distribution and waste management procedures can be well deciphered.

4.3 Data Cleaning and Preprocessing

The dataset came through preprocessing and cleaning in a systematic manner in order to ensure that it was accurate, consistent, and ready to be statistically and geographically analyzed. Imputation of missing values in class areas was made by using suitable placeholder values (e.g., “Unknown” or “No”), such as Type of Organization, Location, and Awareness of C&D waste management rules. There is a gap in missing numbers; thus, to retain the integrity of the data, the median value was taken in substitution of the missing numerical data, especially in the Severity rating. Categorical variables that were used to test the hypothesis, e.g., policy knowledge, were transformed into binary or factors to carry out the two tests: t-test and ANOVA. Sufficiency, effectiveness, and severity rating fields were assigned an appropriate numerical data type. All locations were subjected to standardization of names in an effort to bring uniformity in geocoding and GIS mapping. To have a clear picture of the waste management processes, descriptive statistics, inferential tests, and geographic visualizations might be created due to this preparation stage, which has completely aligned the dataset with analysis procedures using Python.

4.4 Statistical Analysis

4.4.1 Descriptive Statistics

Table 1: Descriptive Statistics of Numeric Variables

Variable	Count	Mean	Std Dev	Min	25%	Median	75%	Max
Adequacy of waste facilities	60	3.63	0.88	2	3	4	4	5
Effectiveness of enforcement	60	3.55	1.09	1	3	4	4	5

Severity of waste disposal issue	60	3.42	1.08	1	3	4	4	5

The descriptive data showed generally positive opinions by the real estate players in the city of Delhi on the facilities that deal with waste in the city, enforcement, and the seriousness of the problem itself. Almost all respondents scored the Adequacy of waste facilities between 3 to 4, which means its average score is 3.63. This means that the condition of facilities is perceived to be satisfactory, but with the possibility of an upgrade. The stakeholders observe a greater variability in the effectiveness of employment of enforcements with slightly lower mean (Avg = 3.55) and a wider range (Std Dev = 1.09). Such fluctuation is likely to depict unevenness in the implementation of policy in various regions. The score of 3.42 in the area of concern about the severity of waste disposal shows that the problems are not considered to be very serious everywhere, even though the problem is recognized. Most of the responses are located in the middle to top of the ratings since each of the variables has a narrow interquartile range (25% = 3, 75% = 4). These results could be used to construct additional inferential and geographical analyses.

4.4.2 T-Test

Table 2: T-Test

Variable	t-statistic	p-value	Interpretation
Adequacy of waste management facilities	0.092	0.942	No significant difference between groups.
Effectiveness of enforcement	4.092	0.127	A difference exists numerically but is not statistically significant at $p<0.05$.
Severity of waste disposal issue	3.828	0.137	No significant difference between groups.

Based on the outcomes of the t-test, with the help of the common criterion of assessing the meaningfulness of the results in the form of $p < 0.05$, none of the compared groups demonstrates statistically significant differences in any of the analyzed variables. They have a meaningful degree

of agreement that responses are equal in regards to the waste management facility adequacy because the t-statistic value is 0.092, and the p-value equals 0.942. There seems to be an arithmetical distinction between the groups; however, this arithmetical difference is statistically insignificant, hence it may be due to chance variance. Enforcement effectiveness shows the variable with the smallest p-value (0.127) and the highest t-statistic (4.092). Second, there is a numerical difference; however, t-statistic = 3.828 and p-value = 0.137, which implies that there is no statistical significance between the Severity of waste disposal issues. According to the results, no significant gap appeared in comparing the views of different stakeholders regarding waste facilities, enforcement, and severity of disposal among the described groups determined by the sample. Nevertheless, in the subsequent studies, the researchers need to investigate enforcement more profoundly.

4.4.3 ANOVA

Table 3: ANOVA Results by Variable

Variable	Sum of Squares	df	F-value	p-value	Interpretation
Adequacy of waste management facilities	4.1437	5	1.0709	0.3868	No significant difference across organization types
Effectiveness of enforcement	5.719	5	0.9483	0.4576	No significant difference across organization types
Severity of waste disposal issue	5.9603	5	1.0279	0.4106	No significant difference across organization types

The ANOVA results showed that perceptions of adequacy of waste management infrastructure and effectiveness of enforcement, and whether the issue of waste disposal is a serious one, did not vary significantly by the different categories of establishments polled. The general responses of the stakeholders involved, i.e., developers, contractors, and lawmakers, are also uniform, considering that p-value (0.3868) manifests a considerably greater value than the above 0.05 criterion of sufficiency. The p-value of efficacy of enforcement is 0.4576, which shows that various

organizations share common perspectives regarding the regulatory enforcement, even when in reality they might have some practical differences. Again, the p-value of the severity of the waste disposal concerns is 0.4106, which means that all the groups encounter or perceive equal degrees of challenges of trash disposal.

It appears the members of the real estate market in Delhi share a collective understanding or skills on how to deal with trash. This homogeneity can be explained by the exposure of all people to the same set of policies, infrastructure, and collection mechanisms of garbage. Policy-wise, the absence of designating statistically significant differences implies that the proposed changes or strategies may be implemented on a large scale with minimum customization, which is designed to address the needs of different organizations. Still, it should be mentioned that targeted interventions would not be superfluous to enhance engagement and efficiency.

4.5 Correlation Analysis

Table 4: Spearman Correlation Between Key Survey Variables

Variable 1	Variable 2	Spearman's r	p-value	n
Enforcement effectiveness	Severity of waste disposal issue	0.458	0.000264	59
Severity of waste disposal issue	Support GIS-based monitoring	-0.279	0.032562	59
Adequacy of waste management facilities	Enforcement effectiveness	0.15	0.251943	60
Adequacy of waste management facilities	Support GIS-based monitoring	-0.068	0.607424	60
Adequacy of waste management facilities	Severity of waste disposal issue	0.026	0.850585	59
Enforcement effectiveness	Support GIS-based monitoring	-0.024	0.853601	60

The Spearman correlation analysis is an appropriate measure to use in cases where one wishes to find out monotonic correlations between significant survey variables. The efficient enforcement and seriousness of waste disposal issues are significantly related ($r = 0.458$, $p < 0.001$), with a

great spread, which is great. The level of the waste disposal problem may be correlated with the level of perceptions of the effectiveness of enforcement, thus implying that people involved in enforcement are more aware of the problem. Another outstanding finding is that support of GIS-based monitoring is negatively associated with the extent of concerns about waste disposal ($r = -0.279$, $p < 0.05$). This implies that the perceivers of a more serious problem may not be very keen on the idea of GIS monitoring, possibly due to their perceived ineffectiveness in achieving solutions to their burning issues. Little significant correlations are showing little direct connection, e.g., there is a modest correlation existing between the sufficiency of waste disposal structures and the effectiveness in enforcing ($r = 0.150$, $p > 0.05$). GIS-based monitoring and adequate facilities did not have a meaningful relationship, and the same was true of the enforcement efficacy and GIS support. In general, the findings indicate there are certain areas that should be investigated further, namely the relationship between enforcement and the degree to which the degree of enforcement is surely the relationship between the severity of waste and the insufficiency of the facility in terms of GIS support.

Table 5: Correlation Matrix of Key Waste Management Perception Variables

Variables	Adequacy of Waste Management Facilities	Effectiveness of Rule Enforcement	Severity of Waste Disposal Issue
Adequacy of Waste Management Facilities	1	0.164	0.025
Effectiveness of Rule Enforcement	0.164	1	0.458
Severity of Waste Disposal Issue	0.025	0.458	1

In this correlation matrix, the perceived efficacy of rule enforcement, the perceived severity of the problem of waste disposal in the project area, and the perceived adequacy of waste management facilities are included, along with two more essential factors. A very minor positive relation is evidenced by the relation between the sufficiency of amenities and the effectiveness of rule enforcement, and it is 0.164. Believers, who perceive the facilities as being satisfactory, might possess a lower association with the perception that the enforcement is working. The perceptions

of facility adequacy appear to be independent of how seriously people perceive the waste problems, given that there is a very weak correlation between the two variables (0.025), indicating that neither will be very critical. More necessary than adequate facilities in decreasing perceptions of severity is possible due to the fact that other variables, including rates of waste generated, unlawful dumping, and community participation, may play a bigger role. The strength between the degree of concern about waste and the effectiveness of rule enforcement is moderate, where the greatest correlation is recorded to be 0.458. It implies that people who believe that there is a critical issue with trash disposal also tend to believe that the rules are not complied with. Judging by these results, enforcement could be one of the areas where the outcomes of waste management can be achieved through intervention.

