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ENVIRONMENTAL SCIENCE ARCHIVES
ISSN: 2583-5092
Volume V Issue 2, 2026

RESEARCH ARTICLE OPEN ACCESS

The Study on Supply Chain Management of Construction and Demolition Waste across Group Housing Development Projects in Bengaluru

Jyothi JS and Chandrashekar JS*

Department of Studies and Research in Environmental Science, Karnataka State Open University, Mysuru; India

*Correspondence for materials should be addressed to CJS (email: jnuchandu@gmail.com)

Received: 2026/09/14
Accepted: 2026/11/22
Published: 2026/11/27

Abstract

Rapid urbanization across Bengaluru has driven a sharp rise in Construction and Demolition (C&D) waste generation. Despite regulatory frameworks such as the C&D Waste Management Rules, 2016, and the updated Environment (C&D) Waste Management Rules, 2025, most group housing projects continue to rely on a linear collect-transport-dispose model, showing limited traceability to authorized recycling plants. This research evaluates the Supply Chain Management (SCM) performance of C&D waste across four group housing developments in Bengaluru: Site 1 at Mallasandra (3,14,354sq.m), Site 2 at Kaggalipura (22,938sq.m), Site 3 at Devanahalli (66,195sq.m), and Site 4 at Devanahalli (1,19,000sq.m). Applying a load-based audit methodology (Volume=16m³×truckloads; Mass=Volume×density×composition), the recorded waste generation rates were 70kg/m², 30.8kg/m², 5.6kg/m², and 51.5kg/m², respectively. Waste during the finishing stage was primarily composed of bricks and blocks (50%-70%), cement, tiles, and packaging materials, whereas superstructure waste was dominated by soil and steel. SCM effectiveness varied widely among sites. Site 1 (Mallasandra), characterized by consistent source segregation and high compliance, achieved a 42.85% diversion rate (9,472tonnes recycled or reused). Conversely, Site 2 (Kaggalipura) recorded 0% diversion due to the absence of segregation and inadequate transport practices. Site 4 (Devanahalli) achieved only 13.47% diversion despite daily collection routines, constrained by unsegregated waste inputs. Meanwhile, Site 3 (Devanahalli) reached 75% diversion primarily through on-site soil reuse. The findings indicate that source segregation rather than collection frequency is the primary operational bottleneck, while recycling plant efficiency was rated as poor across all evaluated sites. To address these challenges, the study proposes a five-pillar circular SCM model aligned with Extended Producer Responsibility (EPR) targets (25% for 2025–26 scaling up to 100% by 2028–29) and mandated recycled content requirements (5% to 25% by 2030).

Keywords: Construction and Demolition Waste; Characterization of C&D Waste; Supply Chain Efficiency; Multi-site Analysis; Waste Generation Rate; Circular Economy; EPR

Introduction: The Urban Metabolism of Bengaluru

Analysing Bengaluru through the framework of urban metabolism helps illustrate its evolution from a regional administrative centre into a major technological hub (Kennedy et al., 2007; Sudhira et al., 2007; Wolman, 1965). In this context, the city functions as an open system that absorbs natural resources and generates substantial material outputs (Kennedy et al., 2007; Wolman, 1965). The primary material inputs have traditionally included sand, gravel, and cement, while construction and demolition (C&D) debris constitutes a major share of the resulting waste stream (Bansal & Singh, 2015; Jain & Bansal, 2022). To manage this, the Greater Bengaluru Authority (GBA) has established an Extended Producer Responsibility (EPR) mechanism under the Construction & Demolition Waste Management Rules, 2025, aiming to enforce producer accountability, recycling targets, and digital

tracking systems (Bruhat Bengaluru Mahanagara Palike [BBMP] & Bengaluru Solid Waste Management Limited [BSWML], 2026; Ministry of Environment, Forest and Climate Change [MoEFCC], 2025).

The Scale of Consumption

Bengaluru exhibits one of the highest material consumption rates in India (Jain & Bansal, 2022). Propelled by rapid IT-sector expansion, the city's built-up footprint expanded by over 1,000% between 1970 and 2024 (Ramachandra et al., 2012; Sudhira et al., 2007). This physical growth has fuelled an immense demand for natural aggregates (Bansal & Singh, 2015; Bureau of Indian Standards [BIS], 2024). Because nearby quarries within the Bengaluru Urban and Rural districts are nearing depletion, material sourcing now extends into peripheral districts and neighbouring states. This supply-demand gap has triggered a resource deficit where legal quarries can no longer fully satisfy urban construction requirements (Jain & Bansal, 2022).

