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Resource Efficiency and Recycling of Construction and Demolition Waste

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Preface

The construction sector is the largest contributor to greenhouse gas emissions and a leading generator of waste. It also uses a lot of natural resources. The sector continues to grow rapidly, especially in the global south. As we build more and upgrade our existing building stock, large volumes of construction and demolition (C&D) waste is being generated. Further, the composition of this waste is getting more complex as newer materials have become a part of the construction supply chain over the last few decades.

C&D waste management is more complex then what is generally perceived. The sheer volume, weight and diverse composition of materials, and their supply and handling logistics play as big a part as their processing for recycling and disposal. As cities become more aware of efficiencies in use of resources and long term environmental impact of materials, recycling, reuse and circularity take a front seat. In spite of this, recycling of C&D waste has failed to take off. Only a handful of recycling facilities are available in India and only a few States have guidelines for building a recycling supply chain. Considering the impact of C&D waste on climate, the scope for circularity in the construction sector, and the Anant Centre for Sustainability's (ACfS) focus on the built environment, we decided to study the challenges related to generation and management of C&D waste.

To determine the appropriate area of study, the ACfS organised a Roundtable on C&D waste management with several experts and subsequently decided on undertaking research to assess the strengths and weaknesses – if any, that can be addressed to achieve greater efficiency and sustainability in the C&D waste management process and to contribute to related policies and processes if relevant. The ACfS decided to use the Life Cycle Assessment (LCA) technique in order to analyse the environmental impact of the C&D waste recycling process. For getting the Life Cycle Assessment of the process and manufacture of products, SimaPro software was used.

The project objectives include the study of C&D waste management strategies and practices, map and analyse the role of regulatory authorities, and quantify the potential climate benefits from C&D waste management. The study of secondary literature brought out the complexities in the quantification and management of C&D waste and the challenges of getting data on the status of C&D waste management in Indian cities. Several newspaper articles and reports listed C&D waste management plants in some locations, but further research showed that no further information was available on some of these recycling plants. Many of the plants had shut down after a few months or did not get commissioned. Studies and documents by GIZ, Development Alternatives and Centre for Science have proved to the most reliable sources of secondary information.

Primary research was conducted in Ahmedabad and Surat by a team comprising Fellows at the Anant Fellowship in Built Environment and another team conducted the study in Noida. In all cities, data gathering required site visits and meetings with several stakeholders. Data was collected through semi-structured interviews of various stakeholders including key people managing the recycling plants at Surat, Ahmedabad and Noida, municipal authorities and architects.

Having identified the challenges in getting data, the ACfS organised another Roundtable on 25th April 2023 to discuss the current challenges in C&D waste management and explore the possible solutions for achieving greater circularity in the construction sector. Stakeholders from the project cities, various experts and project implementing partners participated.

The Roundtable further reiterated the gaps in knowledge about the number of plants in the country and limited uptake of products made from recycled C&D waste. Most significantly, the experts confirmed the findings of the ACfS teams that the transportation of C&D waste from source of generation to dumping sites (not accounted for in the LCA) and from dumping sites to the recycling plant contributes substantially to GHG emissions. In addition, based on the team's interaction with Godrej Properties, the findings from a study by Godrej Properties was incorporated in the report.

Subsequently, a copy of the relevant sections of the Report were shared with the plant managers in the three cities and with Mr. Pradeep Khandelwal – who has been working in the sector since the planning and commissioning of the first C&D plant in Delhi, with a request to identify any gaps or errors in the report. The feedback and data received from Mr. Pradeep Khandelwal and Managers of Noida and Ahmedabad Plants has been incorporated in the Report.

The report highlights the challenges of getting reliable data on the C&D waste generated in the various cities, the C&D waste collected and processed in each plant in India and data on products made from recycled C&D and utilised. Availability of such data will provide a more realistic estimate of the C&D waste being processed and the recycled products utilised.

Dhaval Monani

Associate Professor and Director, Affordable Housing

Director, Anant Fellowship

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Anurita Bhatnagar contributed to the research from the time of its inception and was instrumental in gathering primary data for the Noida C&D Recycling plant; while Athiphan Anbumani, Keziah George and Tripti Mittal - Fellows of the Live Action Project conducted the primary research in Ahmedabad and Surat. Gokulram A, Manager Operation & Applied Research, Anant School for Climate Action and Mohammad Faraz Kazi of Sustain Labs Paris have conducted the LCA of the case-studies.

Miniya Chatterjee, as always, has been a constant source of motivation and constructive feedback, and played a pivotal role in initiating this research.

Last but certainly not the least we are grateful to Dr. Anunaya Chaubey, Provost of Anant National University, who supported this research with resources and advice at every step.

Summary

The world's average extraction of ground resources is 1,112 tonne per hectare (450 tonne per acre), while India extracts 3,904 tonne of resources per hectare (1,580 tonne per acre) (Yusof et al., 2017). Globally, the construction sector accounts for 20% to 50% of the natural resources consumed, including 40% of all extracted raw materials, 25% of virgin wood and 12% of water (Yeheyis et.al. 2013). It also accounts for 39% of energy and process-related carbon dioxide (CO_2) emissions of which 11% of the emissions is attributed to the manufacturing of construction materials and products such as steel, cement, lime, brick and glass. In addition, the construction sector accounts for 45% of all solid waste produced, and 36% of final energy used (GABC et al., 2019). The negative effects of construction waste include air pollution with particulate matter

According to the International Resource Panel (IRP)[1], resource extraction and its processing accounts for approximately half of global greenhouse gas emissions. Promising strategies for reducing GHG emissions include improved recycling of construction materials and designing buildings with lesser material (IRP, 2020). The EPA (2023) too has identified reduction of waste at source, salvaging and re-using components such as doors, etc., recycling and reusing the existing C&D waste materials as a strategy for reducing GHG emissions.

In India, policies, rules and guidelines have been introduced to mandate actions for promoting a circular economy through the use of locally sourced and secondary raw materials that lower the carbon footprint in the country. These include the Guidelines for Sustainable Habitat, 2014 (CPWD), Solid Waste Management Rules, 2016 (MoEFCC), the C&D Waste Management Rules, 2016 (MoEFCC), Guidelines on Environmental Management of C&D Wastes, 2017 (CPCB), and a draft National Resource Efficiency Policy (MoEFCC, 2019). More significantly, the CPWD Guidelines for Sustainable Habitat identified the need for special provisions in the codes of the Bureau of Indian Standards (BIS) and the Indian Roads Congress (IRC) for use of recycled aggregate in combination with naturally occurring aggregates (CPWD 2014). This led to BIS adding the provision that permitted the use of manufactured aggregates in plain, lean, and reinforced concrete (BIS 2016a) and the National Building Code of India (2016) adding the use of recycled aggregate in concrete for bulk fills, bank protection, base/ fills of drainage structures, pavements, sidewalks, kerbs and gutters, etc. (BIS 2016b). The Indian Roads Congress also added provisions regarding the use of recycled aggregate and recycled concrete aggregate for road works such as kerb stones, paver blocks, embankment, sub-grade and sub-base construction, stabilised base course construction, and for replacing a part of aggregates in different types of cement concrete pavements (IRC:121-2017).