4.6 Cross Tabulations with Chi-Square Test

Table 6: Chi-Square Test – Lack of Infrastructure for Waste Segregation vs. Low Adequacy of Waste Management Facilities

Adequacy Low	Lack of Infrastructure: No (0)	Lack of Infrastructure: Yes (1)	Total
0	31	21	52
1	4	4	8
Total	35	25	60

Chi-Square Results:

$\chi^2 = 0.0165$

p-value = 0.8978

Degrees of Freedom (df) = 1

Cramér's V = 0.000

n = 60

The objective of the Chi-Square test is to determine whether perception of the lack of proper waste segregation infrastructure correlates strongly with the adequacy of waste management facilities. As presented in the contingency table, 31 of the 50 respondents who did not believe that the infrastructure was lacking believed that the facilities were satisfactory, as compared to 21

respondents who believed the facilities were inadequate, of the same figure. This is also the case with the 25 respondents expressing that the infrastructure was inadequate.

The Chi-Square statistic ($\chi^2 = 0.0165$) and the extremely high p-value ($p = 0.8978$) indicate no statistically significant relationship between these two variables. What it implies is that we do not have a direct relationship between perceptions of the respondents in the existence of infrastructure to segregate the waste and the rating scores on the current available facilities.

In addition, the value of Cramer's $V = 0.000$ shows that we do not have a large effect size, which further justifies that there is no significant relationship. There is a chance that this result implies that the citizens prioritize the general adequacy of waste management infrastructure over the supply of the segregation infrastructure. Another difference is that the presence of infrastructure is not necessarily the most critical factor in determining perceptions of sufficiency; alternatives of some factors that could be more significant include accessibility, whether it is enforced, and quality of maintenance.

4.7 GIS Mapping

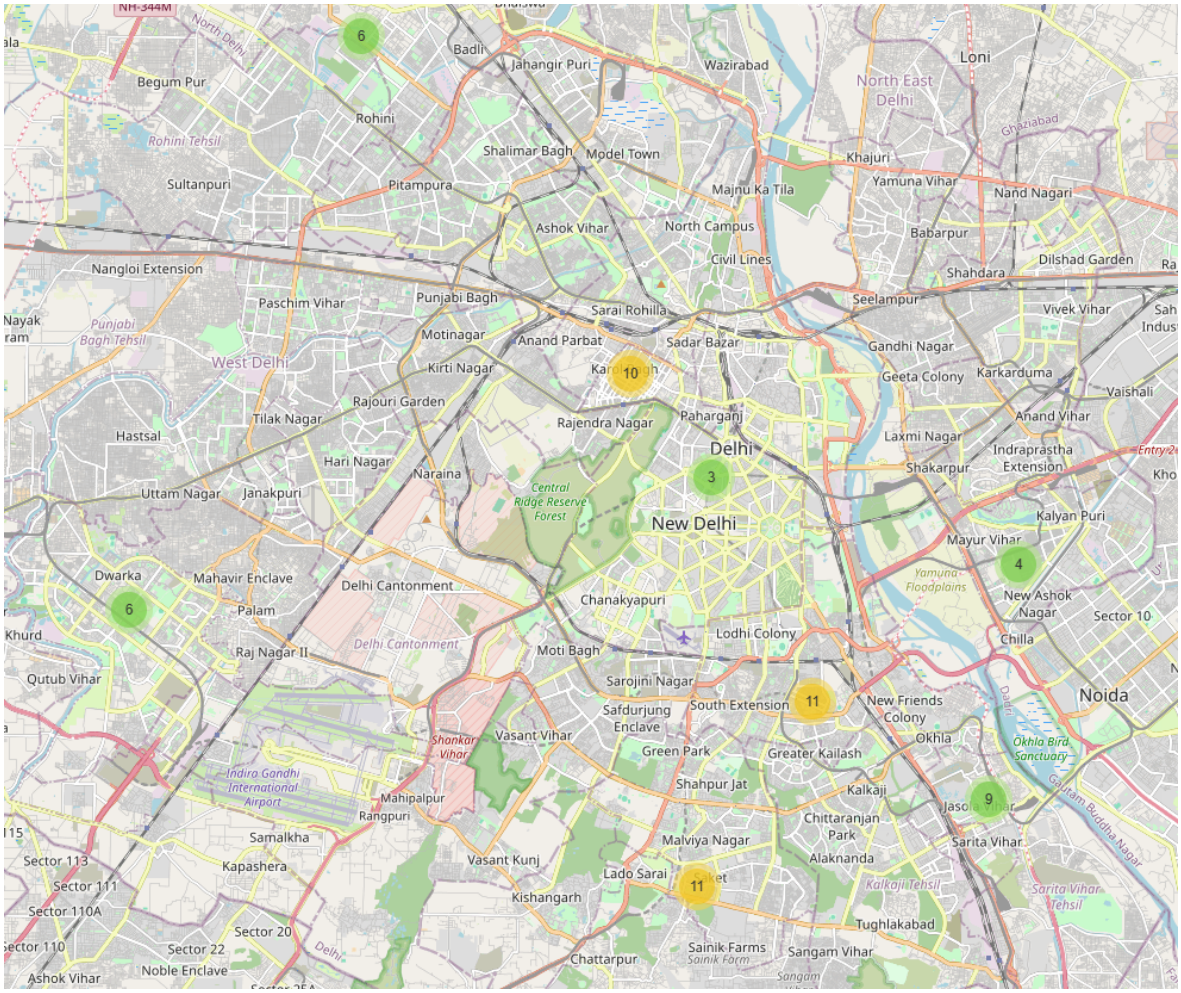

Figure 1: GIS Mapping

Issues in waste management have been identified everywhere in the city of Delhi, yet the GIS visualization of mapping will display the distribution of the problem in a spatial sense. The size and density of each cluster describe how many replies or how serious the complaints are at that place; colored dots identify problems that are discussed in some locations or that the survey receives some replies. There are large yellow clusters (10-11 points) that depict places where the greatest number of challenges were reported. These neighborhoods are in the Central Delhi (e.g., Karol Bagh, Rajendra Nagar, Sadar Bazar) as well as South-East Delhi (e.g., Greater Kailash, Okhla, Lajpat Nagar). Strains in waste management systems are extensive in such places due to a dense population, the abundance of business activities, and constant construction work. The green clumps of 6-9 points show concentrations of problems as moderate, i.e., Dwarka, Noida border

areas, and parts of south Delhi (Vasant Kunj and Saket). The problems might be more localized because of the absence of required facilities or the laxity with regard to the enforcement of the laws on trash disposal. Conversely, in the peripheral areas, such as the Rohini and Noida sectors, there are fewer clusters (4-6 points), which, perhaps, indicates still-new problems with waste management because of the active expansion of city areas. The GIS mapping can be used by the policy makers to determine areas of problems in waste management, as well as establish the areas to be intervened in and plans that deal with those particular areas. Hotspots that have only emerged could use investments in preventative infrastructure, and in Central and South-East Delhi, more regular waste collection, targeted enforcement, and awareness education. Overall, the findings of the spatial analysis will emphasize that to address waste management in the context of Delhi, the locality of the building and the real estate sector determine the strategy that should be adopted.