The Debris Crisis: Metabolic Imbalance

The output side of Bengaluru's urban metabolism faces severe strain (Kennedy et al., 2007). The city generates roughly 4,750 tonnes of C&D waste daily, while formal processing capacity across existing plants is limited to approximately 1,750 tonnes per day (TPD), leaving an unmanaged surplus of 3,000 TPD (BBMP & BSWML, 2026; Central Pollution Control Board [CPCB], 2023). Historically, excess debris has frequently found its way into local water bodies—such as Bellandur and Varthur lakes—and stormwater drainage channels (Rajakaluves), altering local drainage patterns (Ramachandra et al., 2016). This obstruction restricts runoff capacity during monsoons and contributes directly to urban waterlogging (Ramachandra et al., 2012, 2016).

Transitioning to a Circular Metabolism

Current management strategies seek to pivot the city away from a linear model (take-make-dispose) toward a circular metabolism (reduce-reuse-recycle) (Kennedy et al., 2007; Jangam & Myneni, 2025). Within a circular framework, demolition debris originating from urban redevelopments is treated not as waste, but as secondary raw material for subsequent building cycles (BIS, 2024; CPCB, 2023; Jangam & Myneni, 2025).

Demographic and Economic Drivers

Housing a population exceeding 13 million alongside a continuous influx of working professionals, Bengaluru maintains steady demand for residential developments and Grade-A commercial spaces (Sudhira et al., 2007). Regular demolition and reconstruction cycles in established neighbourhoods like Jayanagar and Indiranagar generate a steady stream of material feedstocks, provided recovery infrastructure functions efficiently (Jain & Bansal, 2022; Wu et al., 2014).

Literature Review

Bansal and Singh (2015) emphasized that proper segregation can render 70%-80% of C&D waste reusable. Similarly, Jain and Bansal (2022) pointed out that India's recycling rate remains below 10% due to underdeveloped market linkages and a lack of standardized quality assurance for recycled materials. Jangam and Myneni (2025) demonstrated that recycled aggregates can substitute up to 30% of natural aggregates without structural strength loss, provided the input material is segregated at source.

International studies indicate that supply chain performance in C&D waste management depends on five core variables (Wu et al., 2014; Yuan & Shen, 2011):

- Source segregation
- On-site reuse potential
- Collection frequency and logistical tracking
- Transport compliance
- Integration with authorized recycling facilities

Previous audits conducted by the Bruhat Bengaluru Mahanagara Palike (BBMP) revealed that only 25% of bulk waste generators maintained proper consignment manifest records under the 2016 rules (BBMP & BSWML, 2026; CPCB, 2023).

Study Area and Site Description

Four active group housing projects representing diverse project scales, construction stages, and geographic locations were selected for empirical analysis. Projects in different stages were chosen across Bengaluru in the following localities:

- Site-1: Mallasandra (South Bengaluru)
- Site-2: Kaggalipura (South Bengaluru)
- Site-3: Devanahalli (North Bengaluru)
- Site-4: Devanahalli (North Bengaluru)

Table 1. Details of sites and projects analyzed in the paper

Project	Location	Area (sq. m)	Project Stage & Description
Site 1	Mallasandra	3,14,354	High-rise finishing stage (Largest project)
Site 2	Kaggalipura	22,938	Mid-rise super-structure + finishing
Site 3	Devanahalli	66,195	Early excavation/foundation
Site 4	Devanahalli	1,19,000	Super-structure to finishing

Methodology: Multi-Site Framework

The primary data, gathered directly by the research scholar during site visits from the respective Site Engineers between January 2026 and May 2026, followed a structured site-survey protocol that captured both the superstructure and finishing phases.

Initial Site Exploration

Site access points, temporary material storage zones, and segregation areas were mapped to evaluate internal material flows.

Unit Quantification

Standardized truckloads (16m^3 effective volume) served as the primary measurement unit for waste leaving each site. Calculations followed the formulas:

$Volume = 16m^3 \times truckloads$

$Mass = Volume \times density \times composition\ factor$

Bulk densities were assigned based on predominant waste components:

Table 2. Material waste Density (T/m^3)

Material Waste Category	Density (Tonnes/m^3)
Bricks/ Blocks	1.44
Sand/Cement	1.60
Vitrified Tiles	1.10

Material Characterization

Gross material composition was measured alongside mixed waste percentages derived from visual sampling and site records.