The first plant with a recycling capacity of 500 TPD of construction and demolition (C&D) waste was commissioned in Delhi in 2009. This was followed by the commission of a recycling plant in Ahmedabad in June 2014. On 27 April 2023, Kolkata's first C&D waste recycling plant with a capacity of 1600 TPD was commissioned on a 5 acres plot in New Town, and on 8 October 2023, a 2000 TPD C&D processing plant utilising the CFlo technology was commissioned on a 7 acres plot in Burari, Delhi. Therefore, there is a significant experience of recycling C&D waste in India and thus an understanding of the demand for recycled materials and products.

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1 Established by UNEP in 2007, IRP is a scientific panel of experts that aims to help nations on the sustainable use of natural resources and a better understanding of how to decouple economic growth from environmental degradation while enhancing human well-being.

The findings from the literature review can be summed up as following.

i. Policy interventions are required to achieve material efficiency through revision of building standards and codes, use of building certification systems, green public procurement, higher taxation for virgin material, removal of subsidies on virgin resources, and mandates for reuse of building materials and use of recycled materials.

ii. Evaluation of policies on a life cycle basis prominently shows the changing burden and synergies across life cycle stages and related industrial sectors.Policies should be evaluated on a life cycle basis to reveal burden shifting and synergies across life cycle stages and industrial sectors.

iii. Onsite construction waste management is practiced effectively because of economic incentives, refund of deposits and penalties.

iv. The management of C&D waste recycling facilities face many barriers.

v. Consumer preferences and behaviour play an important role in the choice and use of recycled materials.

vi. The design of concrete mixes requires careful preparation to ensure that the quality of the product is not affected because of the use of recycled aggregates.

This Report is based on a study of C&D waste recycling plants in Ahmedabad, Surat and Noida with the objective of learning about the current status of C&D waste recycling as well identification of the benefits of the C&D waste recycling process using the Life-Cycle Assessment method for the same. The results from the Life Cycle Assessment (LCA) of the C&D waste recycling plants in the three cities show that the environmental impacts in terms of GHG emissions of transporting the C&D waste are higher than the benefits accrued from recycling of the debris. The research therefore shows that intensive efforts are required for the following:

1. In order to accrue maximum environmental benefits of recycling C&D waste, large scale projects should individually or in collaboration with other projects, process and recycle C&D waste on-site (as per the regulations) and use the products and materials on-site to the extent possible, to minimise transportation related environmental impacts.
2. As per the C&D Management Rules 2016, large generators of C&D waste (who generate more than 20 tonnes per day (TPD) or 300 tonnes per project per month) are required to submit a Waste Management Plan and have an Environment Management Plan before starting construction, demolition or remodelling work. The study indicates the need for close scrutiny and monitoring of the Plans, including actions taken for minimising quantity of materials used and waste generated (design and technology).
3. Explore technology options for decentralised recycling of C&D waste that addresses concerns about air and noise pollution. A number of builders working in close proximity could set-up small and semi-mobile recycling plants. For example, CREDAI, which got a few builders to come together to set-up a batching plant, can also facilitate mobile or semi-mobile C&D waste recycling facilities.
4. Provide incentives to private C&D waste recyclers such as Kesarjan and other Building Centres to promote production of varied and higher-end products from C&D waste. Incentives could include access to subsidised electricity (as for agricultural use), and financial support for expanding capacity and for research and innovations for quality of final products.
5. Close monitoring of all Government organisations and their tendered projects (as available for Delhi) to ensure that contractors not only transfer the C&D waste generated to the closest recycling facility but also use the mandated percentage of recycled materials on projects. The off-take of products made from recycled C&D waste will enable the concessioners to run the plants smoothly.

6. Data uploaded on SBM-Urban platform for MSW and C&D waste (as required under Swachh Survekshan) should be available publicly for transparent monitoring and for research and analysis.

In conclusion, C&D waste management contributes to progress towards SDG Goal 12 (Responsible Consumption and Production) through implementation of initiatives that reduce waste, promote recycling, and re-use; and SDG Goal 13 (Climate Action) through implementation of actions that will reduce greenhouse gas emissions and build climate resilience.

The report is organised in three parts. The first part covers literature review for various aspects of C&D waste recycling, including the challenges in strategising C&D waste management. The second part covers the status of C&D waste management in India, and the third part covers the research in Ahmedabad, Surat and Noida as well as Srinagar.

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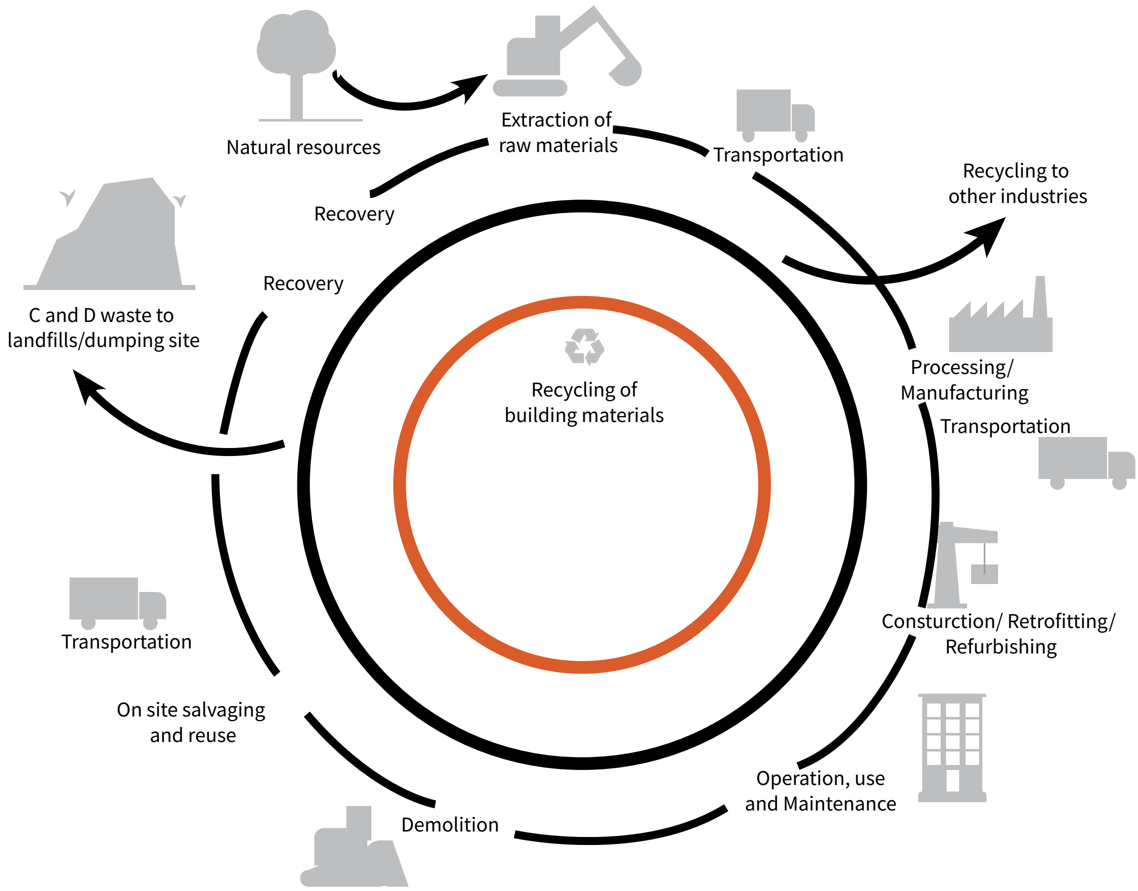
Resource Efficiency and Construction and Demolition Waste

Environment became a major issue following the 1972 United Nations Conference on Environment and all signatory countries of the Stockholm Declaration committed to reduce environmental pollution through recycling and proper disposal of waste (UNEP, 1972). One of the strategies identified for ensuring a trade-off between growth and environmental well-being is to promote a Circular Economy (CE) model. CE promotes a closed loops system by enhancing efficiency in the extraction and use of natural resources, minimising and recycling waste into products and components that lose minimal value (EPA, 2023; EDC, 2023; The Green Brain, 2023).