4.8 Exploratory Data Analysis (EDA)

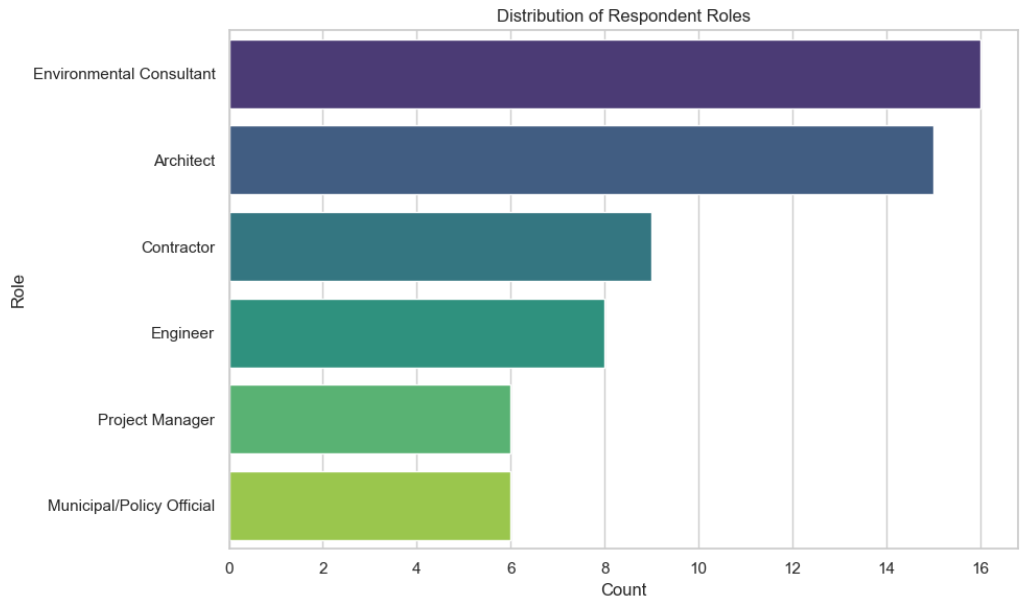

Figure 2: Distribution of Respondent Roles

Other professional opinions were received, as it is indicated in the bar chart illustrating the spread of positions of the respondents in the research. The largest response group is Environmental Consultants with 16, with Architects not far behind with 15. That would be necessary to bring some specialists into the conversation about construction waste management since they directly work on the frontline of sustainable design and compliance with the environment in general, and that would be necessary.

The outline of the middle group is nine contractors and eight engineers, whose experience and expertise provide practical and technical knowledge regarding the adoption of waste management procedures in the site. They are also likely to major in the practical concerns of the implementation of the system of sustainable waste management, and the sustainability of the regulatory conformity.

Even though the six project managers and six municipal/policy officials have the least number of individuals in them, they have the most say in ensuring that the building procedures follow project regimes in terms of time and funding, as well as project terms and regulations. The collaboration between the industry and the municipality should be strengthened since there appears to be no first-hand government participation regarding such research, which may be attributed to the fact that it requires fewer policymakers to participate.

A wide array of perspectives is represented; thus, the findings and recommendations of the research are more likely to cover the subject matter of concern in all aspects, policy, design, environment, and implementation. Since it indicates interdependent roles in sustainable waste management of construction activities, there is also an increase in the dependability of insights.

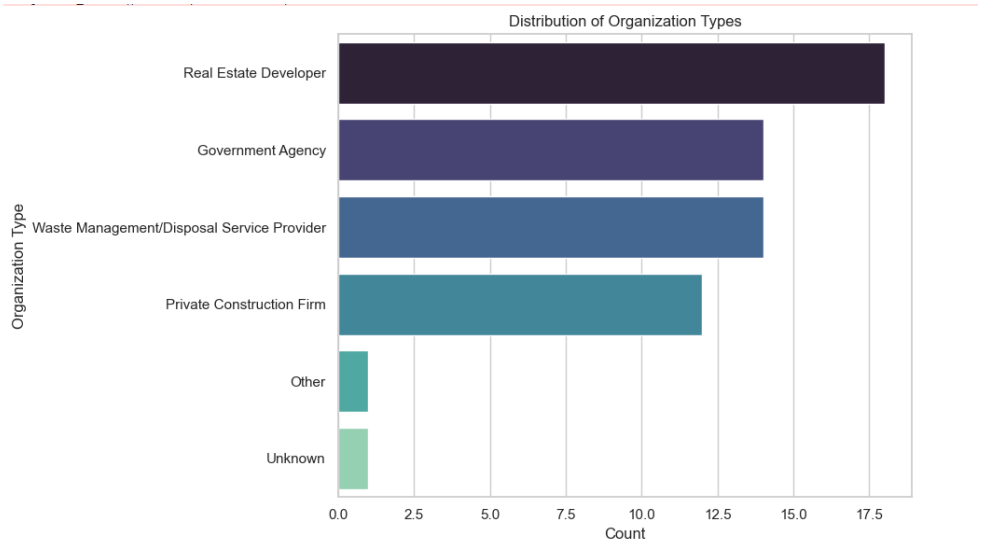

Figure 3: Distribution of Organization Types

Each of the parties interested in the sphere of construction waste management can be considered quite transparent due to the illustration of the types of organizations. The most significant figure of the percentage of respondents, 18, the real estate developers represent, demonstrates their significance in the ways of promoting building activity, and consequently, trash generation.

Government agencies (14) and waste management/disposal service providers (14) are the second largest groupings, implying the existence of significant involvement of regulatory agencies and service providers whose workforce undertakes the operational processes of handling the collection and disposal process of garbage and bill enforcers.

Other organisations with huge influence, though to a lesser extent than the main developers, are the private construction companies (12). This indicates that they have an active role in construction projects. The large number of respondents who did not have a close connection to the construction and waste management industries can be seen as an indication that they did not form any close relations with them, as there is minimal representation in the Other (1) and Unknown (1) categories.

The distribution illustrates that developing elaborate waste management plans would call for a balanced combination of policy, operation, and execution-focused organizations. The overrepresentation of the developers indicates the necessity to focus on the former using sustainable practices, whereas the prevalence of the government and the waste management providers denotes the opportunities that players the policymakers, and implementers can use. The high variety of the stakeholders concerned with this dataset suggests that it can be used to obtain helpful information not only in a long-term perspective but also in the daily improvement of the operational side of the construction waste management.

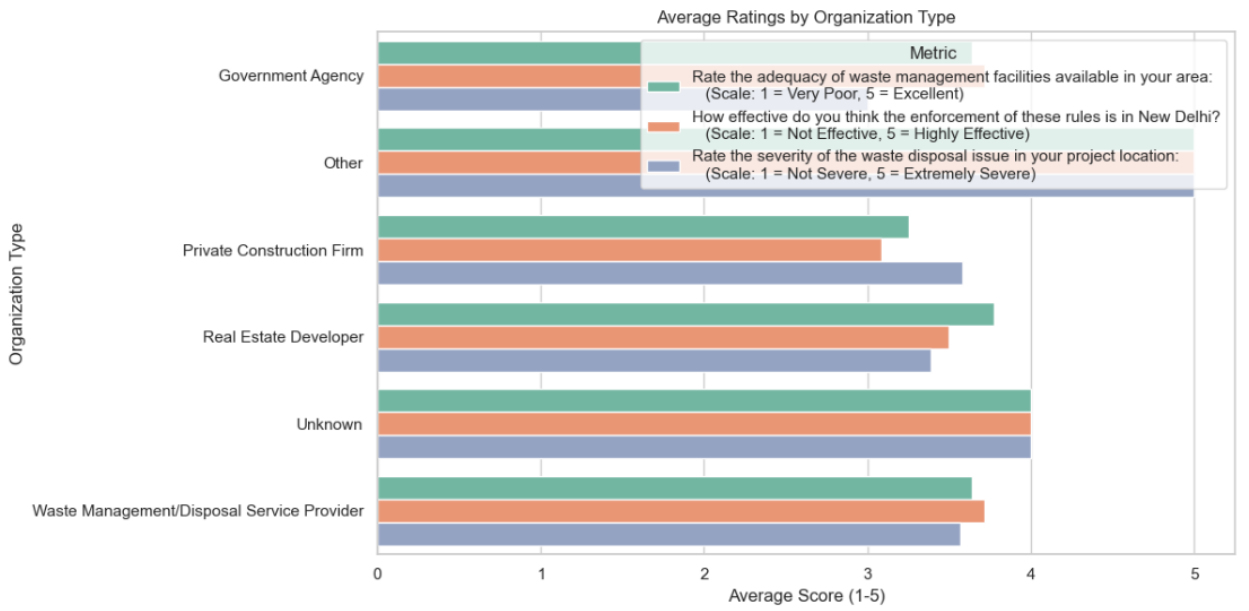

Figure 4: Average Ratings by Organization Types

The graphic shows the average rank of several types of organizations in waste management sufficiency, enforcement quality, and severity of the problem of disposal. Though they continue to report moderate intensity of concerns (~3.5), Waste Management/Disposal Service Providers reported facility adequacy to be reasonably high (near 4), implying satisfaction with existing arrangements. Facility adequacy and enforcement ratings were quite high- almost 3.9 and 3.8, respectively- and the low ratings of the real estate developers in terms of severity (compared to those that provide services) suggest that the former is happier about the situation regarding waste management. The rating of adequacy and compliance was lower (~3.3) in the privately owned construction companies, and the perception of severity was in the middle (~3.6). This can be suspicious of the practicalities of waste management at the place. The agencies of the government scored moderately on the scale of severity (~3.5) and lowest on adequacy (~3.0), indicating that the government bodies perceive significant infrastructure inadequacy even in the face of their activities related to supervision. Though the Other and Unknown groups were not that numerous, they still showed a level of severity similar to other groups (3.9-4.0), which could point to the fact that the difficulties were rather project-specific but not systemic issues. The evidence shows that the majority of individuals are worried about the severity of disposal issues, even though they believe that the system of waste facilities is average and the prosecution of improper facilities is

quite efficient. It reveals the necessity of the cooperation of government officials and commercial construction businesses, helping to increase enforcement and local infrastructure.