Rate Calculation

Waste Generation Rate (WGR) = Total Mass (kg) / Total Built-up Area (sq.m)

Table 3. Performance indicator rating

Performance Indicator	Rating
Segregation frequency	Always / Often/ Sometimes / Never
Collection	Daily / 2-3 times/week / Weekly / Irregular
Transport compliance	Excellent / Good / Poor / Very Poor
Overall compliance	Excellent / Good / Low / Very Low
On-site reuse rating and Authorized plant linkage	Excellent / Good / Poor / Very Poor

Table 4. Performance indicator rating description

Rating Description	Rating %	Rating
Very Poor/ Very Low/ Never/ Irregular	<25%;	1-2
Poor/Low/ Sometimes / Weekly	25% - 50%;	3
Good/ Often/ 2-3 times/week	50%-75%;	4
Excellent/ Always/ Daily	75%-100%	5

Results and Discussion

Waste Composition Characterization

Table 5. Site-wise waste composition

Project Name	Waste Composition Observed
Site 1	Cement, Sand, Vitrified Tiles, Packaging material, Contamination, Electrical, Steel, Plumbing & Sanitary
Site 2	Bricks / Blocks, Sand / Cement, Vitrified Tiles, Packaging material, Plastic, and Others
Site 3	Bricks / Blocks, Sand / Cement, Steel, Soil
Site 4	Bricks / Blocks, Concrete, Vitrified Tiles, Packaging material, Electrical, Plumbing & Sanitary, Steel, and Others

Finishing stage waste was primarily composed of bricks and blocks (50%-70%), cement, tiles, and packaging materials, whereas superstructure waste consisted mainly of soil and steel. These proportions align with previous findings indicating that finishing activities generate 45%-55% of total debris in high-rise developments.

Waste Generation Rate (WGR)

Observed WGR values varied notably across projects: Site 1 recorded 70kg/m², Site 2 recorded 30.8kg/m², Site 3 recorded 5.6kg/m², and Site 4 recorded 51.5kg/m². The high WGR at Mallasandra reflects active finishing works and limited packaging waste minimization, whereas the low rate at Site 3 is attributable to early-stage excavation and substantial on-site soil retention.

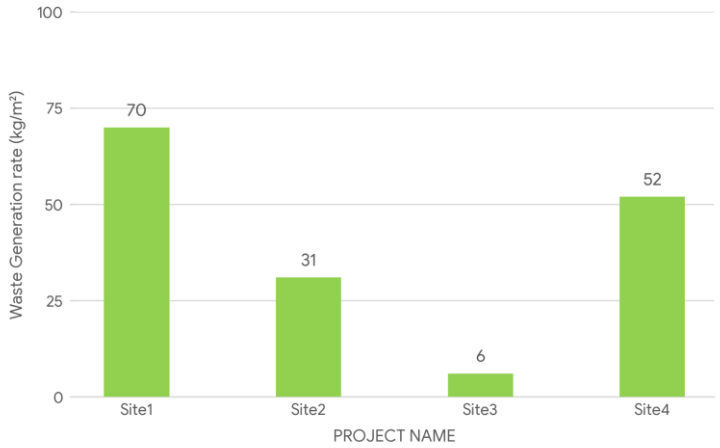

Fig. 1. Waste Generation Rate across Four Group Housing Projects, Bengaluru

Waste Analysis

Table 6. Material waste site-wise analysis

Project	Disposal (T)	Recycle (T)	Reuse (T)	Total Mass (T)
Site 1	12,528	7,168	2,304	22,000
Site 2	708	0	0	708
Site 3	92	12	269	373
Site 4	5,304	480	346	6,130

**T (Tonnes)*

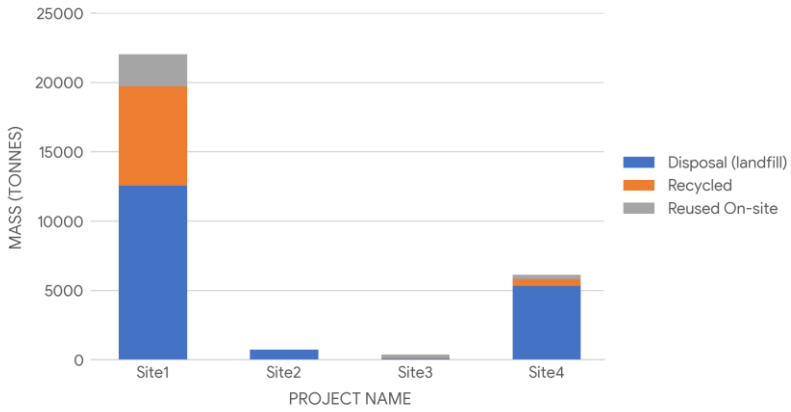

Fig. 2. C&D Waste - Disposal vs Recycle vs Reuse (Tonnes)

Site 1 diverted 9,472T (43%) while landfilling 12,528T. Site 2 demonstrated zero diversion under a strictly linear model. Site 3 achieved the highest diversion percentage (75%), largely driven by on-site soil reuse (269T). Despite daily collection schedules, Site 4 diverted only 13.47% (826T), confirming that collection frequency alone does not ensure circular resource recovery.