Figure 1: Circular Economy and the Construction Sector



In urban areas, the rapid increase in construction, renovation and/ or demolition of buildings and other infrastructure is leading to more extraction of natural raw materials and generation of a huge volume of construction and demolition (C&D) waste (Islam et al., 2019; Tang et al., 2020). C&D waste is one of the primary sources of PM-10 (particulate matter of 10 micrometre or less) that substantially contributes to environmental pollution. The contributors include fugitive-dust or small airborne particles from construction sites, unpaved roads, aggregate storage piles, heavy construction and open fields. Further, since C&D waste is often dumped in low lying landfill sites and rain fed and other natural water bodies, natural drainage channels are obstructed and local water sources and ecosystems are impacted. This often leads to flooding and pollution of soil and groundwater from C&D waste containing elements such as paint. Hence, one of the direct means for reducing the adverse impact of the buildings and the construction sector on the environment is through sustainable management of the building materials and the sector's waste stream.

C&D waste recycling has significant environmental benefits over processing of virgin materials (Faleschini et al. 2016; Hossain et al. 2016; Rosado et al. 2017; Penteado and Rosado 2016; Simion et al. 2013). Replacing virgin aggregates with recycled aggregates leads to energy savings of 17% according to Simion et al. (2013) and 50% according to Hossain et al. (2016). Recycling of C&D waste generates seven times lower CO2 equivalent emissions compared to crushed stone (Simion et al. 2013), and CO2 equivalent emissions of almost ten times can be prevented by replacing virgin materials with recycled materials from the C&D waste processing facility (Coelho and Brito 2013).

In 2022, the Anant Centre for Sustainability (ACfS) decided to undertake research to assess the extent to which the C&D waste stream is being managed sustainably in selected cities of India with the objective of recommending policy or city-level interventions if required.

Aim

The aim of this research is to investigate the C&D waste recycling processes in selected cities of India to assess the strengths and weaknesses – if any, that can be addressed to achieve greater efficiency and sustainability in the C&D waste management process. The ACfS decided to use the Life Cycle Assessment (LCA) technique for the research.

The LCA is a standardised method adopted globally to support decision making for C&D waste management (Bovea and Powell, 2016). It is a technique used for the quantification of environmental impacts such as all relevant emissions, carbon footprint, resources consumed and/ or depleted, and related environmental and health impacts (EC, 2010; Mondello & Salomone, 2020; JRC-IES, 2011; Jolliet et al., 2015). Some of the key applications of LCA include:

1. Identifying environmental hotspots in a product's life cycle for improvement opportunities.
2. Analysing the contribution of different life cycle stages to the overall environmental impact to prioritise improvements in products or processes.
3. Comparing products for evaluating their environmental performance by considering their complete life cycle from selection and production of raw material to construction, operation and final product disposal, including recycling when applicable.

LCA results vary widely due to subjective boundary conditions, differences in methodologies, spatial and temporal variations, as well as lack of reliable data (Crawford 2011). The LCA can be used for waste management services rather than the entire life cycle of the products that have become waste. Hence the LCA for the research covers the processing of C&D waste in accordance with ISO 14040 and 14044 (ISO, 2006a, b).

Objectives

The objectives of the research are:

1. To study the prevalent C&D waste management strategies, challenges and practices.
2. To map and analyse the role of regulatory authorities in C&D waste management., and
3. To quantify the potential climate benefits from C&D waste management in terms of its global warming contribution.

Based on accessibility of the recycling facilities from Ahmedabad, the research focused on three C&D waste recycling facilities - the Surat and Ahmedabad city level C&D recycling plants and Kesarjan Building Centre – a private 30 MT capacity recycling plant. The NOIDA plant was identified as a potential good practice because of its involvement in the recycling of approximately 35,000 cubic metres of waste from the demolition of twin towers (Apex of 32 storeys/ 103 meters high and Ceyane of 29 storeys/97 meters high) covering about 69,677 square meters of area (HT News desk, 28 August 2022; Construction Placements, 31 August 2022).

In addition, the current and planned status of C&D waste disposal in Srinagar has been documented in order to facilitate decision-making for the setting-up of one or more C&D waste recycling plants in the area, and for identifying potential use and demand of the recycled waste and its financial viability.

Research Methodology

Extensive secondary data collection followed by field visits to map the C&D waste recycling processes and the outputs/ products made. Data was collected through semi-structured interviews of various stakeholders including key people managing the recycling plants at Surat, Ahmedabad and Noida, Municipal Corporation/ Authority and architects.

SimaPro - a software tool grounded in the robust science of LCA, presents global warming as the highest impact. It is considered a preferred tool for creating ISO-compliant LCAs, and has been used for assessing the C&D waste management process in terms of its global warming contribution. SimaPro has many advantages, such as its association with many databases, flexibility, user friendliness and generation of transparent results, etc. SimaPro provides not only numerical values but also additional results with a coloured impact graph with percentage units that shows the production process and its impact value. The percentage in the graph is calculated by total impact compared with the same impact category in each process.


NORFOLK
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The Construction Sector and Climate Change