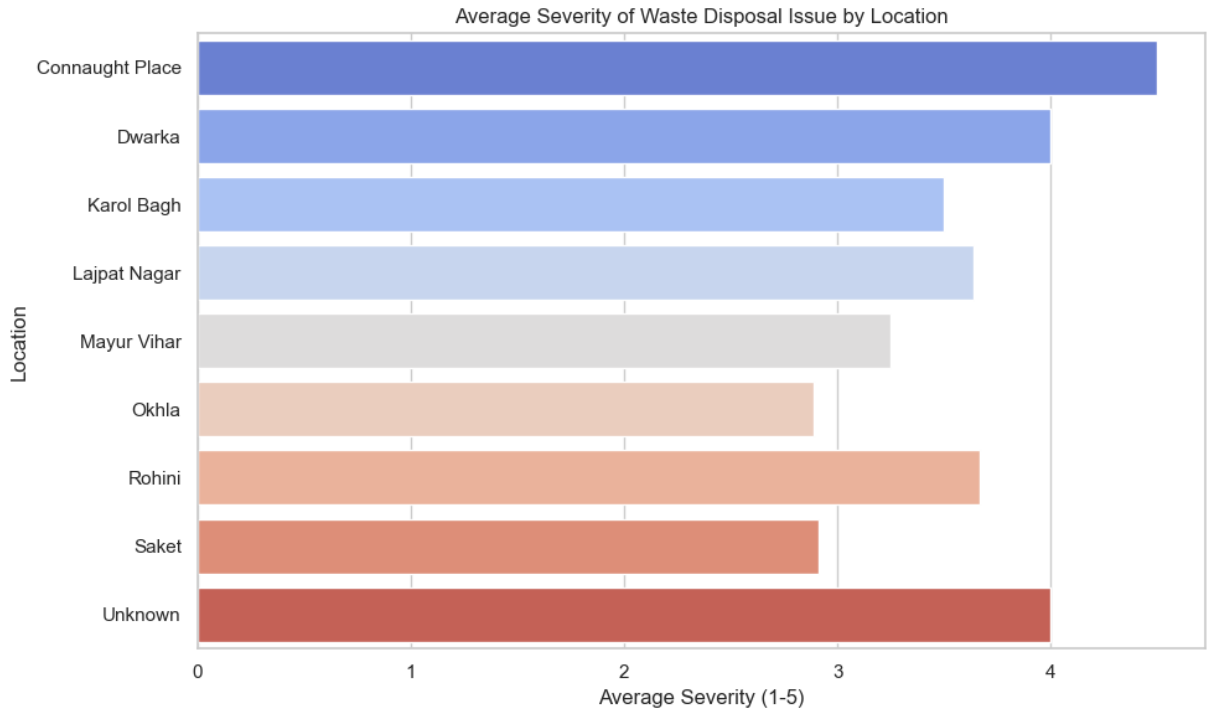

Figure 5: Average Severity of Waste Disposal Issue by Location

The visualization highlights the average severity of waste disposal issues across different locations in Delhi, using a scale from 1 (Not Severe) to 5 (Extremely Severe). Connaught Place scores the highest average severity rating (4.4), indicating that there are serious issues with trash disposal-perhaps due to the relative bend of businesses and pedestrians. This densely populated residential recreation area is experiencing a high level of trash disposal stress, with Dwarka right behind it with a ~4.0. Although the severity level has reportedly been slashed extensively (~ 3.6-3.7), central marketplaces Karol Bagh and Lajpat Nagar still face major challenges, most probably because of their humongous daily garbage generation rates. Okhla, as an industrial district, has a far lesser severity in its means(~2.9), which is probabilistically due to systematic waste disposal in industrialized areas, unlike Mayur Vihar with a moderate range (~3.3). The situations portrayed by Rohini (~3.6) and Saket (~3.0) are confused, which suggests that the waste management performances of various communities vary. The input of worry levels of approximately 4.0 in the Unknown category indicates that the issues of waste remain high in the areas that have not been identified or are not given specific names. Places like Connaught Place, Dwarka, and other peak

footfall marketplaces specifically require location-based intervention because, in general, the core business centers and concentrated localities of residential places experience the worst difficulties with garbage disposal.

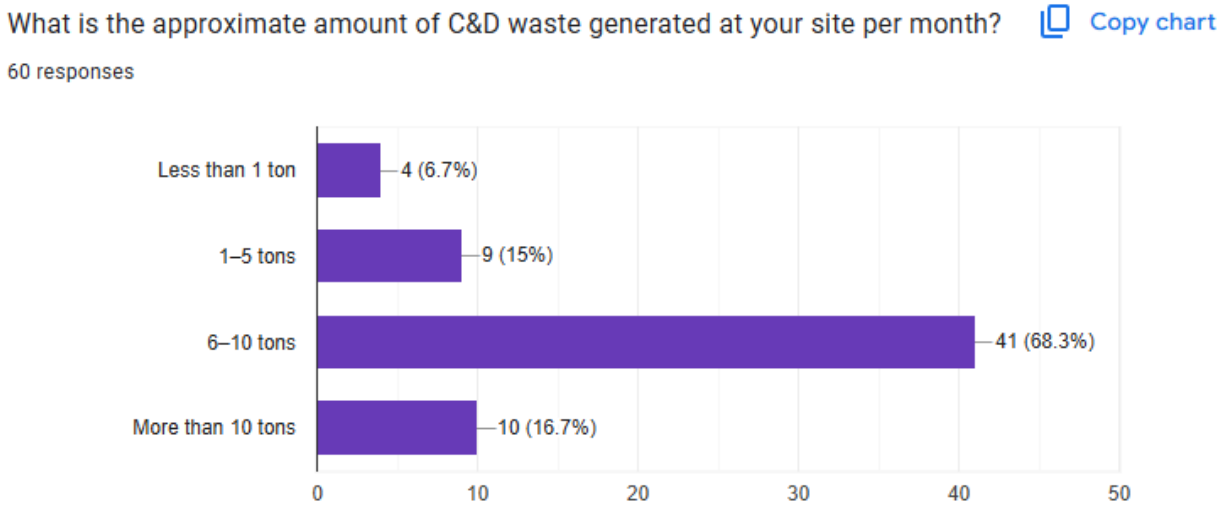

Figure 6: Monthly Construction and Demolition (C&D) Waste Generation at Project Sites

The chart indicates the mean monthly amount of C&D garbage out of 60 project sites. The industry seems to produce medium-high volumes of trash, with 68.3 percent of respondents (41 locations) reporting they generate 6-10 tons of C&D waste each month. This indicates active construction works that generate huge amounts of garbage, which could strain the facilities for waste disposal. Just 16.7 percent (10 sites) reported generating over 10 tons every month, or were either quite busy or working on mega projects. The smaller business or more efficient use of material was shown, 15 percent (9 locations) posted production of only 1-5 tons per month. Likely referring to small projects or rehabilitation work or places with productive waste reduction policies, 6.7 per cent of respondents (4 sites) reported lower than 1 ton per month. The statistics reveal that most of the C&D waste is at 6-10 tons; therefore, there must be a plan to minimize the waste at plants of medium and large size. The possible approaches include reusing materials, sorting them at the sites, and establishing partnerships with recycling centers. Effective management of such high volumes of waste sources can be of significant help in reducing the environmental impact of building operations in the region.