Diversion Efficiency and SCM Bottleneck

Table 7. Site wise Diversion efficiency

Project	Total Disposal (T)	Total Diversion (T)	Diversion Rate%
Site 1	22,000	9,472	43%
Site 2	708	0	0%
Site 3	373	281	75%
Site 4	6,130	826	13%

**Total Disposal includes diverted materials*

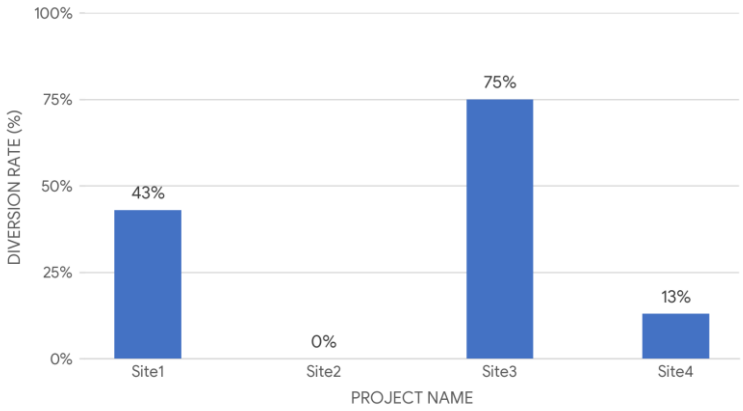

Fig. 3. Total Waste Diversion Efficiency (Recycle+Reuse)

Supply Chain Management Assessment

Segregation, Collection, Transport and Compliance Matrix

Table 8. Site wise supply chain management matrix

Project	Segregation	Collection	Transport	Compliance
Site 1	Always	Daily	Excellent	Excellent
Site 2	Never	Weekly	Poor	Very low
Site 3	Never	Very poor	Very poor	Low
Site 4	Never	Daily	Good	Low

Key Insight: Source segregation serves as the strongest determinant of diversion success. Site 1 practiced consistent segregation and achieved a 43% diversion rate alongside excellent compliance. Conversely, Site 4 maintained daily collection routines but lacked segregation, resulting in a 13.47% diversion rate. Although Site 3 recorded poor collection and transport ratings, it attained the highest diversion rate (75%) by managing earthwork entirely on-site rather than relying on external transport. Furthermore, all sites received poor ratings regarding linkage to authorized recycling plants, pointing to persistent structural market bottlenecks despite the 2025 regulations.

Table 9. Site wise Reuse and Recycle analysis

Project	On-site Reuse Rating	Authorized C&D Recycle Plant Linkage
Site 1	Good	Poor
Site 2	Very poor	Poor
Site 3	Good	Poor
Site 4	Poor	Poor

Conclusion

This multi-site assessment demonstrates that Bengaluru's C&D waste supply chain is at a critical juncture. While city-level generation (4,750 TPD) significantly outpaces processing capacity (1,750 TPD) (BBMP & BSWML, 2026), the 2025 regulatory updates and newly allocated infrastructure investments provide a framework for improvement (BBMP & BSWML, 2026; MoEFCC, 2025). Source segregation emerges as a vital operational factor: projects practicing consistent segregation achieved 43% diversion compared to 0%–13% for unsegregated sites . Universal low ratings for authorized plant linkages highlight the need for enhanced digital tracking and stronger economic incentives (CPCB, 2023; Yuan & Shen, 2011). Achieving complete recycling targets by 2028–29 will necessitate rigorous EPR enforcement, mandatory on-site material reuse, and minimum recycled content mandates for future construction projects, supporting sustainable growth through 2030 (BIS, 2024; Jangam & Myneni, 2025; MoEFCC, 2025).

Abbreviations

C&D: Construction and Demolition; **SCM:** Supply Chain Management; **EPR:** Extended Producer Responsibility; **GBA:** Greater Bengaluru Authority; **NA:** Natural Aggregates; **TPD:** Tonnes Per Day; **IT:** Information Technology; **BBMP:** Bruhat Bengaluru Mahanagara Palike; **WGR:** Waste Generation Rate; **kg:** Kilogram; **sq.m:** Square meter; **kg/m²:** Kilogram per square meter; **T:** Tonnes.

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Author Contributions
JJS conceived the concept, wrote the manuscript and CJS edited, reviewed and approved the manuscript.

Funding
Not applicable.

Availability of data and materials
Not applicable.

Competing interest
The authors declare no competing interests.

Ethics approval
Not applicable.

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Citation: Jyothi JS and Chandrashekar JS (2026) The Study on Supply Chain Management of Construction and Demolition Waste across Group Housing Development Projects in Bengaluru. Environmental Science Archives 5(2): 628-633.