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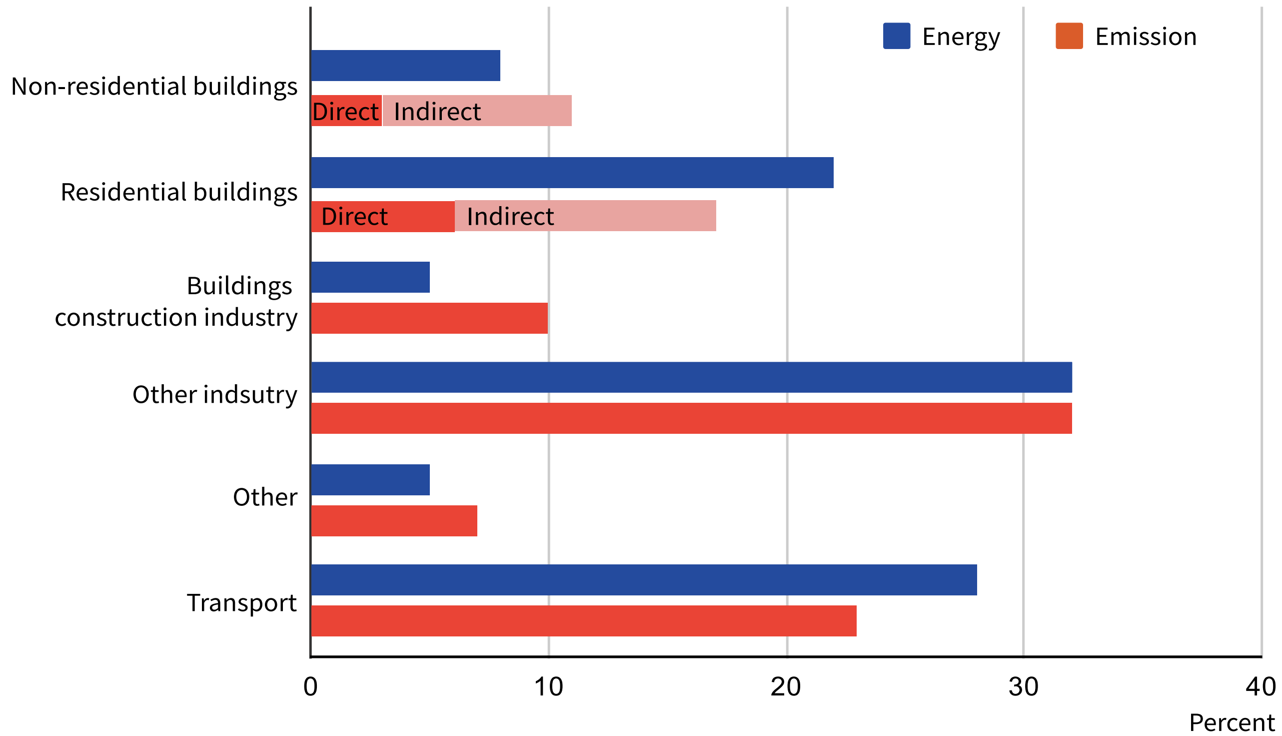
Worldwide, the construction sector accounts for 20% to 50% of the natural resources consumed, including 40% of all extracted raw materials, 25% of virgin wood and 12% of water (Yeheyis et.al. 2013). The construction sector also accounts for 39% of energy and process-related carbon dioxide (CO_2) emissions of which 11% of the emissions is attributed to the manufacturing of construction materials and products such as steel, cement, lime, bricks and glass and 28% is attributed to buildings operations. It also accounts for 45% of all solid waste produced, and 36% of final energy used (GABC et al., 2019).

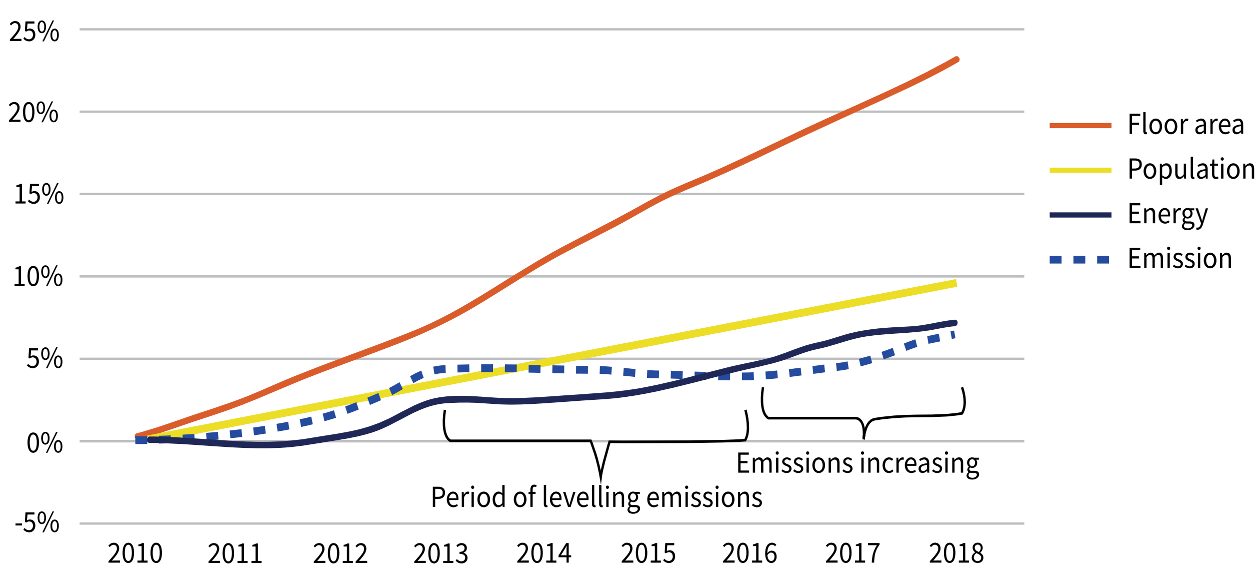
Figure 2: Global Share of Buildings and Construction Final Energy and Emissions, 2019



Source: GABC et al. 2019

As per the Alliance for an Energy Efficient Economy (AEEE), the data provided by India to UNFCCC in the Third Biennial Update Report 2021 shows that in India, 32% of the total national GHG emissions that cover operational and embodied emissions are due to the building and construction sector (Bhardwaj, S. 2022). It is estimated that about 80 per cent of the Indian construction sector's GHG emissions comes from manufacturing of materials like cement, bricks, steel and lime. The sector therefore has great potential for achieving resource efficiency.

Figure 3: Buildings, Construction and Energy-Related Emissions Globally, since 2010



Source: UNEP. 2020

The cement industry is one of the largest emitters of CO2, and India is the second largest producer of cement in the world. In FY 2022, the domestic production in India was nearly 356 MT of cement and accounted for more than 8% of the global installed capacity (IBEF, 2023; TERI et al., 2020). In 2018, the cement industry accounted for approximately 7% of the total CO2 emissions in the country (IEA and UNDP, 2018).. With the production of cement estimated to increase by approximately 6-8 per cent in FY 2023 and 2024, the industry's CO2 emissions will grow (IVAR, 2023).

These figures clearly highlight the need for actions to reduce GHG emissions in the building and construction sector, including the extent to which raw materials are extracted for direct use (such as sand) and the production of building materials.

1.1 Environmental Concerns beyond GHG Emissions

Utilisation of C&D waste as construction material would help in reducing the mining and extraction of virgin materials, reduce the requirement of land for dumping of C&D waste and result in substantial environmental benefits. One approach is to recycle the C&D waste such as concrete and debris into aggregate or concrete products. Metals, including steel, copper and brass are also recycled. The construction costs due to purchasing/ using of recovered/ recycled C&D materials has the advantages of decreasing cost (less wastage) and a significant environmental impact in the form of reduced extraction of virgin raw materials. To illustrate, according to Climate Calculator Research the reuse and recycling of 95% of C&D waste in building a new green home in California resulted in 75% reductions of the total emissions in the first year after construction (Roberts, J., 2009).

A study by Development Alternatives and GIZ in 2015 assessed the criticality of ten naturally available raw materials used in the construction industry in India and their ability to be replenished over time. Criticality was assessed based on seven parameters to which weightage (low, medium or high) was assigned. The distinguishing factors in selecting the critical resources included their limited natural availability, lack of recyclability and energy consumed during extraction, production and transport. Top soil, which is used for making good quality bricks, was found to be the most critical resource because of its use for agriculture and the environmental effect of using the top-soil. Fly-ash bricks were identified as a viable alternative. The second material identified was sand because its mining from river beds impacts the environment by disrupting eco-systems, river flow and the hydrological system. Ban on sand and stone mining has resulted in illegal trade as well as demand for M-sand and stone aggregates. Mining of limestone, 95% of the total being used for cement in India (Indian Bureau of Mines, 2014), results in air pollution and reduction in forest cover. Hence, alternatives such as fly ash based cement have been introduced and have a large market-share (Nagrath, et al., 2015).