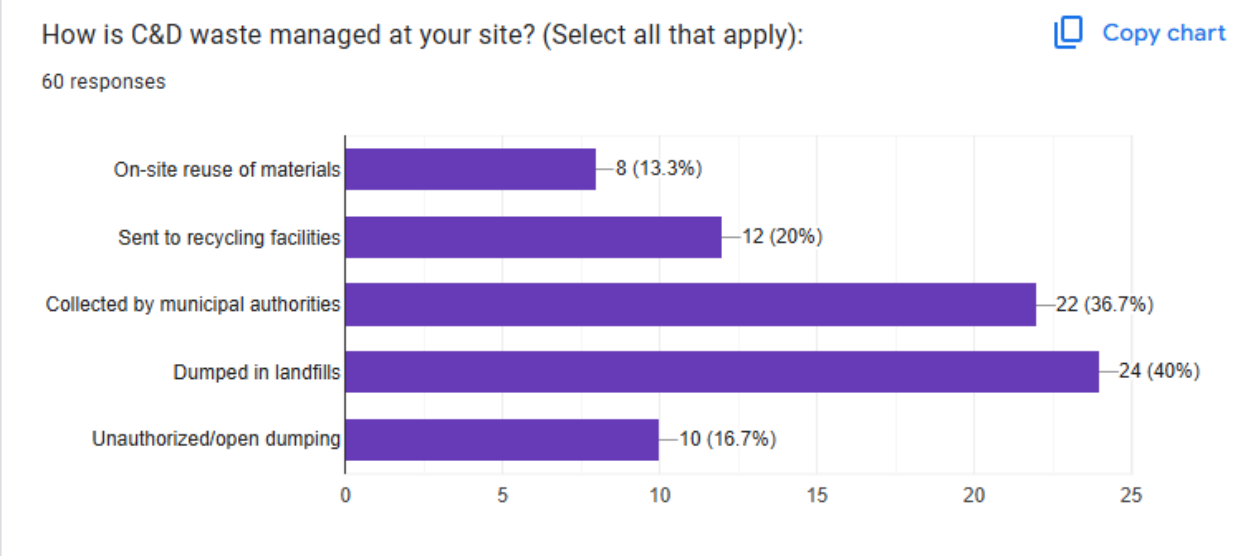

Figure 7: Methods of Construction and Demolition (C&D) Waste Management at Project Sites

The figure illustrates the various methods used by 60 facilities examined to deal with C&D waste, since several choices were presented to the respondents. The most common is non-recovery or non-recycling, in which garbage is disposed of, representing 40 percent of the sites. Although this technique may seem quite primitive, it poses dramatic environmental issues regarding land and pollution. Collection by municipal authorities is the second most common method, signified by 36.7 percent of sites. This means that waste management agencies, which are owned by the locals, are in charge of recycling C&D trash. The two most notable determining factors affecting the effectiveness of this strategy include the infrastructure and the frequency of collection. Although this is a more sustainable opportunity, a minor fraction (20%) of the respondents were willing to dispose of their garbage in recycling centers (12 sites). The on-site reuse of material is the least widespread circular economy approach, with only 13.3 percent of sites relying on such a strategy, which demonstrates that the construction industry does not completely adopt this trend. Concerning, 16.7 percent (10 sites) are open or illegal dumps, and are representative of how the wrong methods of disposal of waste can prove extremely harmful in terms of health and environmental consequences. The data indicate that sustainable waste management methods should be encouraged during building projects by increasing the recycling infrastructure, campaigns, and implementing the available strategies.

Figure 8: Perceived Adequacy of Waste Management Facilities

This figure illustrates respondents' ratings on the adequacy of waste management facilities in their respective areas, using a scale from 1 (Very Poor) to 5 (Excellent). They graded it between 1 (Excellent) and 5 (Very Poor). Thirty (50 percent) of the total 60 rated the facilities with a 4 out of a maximum of 6 points, which indicated that the respondents believed that the services were all right but could be improved. A relatively small but significant percentage, 23.3 or 14 individuals, responded with a sufficiency rating of 3, which also means a moderate satisfaction, but is pointing to possible discrepancies in that area of the delivery or the coverage. The largest percentage of 13.3 per cent (8 respondents) scored the highest of 5, which meant that they are quite satisfied, and maybe indicating locations that are well serviced and process efficient. Conversely, 7.1 percent of the respondents rated the sufficiency as 2, and another 1.7 percent of the respondents ranked to be one out of 1 to 5, implying discontentment and possibly a lack of proper waste management infrastructure. Although most of the responders might have given a favorable reflection concerning the current facility provision, the figures indicate that the population size that is dissatisfied with the service is significant. Targeted improvements must be made so that regions that are not performing well can be improved in a bid to ensure that every region has equal opportunities to acquire enough waste management facilities.

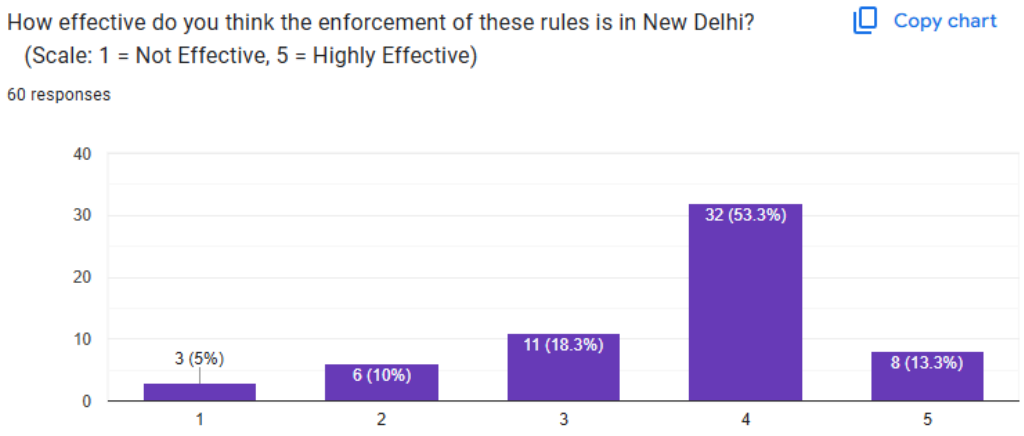

Figure 9: Perceived Effectiveness of Waste Management Rule Enforcement in Delhi

This chart represents the view of the respondents on how effective the enforcement of the laws meant to provide waste management in Delhi is on a scale of 0 (Not Effective) to 5 (Highly Effective). The 60 survey respondents had 32 or a percentage of (53.3) people giving the enforcement a score of 4, which also expresses a broadly positive picture wherein one accepts that there is good monitoring and implementation but yet understands that there is scope to improve. The number who rated enforcement a perfect score of 5 points was only 13.3 percent (8 respondents), which shows that the level of trust towards the ability of the system to ensure that all people complied was high. The neutral mark (3) was expressed by 18.3 percent or 11 people, which means that enforcement effectiveness could differ according to the places, or respondents had both positive and negative experiences. Inappropriate surveillance, possible gaps in control, or a general failure to press charges against offenders were raised by 10% (6 cases) of the participants who rated the enforcement as 2, and 5% (3 cases) as 1, respectively. Even though rule enforcement impresses most people, findings indicate that one-third of the population has a neutral or poor score of the rule enforcement and needs to enhance its uniformity, openness, and public confidence in the rule enforcement.

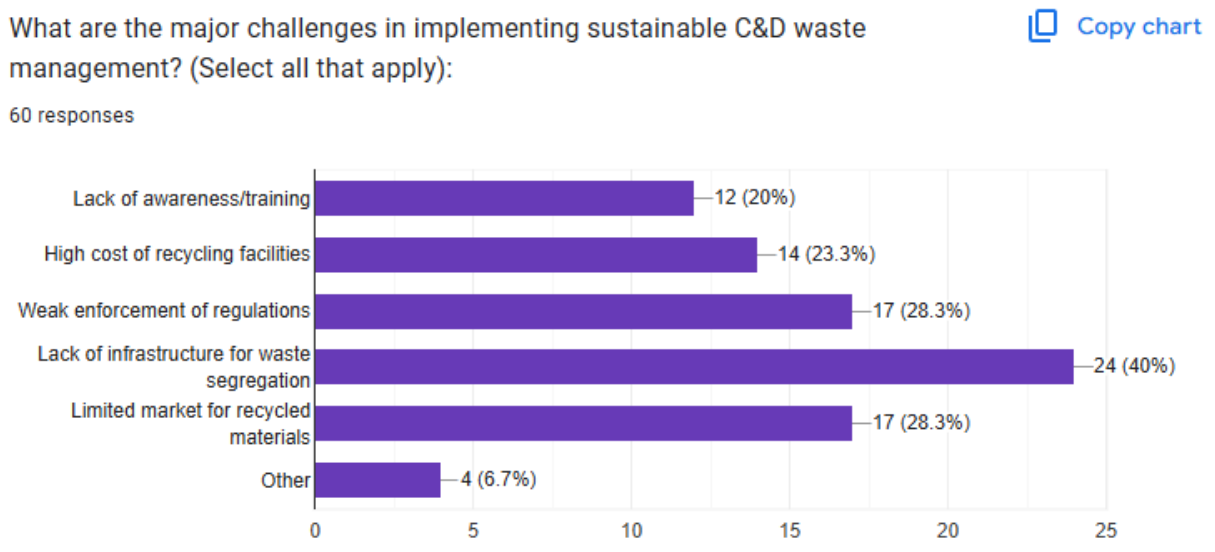

Figure 10: Key Challenges in Implementing Sustainable C&D Waste Management

In this figure, the top barriers to achieving sustainable C&D waste management, as reported by 60 respondents, are listed. With 40 percent (24 individuals), the lack of waste segregation infrastructure remains the greatest challenge, as this is the reason why specialized facilities and processes are needed to handle highly productive facilities to easily tackle the garbage at its point of origin. Failure to enforce regulations and limited markets to absorb recyclable materials were shown by 28.3 percent of respondents (17) as two major barriers of similar magnitude. Lack of proper monitoring reduces compliance, and lack of demand for recycling programs is a discouragement to these programs; both reflect economic and governance failures, respectively. One of the central issues is the high cost of recycling facilities that make sustainable measures less economically favorable to many parties and constitute the problem to the extent of 23.3%, or 14 respondents. The lack of knowledge among industrial professionals and employees when it comes to efficient waste disposal and sustainable practices seems to exist, as suggested by the 20 percent of the respondents who were not provided with any kind of training or awareness. A small number (6.7%, 4 respondents) cited Other problems, which could have been some problem peculiar to a particular area, some operational problem, or some policy problem that was not already encompassed in the other categories. The data showed that in order to reach sustainable management of C&D waste, infrastructural gaps would have to be solved, increased enforcement, stimulate demand in the marketplace to buy recycled products, and increase training.

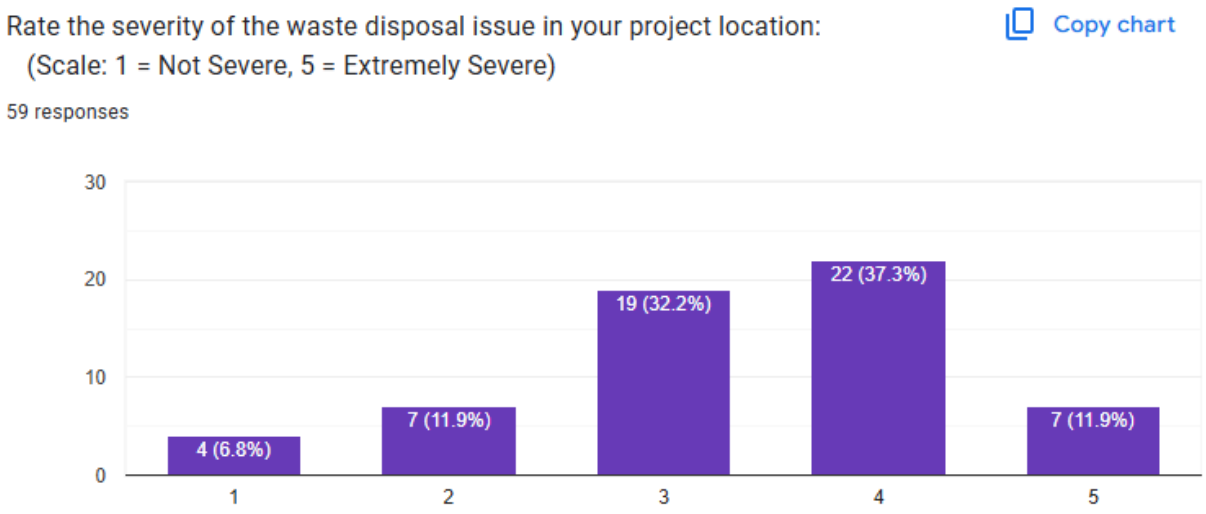

Figure 11: Severity of Waste Disposal Issues at Project Locations

The bar graph indicates the degree of concern with garbage disposal in various project sites, as indicated by 59 respondents. On the 5-point scale, 37.3 percent (22 respondents) rated it as 4, which means they were seriously concerned; most of the respondents (37.3 percent) rated it as severe. The number reporting level 3 intensity, i.e., moderate to significant problems, was 32.2 percent (19 respondents). Only 11.9 percent (7 respondents) rated it as extremely severe (rating 5), yet it already indicates that there are quite a few locations with severe waste management problems and which do require urgent assistance. By contrast, 6.8 percent (4 respondents) rated the severity as 1, and 11.9 percent (7 respondents) rated the severity as 2, which implies that some locations experienced mild to serious issues of trash disposal. 70 percent of the surveyed candidates have assigned a score of 3 and above to the nature of the problem, implying that trash management is a significant issue on most project sites. The mentioned challenges cannot be properly eliminated without direct actions on the way to improved infrastructure, stricter compliance with regulations, and more attentive waste management methods.

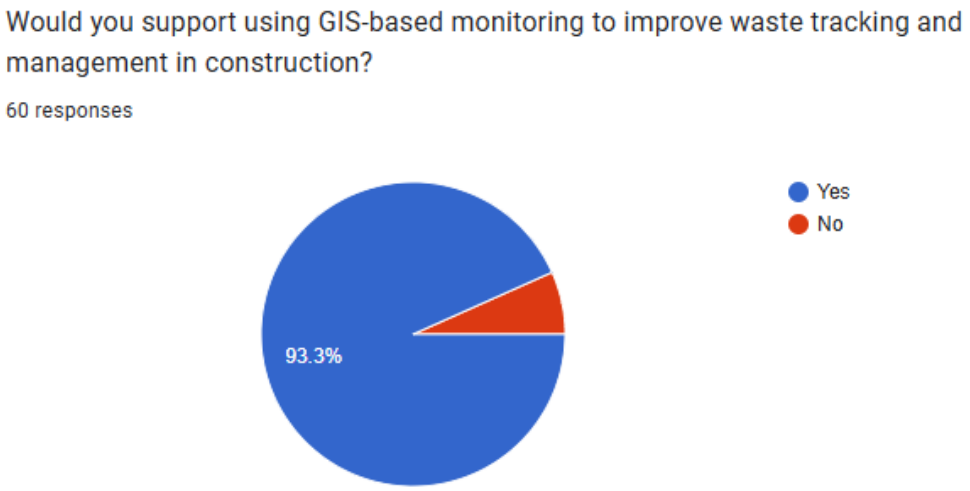

Figure 12: Support for GIS-Based Monitoring in Construction Waste Management

According to the responses of 60 respondents, it has been depicted in graphic format that the stakeholders prefer the deployment of GIS-based monitoring to enhance the monitoring and management of waste in building projects. The possible advantages of GIS in increasing efficiency, transparency, and the decision-making process of the waste management procedure are agreed upon, evident by the majority of the 93.3 percent of people willing to implement such a technology. The low percentage of those who disagreed with the idea (6.7) shows that there is little resistance to the consideration of using GIS solutions. Since it is perceived that technology can help in resolving complex waste management issues, such as real-time monitoring, detection of illegal dump sites, and enhancement of material reuse or recycling, the response to it was an overwhelming yes. The construction industry is ready to change to new methods that will enhance sustainable development objectives, which is evidenced by this much support. This is an indication that the problem of training cost and infrastructure readiness is solved; any further waste management program based on GIS will most probably be welcomed positively.