Table 1: Secondary Raw Materials replacing Primary Resources in Construction

Primary Resource	Secondary Raw Materials	Source of Secondary Raw Materials	Application
Soil	Fly ash Industrial wastes like marble sludge	Thermal power plants Industries	Fly ash bricks Alternates/ waste based bricks
Stone	Demolition waste	C&D waste	Recycled aggregate Replacement in asphalt mixtures, Portland cement, concrete.
Sand	Demolition waste Natural stone	Construction Sites Quarry	M-sand
Limestone	Crushed limestone Calcined clay Fly ash Slag	Low quality limestone Overburden from clay mines Thermal power plants Sponge iron Industries	Blended cements

Source: Development Alternatives & GIZ, 2015

Given the scarcity of both natural material and land, as well as the environmental benefits of using C&D waste, greater efforts are required to promote the increase in the use of C&D waste for construction and related purposes.

1.2 Construction and Demolition Waste

C&D waste is produced throughout the lifecycle of any civil work that can be classified as: (i) construction of new buildings, (ii) remodelling or renovation of existing buildings, (iii) demolition of old buildings, and (iv) civil and infrastructural works (CPCB, 2016; Peng et al., 1997; Yuan and Shen, 2011; Wu et al., 2014). The amount and type of C&D waste depends on the type of projects (residential or non-residential); size of the projects; and construction technology employed.

Figure 4: C&D Waste Sources and Components

Activity	Waste Type
Site Preparation	• Site clearance, land excavation and levelling, foundations for site enclosures, construction of material storage premises and accommodation for construction workers, roadworks and installation of utilities and infrastructure. • Product damage during transportation, incorrect or excessive purchases, inappropriate storage, supply of deficient quality products • Plant soil, soil, sand, gravel, rock, clay.
Civil and Infrastructural work	• Roads, flyovers, bridges, airport runways buildings and/ or installation of public utilities (telephone/ water/ electricity/ sewage pipelines) and construction or renovation of public infrastructure (bridges/ flyovers). • Concrete, asphalt, paving, stone, sand, gravel, metal, & pebbles
Construction of new buildings/ renovation/ refurbishing of existing buildings	• Generated during building construction, remains of building materials and components (offcuts, breakages, etc.); damage to or non-use of materials; excess procurement, paper & cardboard packaging materials. • Waste resulting from temporary work, testing, formwork, redesign, etc and debris from demolition & reconstruction due to faulty execution; design changes, project errors, new customer requirements etc. • Concrete, steel reinforcement, bricks/ blocks (fly-ash/ AAC) and timber.
Demolition	• Partial or total demolition or reconstruction of buildings and/or civil infrastructure. • Soil, gravel, rubble, aggregates, concrete, ceramics, bricks/ blocks (fly-ash/AAC), stone blocks, overlay plates, tiles, plaster, sand, stones, wood, glass, asbestos, different hazardous paints, fasteners, adhesives, wall coverings, insulation, and dirt. • Metals, colours, glues, resins, electrical wires, insulating materials, etc. if not picked-upon site during the demolition process
Finishing	• Cement mortar, plastering materials, mosaic tiles, flooring. partitioning, ceiling and wall finishing materials, doors & windows, ceramics, water-proofing and paints. • Water tanks, roads, footpaths and other public infrastructure related services. steel bars, moulds/ shuttering, conduits

Construction waste comprises non-biodegradable building materials, debris and rubble from construction of buildings and/ or installation of public utilities (telephone/ water/ electricity/ sewage pipelines) and construction or renovation of public infrastructure (bridges/ flyovers). It is of two types: (a) structural waste (concrete fragments, steel reinforcement and abandoned timber plates) obtained during the course of construction, and (b) finishing waste such as cement mortar, plastering materials, mosaic tiles, ceramics and paints (Poon et al., 2001).

The typical causes of waste production in this phase include timber formwork (30%), wet finishing (20%), concrete work (13%), masonry work (13%) and material handling (10%) (Poon et al., 2004a). Mokhtar et al. (2011) found that factors such as project size, building type, construction method, excess material procurement, storage methods and handling, technical problems and errors by key stakeholders of the project affect waste generation during construction of new buildings. Further, studies have also revealed that the attitude and behaviour of on-site workers can play an important role in the quantum of waste produced (Al-Sari et al., 2012; Teo and Loosemore, 2001).

In practice, the contractors usually assume that the wastage rate is 1% to 10% of the purchased construction materials (Shen et al., 2005). The actual percentage of construction material that becomes waste depends on previous experiences from direct measurement on the construction site. However, such information is not robust for making an effective waste management plans (Llatas, 2011; Solis-Guzman et al., 2009).

Renovation waste includes concrete, wood, plastic, paper, ceramics, bricks, tiles, plaster and all materials originating from worksite construction, repairing, propping, growth, gradual accumulation of additional layers or matter, expansion or renovation activities (Donovan 1991, Bringezu et.al. 1998). In addition, road maintenance, dismantling and renovation activities may result in asphalt and pavement materials such as sand, gravel, metal and materials. Renovation waste is also generated when underground hydraulic and electrical installation work or repairing activities are undertaken.

Demolition waste is generated from partial or total demolition and/ or reconstruction of buildings and/or civil infrastructure. Demolition activities result in nearly 100% of the demolished structures ending up as waste, except for the materials that have a secondary market (Poon et al., 2004b; Joshi, 1999). The composition of the large amount of demolition waste varies depending on the type, shape, size, age and use of the demolished structure. The main material of the building or civil infrastructure comprises soil, gravel, rubble, aggregates, concrete, ceramics, bricks, tiles, plaster, sand, stones, pieces of sanitary ware, wood etc. Demolition materials often also contain metals, colours, glues, resins, wires, insulating materials, etc. if not picked-upon site during the demolition process. Thus, demolition waste differs from construction waste because it contains finishing materials such as paints that result in environmental pollution. Consequently, it requires safer methods of recycling, reuse or disposal.

Excavation waste is generated from site clearance, land excavation and levelling and/or general foundations for buildings, roadwork and other relevant activities. It consists of excavated soil, sand, gravel, rocks and clay. The composition of the excavation waste depends on the local geological characteristics and the type of constructions or civil works or installation and service of public utilities (telephone/ water/ electricity/ sewage pipelines).

1.2.1 C&D Waste Composition

The components and quantities of C&D waste generated varies due to different types of construction practices. Hence is varies regionally as well as from city-to-city. Therefore, the initial stage for studies on C&D waste is data gathering and identifying the types of waste materials being generated. Most studies focus on concrete, bricks, timber, steel and drywall that form a significant quantity C&D waste (Cochran et al, 2007; Gheewala et al, 2009; and Martinez-Lage et al, 2009).

Table 2:Composition of C&D Waste Generated by Material and Activity, 2018

C&D Debris	Waste During Construction	Demolition Debris	Total C&D Debris
Concrete	24.2	381.0	405.2
Wood Products7	3.4	37.4	40.8
Drywall and Plasters	3.9	11.3	15.2
Steel8	0	4.7	4.7
Brick and Clay Tile	0.3	12.0	12.3
Asphalt Shingles	1.2	13.9	15.1
Asphalt Concrete	0	107.0	107.0
Total	**33.0**	**567.3**	**600.3**

Source: USEPA, 2020b

In urban areas, the C&D waste primarily consists of soil, sand and gravel (47%), bricks & masonry (32%), concrete (7%), metal (6%), wood (3%) and various other minor wastes (5%) (MoHUA, 2021). Bricks, tiles, wood and metals are sold for reuse/ recycling. The remaining materials are generally sent to landfills.