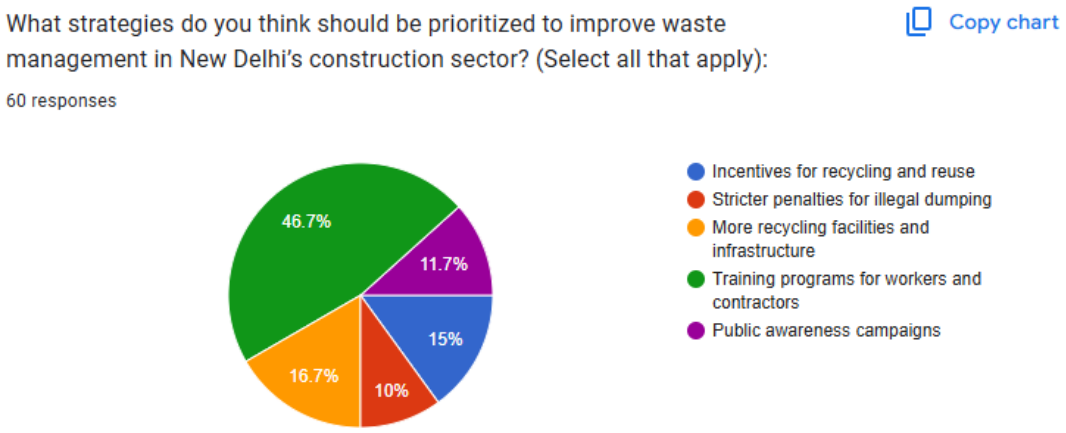

Figure 13: Priority Strategies for Improving Waste Management in Delhi's Construction Sector

The figure represents the result of 60 participants based on their comments on the distribution of the proposed methods that should be used in enhancing waste management in the construction industry of Delhi. The largest number of respondents, 46.7 percent, chose training programs for workers and contractors, which means that there is a strong belief in the necessity of implementing awareness raising and skill development among ground stakeholders on the necessity of having sustainable waste management. The second reason was better physical resources to support recycling actions, that is, more recycling facilities and infrastructure (16.7%). It can provide incentives in the form of money or policy to businesses, encouraging them to adopt sustainable waste management practices, since 15 percent of respondents reported interest in incentives based on recycling and reuse. Nevertheless, there was much less attention to the public awareness campaigns (11.7%) and harsher sentences in the case of illegal dumping (10%). This implies that infrastructure and capacity-building are more urgent needs, per the reaction of the respondents, despite the relevance of regulation and awareness. In the above findings, it can be seen that to prevent long-term objectives of sustainable and efficient construction waste, interventions focusing on the infrastructure or building skills, and not punishment or awareness, are desirable.

4.9 Findings

RQ1: Current Practices and Strategies for C&D Waste Management in Delhi's Real Estate Sector

According to the findings, C&D waste management processes are yet to stabilize in the real estate business of the city of Delhi, as various projects adopt them at variable levels. A good number of respondents, that is, 32.2 percent of them, rated waste disposal issues as somewhat serious, with 37.3 percent of them having categorized it as very serious according to the survey results. The challenges associated with sorting, disposing as well as recycling of building wastes are clear here. Common happenings include recycling of materials such as concrete and steel, simple segregation of wastes on site, and semi-compliant with municipal regulations of transporting and disposing of waste. However, huge gaps still exist in the infrastructure. Other problems that slow effective landfill diversion of waste include a lack of recycling centers, poor transportation arrangements, and monitoring procedures. Stakeholders will choose training programs for employees and contractors (46.7%), recycling incentives (15%), and finally improved recycling infrastructure (16.7%). The preferences indicate that individuals are aware of the fact that tighter waste management performance must involve investing in infrastructure and upgrading human potential.

RQ2: Key Stakeholders and Their Roles

There is a complicated network of stakeholders in Delhi who control and regulate the management of building debris. The role of regulatory bodies such as the Central Pollution Control Board (CPCB) and the Municipal Corporation of Delhi (MCD) mainly involves policymaking, monitoring, and enforcement of compliance. The builder and developers have the operating responsibility of ensuring segregation of wastes, proper storage, and safe transfer to suitable recycling or disposal facilities. The contractors and subcontractors are usually pressed to deliver projects as planned, and thus, cheap on proper disposal methods. The other survey result is that the individuals do not believe that there is effective enforcement of the rules. Considering the correlation between the two variables, we find that the degree to which the severity of the waste people meet has a moderately positive relationship (0.458) with the effectiveness of the rules being enacted. This implies that individuals will perceive that there are more severe waste issues when they feel that the implementation of laws is not followed. Other advocacy and awareness roles are

performed by local non-governmental organizations (NGOs) and other community members, which lack the structural form when compared to formal stakeholders.

RQ3: Utilization of GIS Mapping for Identifying Waste Hotspots and Inefficiencies

An overwhelming percentage of people (93.3) answering the survey concluded that it is a brilliant idea to use GIS to monitor trash. According to geographical mapping of survey results and geographical records, high-severity waste disposal problems cluster in a small number of urban pockets, especially in the fast-developing outskirts of Delhi. Such concentrations have been caused by the absence of authorized recycling plants, inadequate waste transport infrastructure of waste, and dense construction in the neighboring districts. The study of geographic information systems (GIS) indicated spatial inefficiencies such as unequal distribution of recycling centers and long haul distances to disposal sites by overlaying the enforcement coverage, locations of waste facilities, and the reported severity ratings. Comprehensively, GIS integration with survey and statistical data allows policymakers to allocate their resources more efficiently, monitor compliance in real-time, and introduce accountability into the entire chain of waste management.

Chapter 5: Conclusion and Recommendations

5.1 Conclusion

This research was aimed at examining the current scenario of the management of C&D waste in the real estate sector of Delhi, identifying the roles and responsibilities of key players, and comparing whether GIS mapping could be used to enhance the effectiveness of the processing of the trash. The cross-tabulations, GIS mapping, plus statistical correlations, as well as survey findings, give a complete picture of issues, the dynamics of the stakeholders, as well as the potential for improvements.

The management methods used in C&D waste are not consistent, but have worsened due to the infrastructural problems and enforcement constraints. Among respondents, it has been rated as moderate to high by a large percentage, which contributed to 37.3 percent of a five-point scale, with 4 out of 5. Weak monitoring, inaccessibility to recycling, and defective transport arrangements are all factors against the extensive application of on-site sorting and reuse of materials. The most preferred choices of the respondent, which are the contractor and worker training program (46.7 percent of the total number), recycling incentives (15 percent), and the development of a better recycling infrastructure (16.7 percent of the total), depict an increased need for capacity and new plants.

Second, the roles of stakeholders cannot be ignored, but are not always attended to. According to the correlation analysis, there is a moderate positive correlation ($r = 0.458$, $p < 0.001$) between perceived severity of waste and effectiveness of the enforcement. This implies that, when there is laxity of enforcement, there is an increased severity perception, and policy and enforcement lie within the hands of regulatory bodies such as the Central Pollution Control Board (CPCB) and the Municipal Corporation of Delhi (MCD). Though the responsibility of operation is on developers, contractors, and subcontractors, the disposal of waste method is often compromised by the limitations of the project and the cost requirement. The system of activities to manage waste in institutions lacks the effective integration of the roles played by community groups and NGOs, despite the role they play in creating lobby issues and awareness.

Regarding the third aspect, 93.3 percent of respondents said that they would like to use GIS mapping to track the trash, which means that it is a solidly supported and potentially revolutionary

technology. The research on geographic information systems (GIS) revealed that most wasteful areas featured fast urbanization, uneven coverage of the implementation policies, and little availability of recycling plants. This is because with GIS, we can track more accurately and allocate resources to areas that are considered spatially inefficient, such as unequal distribution of facilities and the long route to transportation.

Finally, after survey analysis, statistical testing, and GIS mapping, it is apparent that C&D waste management in Delhi has to be more structured and data-driven. It is essential to enhance collaboration efforts among stakeholders, enhance enforcement, and address infrastructural gaps. All of this, sustainable building, improved waste tracking, and fewer environmental impacts may occur as the city uses GIS-based monitoring along with its recycling incentives and stakeholder training.

5.2 Recommendations

The findings of the study imply several particular actions that the Delhi real estate market may implement to improve the situation with control over the Construction and Demolition (C&D) waste. A strong positive correlation between the perceived effectiveness of legislation and the level of waste was also discovered in the course of the investigation, which proves the importance of focusing on improvements in the enforcement of measures. To be always in compliance, local authorities must incorporate real-time reporting systems, harsher punishment for unlawful dumping, and use more frequent inspections. The increase in the recycling infrastructure is also vital, and money should be spent on widely distributed recycling plants in the regions where the garbage production rate is high, as the main aim should be to reduce distances to transportation and enhance on-site sorting. As an additional incentive to voluntary compliance and innovation in the field of waste management, it would be advisable to add a financial incentive such as tax credits, certifications, or recognition of developers who adopt environmentally friendly methods. Delhi could assist environmental protection and efficient operations of the construction industry by having an environment-friendly C&D waste management regime that is sustainable, efficient, and transparent. This can be given through merging with good enforcement, enhanced infrastructure, technological integration, and capacity building. Through collaboration, we would be able to find solutions to our current issues and offer the foundation for the techniques of waste management that can be sustainable and strong in the future.