1.2.2 Estimation of C&D Waste Generation

The quantification of C&D waste is essential for establishing an effective management system at both project level and city/ regional level (Bergsdal et al., 2007; Li and Zhang, 2013; Yost and Halstead, 1996). Many C&D waste quantification methods and their applicability have been identified in literature. The three methods for quantification of C&D waste are for: i) construction waste which is relatively clean, heterogeneous and generated from the various construction activities, ii) demolition waste which is also heterogeneous but is a mixture of building materials such as aggregate, concrete, wood, paper, metal, insulation, and glass that may contain lead, asbestos and different hazardous paints, fasteners, adhesives, wall coverings, insulation, and dirt, and iii) mixed waste containing electrical wiring, rebar, wood, concrete and bricks. Researchers, who have used various methods to quantify C&D waste generated at different levels, have identified the challenges involved.

1.2.2.1 On Site-Calculation Method

The on-site-calculation method for C&D waste involves measurement of C&D waste at construction sites of new buildings, either directly or indirectly. Direct measurement is done either by weighing or measuring the volume of the waste. The indirect measurement entails analysing contractors' documents and records on a construction site or a landfill to estimate the volume of waste generated. Although the indirect measurement method can only provide approximate estimates, it is more frequently used. Both methods require consensus of contractors, and substantial time, labour and money.

One of the first on-site estimate of the quantities of C&D waste was conducted in the Netherlands by studying 184 dwellings developed in 5 different projects (Bossink & Brouwers, 1996). C&D waste was classified and weighted according to 9 fractions: debris piles, bricks, concrete, blocks, tiles, mortars, aggregates, packages and others. The study found that depending on the type of building materials supplied on site, around 1% to 10% of the volume of the material becomes waste.

1.2.2.2 Site Visit at Construction or Landfill Sites

A survey, including sampling and weighing of waste at construction sites or C&D waste at landfill sites, is often used for determining the management system needs for local solid waste, would be the preferred method for getting detailed data on the amount of C&D waste generated. However, there are challenges to undertaking this method. This includes locating all the illegal C&D debris dumping sites and difficulty in obtaining permission to study samples at private landfill sites. More importantly, this method would be both cost and time prohibitive.

1.2.2.3 Generation Rate Calculation

Generation Rate Calculation (GRC) method is a common estimation technique that can be implemented for construction, renovation and demolition activities. This method uses different parameters for estimation of waste including per capita multiplier, area-based calculations and financial value extrapolation.

The per-capita multiplier method is developed from the method used to quantify municipal solid waste. The per-capita multiplier is an easy way to quantify C&D waste in a region but can fluctuate substantially due to increased C&D activities while the population remains almost constant (Yost and Halstead, 1996; Gao, 2018; Wu, et.al., 2011). Yost & Halstead (1996) proposed a more accurate method that combines building permits data from national statistics, which provide the number and estimated financial value, with empirical waste generation rate data.

The area-based method, wherein construction/ renovation/ demolition waste generated per unit area is multiplied by the total area, is the most frequently used method in literature. The per capita multiplier method is used at project and region levels. This method requires information about the total construction or demolition area from project plans or government departments. Then, the total C&D waste generation amount can be estimated by multiplying the generation rate by total area (Wu, Z. et.al, 2014).

1.2.2.4 Others

Another estimation method for construction waste is to have a fixed percentage of the total purchased construction materials. The total amount of construction waste if often calculated as 10% of the purchased quantities (Wu, Z. et.al., 2014). Lifetime Analysis Method is mainly used for quantifying demolition waste. The assumption is that constructed buildings will eventually become demolition waste. Consequently, the demolition waste over time and can be projected by assuming realistic lifetimes of the buildings and materials (Wu, Z. et.al. 2014).

GIS and Building Information Modelling (BIM) are the other methods for estimation of C&D waste generation for demolition of old buildings (Gao, 2018).

1.2.3 Appropriate Quantification Method for C&D Waste in India

Reviews of quantification methods in literature by Wu, Z. et.al. (2014) and Gao et al (2018) showed that although appropriate quantification methodology is essential for effective waste management, no single quantification method can be appropriate for varied scenarios. Often a combination of two or more methods are used for estimating C&D waste. Thus, the appropriate methodology should be selected according to actual quantification objectives and practical conditions.

In India, authenticated data on C&D waste generation is not currently available because of the uncertainties in estimating the quantum of C&D waste generated. This is attributed to different methods adopted for estimation, the varying pace of developmental activities, redevelopment activities and increase in demolition of old buildings.

Table 3: C&D Waste Estimates for India

Year	C&D waste estimate in MT / annum	Estimate by
2000-2001	10-12	Ministry of Urban Development,TIFAC - Technology Information, Forecasting and Assessment Council, Department of Science and Technology
2010	12-15	Ministry of Environment and Forest
2013	530	Centre for Science and Environment
2015	10-12	Ministry of Urban Development
2015	750	Development Alternatives and GIZ
2016	530	Ministry of Environment, Forest and Climate Change
2017	150	Building Material and Technology Promotion Council

Source: Roychowdhury, Somvanshi & Verma, 2020

A number of estimates of annual C&D waste generation have been made by Government and private agencies since 2000. The estimates vary from 10 to 15 to 625 MT of C&D waste per year (BMTPC, 2018). The Building Materials & Technology Promotion Council (BMTPC) and Centre for Fly Ash Research & Management (CFFARM) provided an annual estimate of 165-175 MT of C&D waste in Indian towns from 2005-2013 (Gupta and Malik, 2018). The MoUD and TIFAC estimated generation of 10 to 12 MT of C&D waste annually. This is around 8.29 to 9.95 kg per capita-year, which is much lower than the 175 kg per capita-year reported by Ram and Kalidindi (2017) in Chennai.

Table 4: Annual C&D Waste Generation in Some Cities in India

City	Population (Census 2011, in millions)	Daily C&D waste generation (tonnes/day)	Annual C&D waste generation (MT/ annum)
Mumbai	12.44	2500	0.75
Delhi	16.79	6500	1.95
Bengaluru	8.44	875	0.26
Chennai	6.5	2500	0.75
Kolkata	4.5	1600	0.48
Jaipur	3.47	200	0.06
Patna	2.51	250	0.08
Ahmedabad	6.06	700	0.21
Bhopal	1.92	50	0.02
Coimbatore	2.62	92	0.03

Source: Development Alternatives & GIZ, 2015

1.2.4 Recent Initiatives for C&D Waste Quantification in India

Two studies of C&D waste generation in India provide a more current estimation of C&D waste generation.

1.2.4.1 Chennai Research

In Chennai, using a combination of the area-based method and per capita multiplier, Ram and Kalidindi (2017) estimated total floor areas of demolished buildings from demolition permits and of newly construction activities from construction permits and estimated the generation rate as 175Kg/ capita/year. The study shows that in the absence of a comprehensive monitoring system for removal and dumping of debris, a long and difficult process is involved in accurately estimating the actual quantity of C&D waste generated. This highlights the fact that the estimation of C&D waste in an urban area requires documentation on permits for new construction, reconstruction and demolition of buildings.

1.2.4.2 Study by Godrej Properties

In 2021, Godrej Properties Limited used the on-site-calculation method to conduct an on ground study to measure actual waste generated during construction of mid-scale residential projects in India. The aim was to specifically understand the quantum, composition and distribution of waste generated at every stage of construction. The study was undertaken across 14 construction sites being developed by Godrej Properties Limited and Mahindra Lifespace

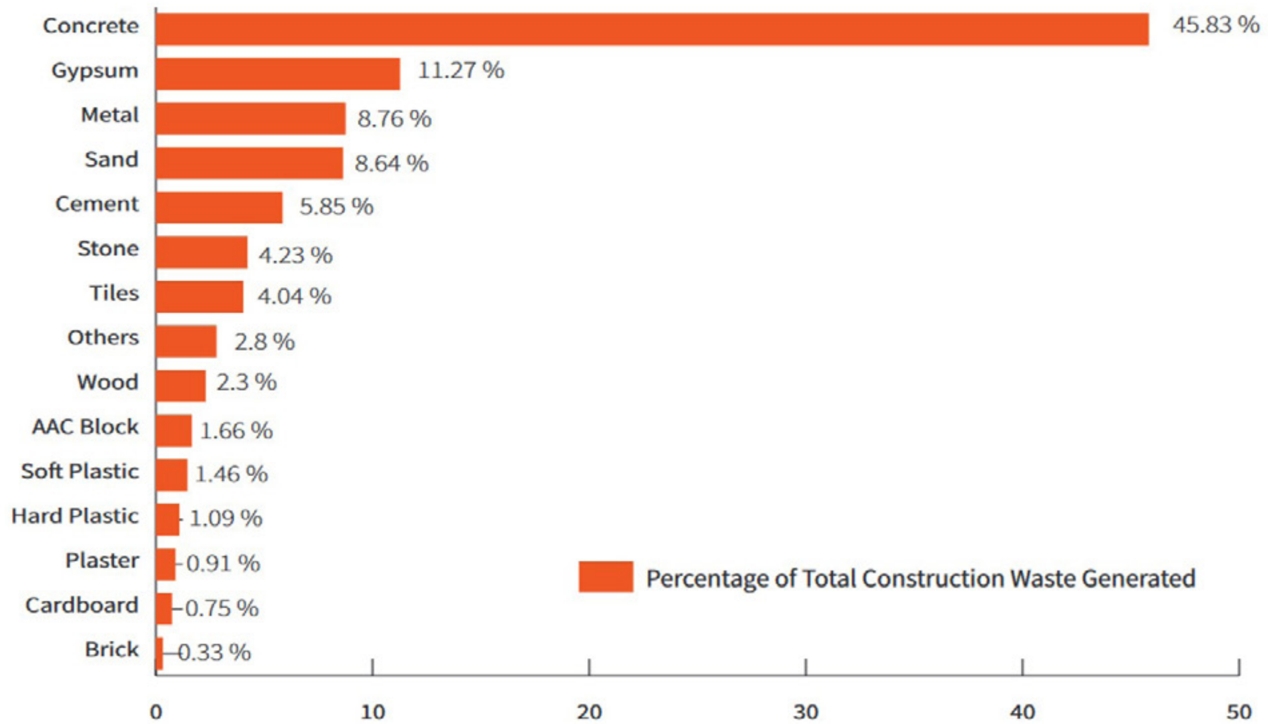
Developers Limited across 4 cities (Bengaluru, Gurugram, Mumbai and Pune). 13 of the 14 sites used Mivan construction methodology and one followed traditional practice of using bricks or autoclaved aerated cement blocks (AAC Blocks) as infill for columns, beams and slab structures (Feedback Foundation & Godrej Properties Ltd, 2023).

Table 5: Godrej and Mahindra Projects Selected for C&D Waste Generation

Project Name	Site Area (Hectares)	Site Area (sqm.)	Built up area (sqm)	No. of Towers	No. of Units
National Capital Region					
Godrej Meridian	5.99	59,865	186,560	7	754
Godrej Nature Plus	7.58	75,838	210,015	12	1094
Mumbai					
Godrej Golf Meadows	1.53	15,257	62,966	2	536
Godrej Nirvaan	3.24	32,428	104,444	6	1176
Godrej Emerald	2.55	25,455	174,658	7	1279
Bengaluru					
Godrej Nurture	2.39	23,917	91,372	7	684
Godrej Ananda	8.23	82,273	95,627	3	806
Godrej Royale Woods	5.26	52,609	122,580	6	1178
Mahindra Eden	3.14	31,363	97,827	4	527
Pune					
Godrej Nurture	6.84	68,392	101,037	5	714
Godrej Park Greens	3.29	32,901	292,254	7	1190
Godrej Hillside	1.74	17,401	41,145	3	588
Godrej Park Springs	1.98	19,830	68,841	4	752
Mahindra Happiness	2.80	27,964	48,109	4	692
TOTAL	56.55	565,491	1,697,434	77	11,970

Source: Feedback Foundation Charitable Trust & Godrej Properties Ltd. 2023

Figure 5 : Construction Waste Generation as Percentage of Total Waste Generated on Construction Sites



Source: Feedback Foundation Charitable Trust & Godrej Properties Ltd. 2023

The main findings from this research are:

I. The construction waste generated per square meter of built-up area of a mid-scale residential project is 45.75 Kg/Sqm for traditional construction and 39.18 Kg/Sqm for Mivan construction project in India. Based on the assessment on site, only 14.39% (525 tonnes) of the total waste comprising metal, soft plastic, hard plastic, cardboard, and wood enters the recycling value chain. The remaining 85.61% (3,123 tonnes) of waste mostly comprises of concrete, which is used in the core and shell stage of the construction, and gypsum. Thus, 14% of waste generated on the sites surveyed is recycled in the secondary market, while the remaining 86% comprising primarily of concrete and debris is unaccounted for according to the Report.

Construction Type		Waste Generated			
		Site Preparation	Construction of core and shell	Finishing	Total
Traditional Construction	in Kg/Sqm	0.65	19.91	25.08	45.64
	in %	1.4	43.6	55.0	100
Mivan Construction	in Kg/Sqm	1.94	16.68	20.56	39.18
	in %	4.9	42.6	52.5	100

II. Maximum waste is generated during the finishing stage of a construction project,

III. About 141 different types of materials are found in the construction waste, of which 95 materials are currently recycled and 46 materials have the potential to be recycled.This waste provides a tremendous opportunity for developing a suitable recycling ecosystem.

Ram and Kalidindi's (2017) study shows that one of the options for estimating is to adopt rule of thumb methods for initial waste estimation based on available data on the number of new constructions and demolitions (due to reconstruction) in a given city (NIUA & GIZ. 2020).

An acceptable estimate is possible with accurate hard-copy records of permits issued over the years. Currently, information on construction activities is available from permits issued by local governments in all urban areas as well as the State level Real Estate Regulatory Authorities (RERA). However, demolition permits are not mandatory and hence estimates for areas under demolition are based on permits for redevelopment. Accurate information on permits issued separately for construction and for demolition of buildings if made accessible through online building plan approval systems (OBPAS) can support estimation of C&D waste generation.. In India, OBPAS is mandated from 2015 through the Atal Mission for Rejuvenation and Urban Transformation (AMRUT).