References

Abraham, P.S. and Gundimeda, H., 2018. 'Greening'the Buildings-An Analysis of Barriers to Adoption in India. *Cities and the Environment (CATE)*, *10*(1), p.10.

archive.pib.gov.in, 2020. *Salient features of Construction and Demolition Waste Management Rules, 2016 and its implication.* [Online] Available at: https://archive.pib.gov.in/documents/rlink/2016/mar/p201632901.pdf

Avilova, I.P., Krygina, A.M., Krygina, N.M., Koshlich, Y.A. and Oberemok, M.I., 2020, July. Sustainable development of civil and residential real estate based on the construction waste recycling. In *IOP Conference Series: Materials Science and Engineering* (Vol. 890, No. 1, p. 012187). IOP Publishing.

Backes, J.G. and Traverso, M., 2021. Application of life cycle sustainability assessment in the construction sector: a systematic literature review. *Processes*, *9*(7), p.1248.

Clarke, E. and Visser, J., 2019. Pragmatic research methodology in education: possibilities and pitfalls. *International Journal of Research & Method in Education*, *42*(5), pp.455-469.

Devaki, H. and Shanmugapriya, S., 2023. Investigating barriers to sustainable management of construction and demolition waste: the case of India. *Journal of Material Cycles and Waste Management*, *25*(3), pp.1594-1607.

Faruqi, M.H.Z. and Siddiqui, F.Z., 2020. A mini review of construction and demolition waste management in India. *Waste Management & Research*, *38*(7), pp.708-716.

Gálvez-Martos, J.L., Styles, D., Schoenberger, H. and Zeschmar-Lahl, B., 2018. Construction and demolition waste best management practice in Europe. *Resources, conservation and recycling*, *136*, pp.166-178.

Hassan, S.H., Aziz, H.A., Johari, I. and Hung, Y.T., 2022. Construction and demolition (C&D) waste management and disposal. In *Solid Waste Engineering and Management: Volume 2* (pp. 165-216). Cham: Springer International Publishing.

Ikhuoso, O.A., 2018. The role of educational programs to enhance stakeholder participation for sustainable waste management in developing countries: An investigation into public secondary schools in Nigeria. *Int J Waste Resour*, *8*(350), p.2.

Islam, N., Sandanayake, M., Muthukumaran, S. and Navaratna, D., 2024. Review on sustainable construction and demolition waste management—challenges and research prospects. *Sustainability*, *16*(8), p.3289.

Jain, M.S., 2021. A mini review on generation, handling, and initiatives to tackle construction and demolition waste in India. *Environmental Technology & Innovation*, *22*, p.101490.

Kalra, N., 2019. Community participation and waste management. In *Sustainable Waste Management: Policies and Case Studies: 7th IconSWM—ISWMAW 2017, Volume 1* (pp. 115-123). Singapore: Springer Singapore.

Kar, S., & Jha, K. N. (2021). Exploring the critical barriers to and enablers of sustainable material management practices in the construction industry. *Journal of Construction Engineering and Management*, *147*(9), 04021102.

Kaushik, V. and Walsh, C.A., 2019. Pragmatism as a research paradigm and its implications for social work research. *Social sciences*, *8*(9), p.255.

Matemilola, S. and Muraina, O., 2023. Sustainability and sustainable development in real estate industry. In *Encyclopedia of Sustainable Management* (pp. 3244-3250). Cham: Springer International Publishing.

Nithya, M. and Ramasamy, M., 2021. Sustainability in construction industry through zero waste technology in India. *Materials Today: Proceedings*, *46*, pp.849-851.

Priyadarshini, P. and Abhilash, P.C., 2020. Circular economy practices within energy and waste management sectors of India: A meta-analysis. *Bioresource Technology*, *304*, p.123018.

Ramanathan, M. and Ram, V.G., 2020. Status of C&D waste recycling in India. In *Sustainable Environmental Geotechnics: Proceedings of EGRWSE 2019* (pp. 95-105). Springer International Publishing.

Randhawa, P., Marshall, F., Kushwaha, P.K. and Desai, P., 2020. Pathways for sustainable urban waste management and reduced environmental health risks in India: winners, losers, and alternatives to waste to energy in Delhi. *Frontiers in Sustainable Cities*, *2*, p.14.

Sharma, M., 2018. Development of a 'Green building sustainability model'for Green buildings in India. *Journal of cleaner production*, *190*, pp.538-551.

Sharma, N., Kalbar, P.P. and Salman, M., 2022. Global review of circular economy and life cycle thinking in building Demolition Waste Management: A way ahead for India. *Building and Environment*, *222*, p.109413.

Singhal, S., Thapar, S., Kumar, M. and Jain, S., 2022. Impacts of sustainable consumption and production initiatives in energy and waste management sectors: examples from India. *Environment, Development and Sustainability*, *24*(12), pp.14184-14209.

Sinha, T., Clarke, S. and Farquharson, L., 2018, July. Shrek, Saunders and the onion myth: Using myths, metaphors and storytelling. In *ECRM 2018 17th European Conference on Research Methods in Business and Management* (p. 366). Academic Conferences and publishing limited.

Viswalekshmi, B.R., Bendi, D., Opoku, A. and Kugblenu, G., 2024. Impact of construction and demolition waste on the realisation of the sustainable development goals. In *The Elgar Companion to the Built Environment and the Sustainable Development Goals* (pp. 265-279). Edward Elgar Publishing.

Wichai-Utcha, N. and Chavalparit, O., 2019. 3Rs Policy and plastic waste management in Thailand. *Journal of Material Cycles and Waste Management*, *21*, pp.10-22.

Zhao, X., Webber, R., Kalutara, P., Browne, W. and Pienaar, J., 2022. Construction and demolition waste management in Australia: A mini-review. *Waste Management & Research*, *40*(1), pp.34-46.

Appendix

Questionnaires

Survey Questionnaire: Sustainable Strategies for Waste Management in Real Estate Construction in Delhi

Section A: General Information

1. What is your role in the construction or waste management sector?

- Project Manager
- Contractor
- Engineer
- Architect
- Environmental Consultant
- Municipal/Policy Official
- Other

2. Type of organization you are associated with:

- Private Construction Firm
- Government Agency
- Real Estate Developer
- Waste Management/Disposal Service Provider
- Other

Section B: Location (GIS Mapping)

3. Select the location/area of your project or construction site in Delhi:

- Rohini
- Dwarka
- Lajpat Nagar
- Saket
- Karol Bagh
- Okhla

- Mayur Vihar
- Connaught Place

Section C: Waste Generation and Management

4. What is the approximate amount of C&D waste generated at your site per month?

- Less than 1 ton
- 1–5 tons
- 6–10 tons
- More than 10 tons

5. How is C&D waste managed at your site? (Select all that apply):

- On-site reuse of materials
- Sent to recycling facilities
- Collected by municipal authorities
- Dumped in landfills
- Unauthorized/open dumping

6. Rate the adequacy of waste management facilities available in your area:
(Scale: 1 = Very Poor, 5 = Excellent)

- 1
- 2
- 3
- 4
- 5

Section D: Awareness and Policies

7. Are you aware of the Construction and Demolition Waste Management Rules (2016)?

- Yes
- No

8. How effective do you think the enforcement of these rules is in Delhi?
(Scale: 1 = Not Effective, 5 = Highly Effective)

- 1
- 2
- 3
- 4
- 5

9. Which stakeholders should play the most significant role in C&D waste management?

- Government/Regulatory Bodies
- Construction Companies
- Waste Management Service Providers
- Local Communities
- Other

Section E: Barriers and Challenges

10. What are the major challenges in implementing sustainable C&D waste management? (Select all that apply):

- Lack of awareness/training
- High cost of recycling facilities
- Weak enforcement of regulations
- Lack of infrastructure for waste segregation
- Limited market for recycled materials
- Other

11. Rate the severity of the waste disposal issue in your project location:
(Scale: 1 = Not Severe, 5 = Extremely Severe)

- 1
- 2
- 3

- 4
- 5

Section F: Technological and Strategic Improvements

12. Would you support using GIS-based monitoring to improve waste tracking and management in construction?

- Yes
- No

13. What strategies do you think should be prioritized to improve waste management in Delhi's construction sector? (Select all that apply):

- Incentives for recycling and reuse
- Stricter penalties for illegal dumping
- More recycling facilities and infrastructure
- Training programs for workers and contractors
- Public awareness campaigns