When the built up area (in sqm.) of construction or renovation or demolition of buildings can be identified from the number of permits issued, the following thumb rules are used to estimate the C&D waste generation:

i. 50 kg of C&D waste produced per sqm. of new construction,

ii. 400 kg of C&D waste produced per sqm. of demolition and

iii. 45 kg of C&D waste produced per sqm. of renovation

The thumb rule shows that the waste produced per sqm. of demolition is almost eight times higher than for new construction. Hence, both permits for demolition and permits for new construction are essential for realistic estimation of C&D waste generation. Applying the above estimation method, one can arrive at the net rate of C&D waste produced in kilograms as per the number of permits given for a particular duration.

The estimate of waste generation for new construction is close to findings from the Godrej Properties on-site quantification of construction waste of 45.75 Kg/Sqm for traditional construction and 39.18 Kg/Sqm for Mivan construction.

1.3 Management of C&D Waste

The management of construction waste entails effective utilisation of construction resources, including reducing the quantity of waste generated and utilising the waste generated. The focus on resource efficiency has led to a change from dumping of construction waste in landfill sites to C&D waste prevention and initiatives to reduce, reuse and/ or recycle the waste produced. The benefits of recycling include (EPA, 2023b) not only include conservation of resources for the future, reduction in GHG emissions and other pollutants and energy saving but also creation of jobs and development of greener technologies.

The preferred options for reducing the adverse impacts of C&D waste on the environment are reducing the overall quantity of waste generated and disposed, the reuse or recycling of the salvageable components or products, and re-manufacturing materials or products from the processed C&D waste. Reusing of raw materials, using recyclable materials and reducing the use of resources and energy can be applied throughout the life cycle of a construction project - starting from design, construction, use and extraction of raw materials to transport, dismantling, and disposal.

1.3.1 C&D Waste Management Strategies

Management of such C&D waste is a challenge. In recent years, several researchers and organisations have carried out related research and have proposed various waste management strategies ranging from prevention of waste by preserving existing buildings to using construction methods that allow the disassembling of the building (U.S. EPA, 2020).

A circular economy-based development approach is one of the key strategies being adopted for achieving the 2030 Agenda for Sustainable Development Goals (SDGs). The economic advantages of this approach was highlighted by Accenture that suggested that India can unlock approximately half-a-trillion USD worth of India's GDP value by 2030 through adoption of circular business models while reducing overall GHG emissions by up to 20% across key industrial sectors (MoHUA, 2021; FICCI and Accenture, 2021). This can be achieved by a combination of strategies - reduction in waste generation and energy consumption, improved utilisation of products/ assets, product life extension, and value recovery from waste streams.

The key strategies recommended for reducing C&D waste in India are (iCED & TERI, 2022):

i. Prevent the generation of waste by preserving existing buildings;
ii. Optimise the size of new buildings;
iii. Design new buildings for adaptability so that their useful lives are prolonged;
iv. Use construction methods that allow the disassembling of the building and facilitate the reuse of materials;
v. Employ alternative framing techniques, and
vi. Reduce the use of interior finishes.

Further, effective C&D waste management involves the participation of various organisations or individuals that have different roles, concerns, and goals. The different stakeholders tend to be concerned about factors that are of immediate concern to them. Zhao (2021), in his study on the influence of stakeholder-associated factors on C&D waste management, lists 35 factors, each of which is linked to at least one stakeholder who initiates or is directly engaged in the factor. The aim is to ensure that stakeholders engaged in the C&D waste management process, understand their roles and responsibilities clearly and make informed decisions. He groups the factors in the following broad groups:

i. Regulatory environment, including legislation and its enforcement, as well as incentives and penalties.
ii. Government and public supervision, especially for the enforcement of relevant regulations and for reducing illegal dumping of C&D waste.
iii. Advances in technologies, including Building Information Modelling (BIM) and Geographic Information System (GIS). Research indicates that one third of the C&D waste could be reduced at the design stage while

around 4% to 30% of the total weight of building materials delivered to a building site may become waste due to damage, loss and over-ordering.

iv. C&D Waste Recycling market, including specifications for technical or quality standards for recycled products and location of markets in proximity of developing areas to minimise transport costs.

v. Knowledge, awareness, attitude, and behaviour of stakeholders, including training.

vi. Project specific factors including adoption of low-waste methods in design and construction, coordination amongst project participants, effective site and contract management, Waste Management Plan for the project and selection of contractors with C&D waste management capabilities.

To effectively use a C&D waste management plan, submitting and implementation of this plan should be mandatory. This ends in a reduction of C&D waste. In the current context, recycling of C&D waste by plants is an inexpensive opportunity to the existing unsustainable land filling and illegal dumping of rubbish in an unauthorised place (Ulubeyli, S. et al., 2017).

1.3.2 Recycling Plants for C&D Waste

In the US, prior to the introduction of recycling initiatives for C&D waste, the construction waste was loaded into one container and taken to the landfill. The recycling of construction waste, specifically the separation of concrete, metal or wood, started on job sites in the 1990s. The few businesses that demanded the recycling of construction waste were willing to pay more to recycle the materials. At the same time, the materials that were separated had to be especially clean because the contractors were not willing to put in time to separate the C&D waste. The only way to run a waste recycling business at the time was to have a service that was less expensive than the landfill.

C&D waste recycling companies, which originated before 2000, started with sorting and picking methods on ground and graduated to introduction of a sort line. In late 2007, when the price of fuel for transportation increased, businesses started to pay more attention on how to handle their waste. Subsequently, climate change, plastic pollution and resource efficiency raised the significance of recycling (Redling, A. 2019).

The C&D waste recycling plants can be stationary, partially mobile or mobile. Another factor is that the collection and transportation of C&D waste to recycling facilities is associated with costs, pollution and traffic congestion (Constro Facilitator, 2023; Ulubeyli et al., 2017). Consequently, the choice of mobile, semi-mobile, or stationary recycling plant depends on the processing capacity, waste volumes, location, and mobility requirements of a construction project.

Stationary recycling plants are permanently installed at a location, are suitable for processing large volumes of waste over an extended period, have higher level technologies and require higher initial investment for setting up of the plant,. These plants are suitable in high density areas, typically the most advanced type and may have dry and wet processing recycling facilities. They can process high volumes of C&D waste and are typically provided with sorting equipment for separation of unwanted components. The initial step of such plants is removal of metallic waste from C&D waste followed by a through screening process and separation of aggregates of different sizes. In wet processing plants, recycled materials get washed and lightweight materials and sludge are separated at the end of the recycling process. They are capable of producing a high quality of products, and are efficient due to the production of different recycled products of various grading. All types of C&D waste recycling operations can be carried out in stationary recycling plants.

Mobile recycling plants, whose capacities are up to 100 tonnes/hour, are typically mounted on trailers and can be moved to a different project sites by a truck. Mobile recycling plants are ideal for processing small to medium volumes of C&D waste at different locations or temporary construction sites. They are economically feasible for recycling 5,000 to 6,000 tonnes of waste per site. However, since mobile plants deploy basic technologies, and have limited cleaning facilities, the recycled product is normally of low quality. In addition, since such plants can cause high and unacceptable levels of dust and noise, they cannot be used close to residential areas. The advantage of mobile recycling plants is that they can be transported to demolition sites, but they can only process non-contaminated concrete or masonry waste (Ulubeyli et al., 2017).

Semi-mobile recycling plants are typically larger and can process higher volumes of C&D waste than mobile plants. These plants are partially portable and can be relocated on a trailer within a site or to a different site. In such a plant, the contaminants are removed manually while ferrous materials are removed by magnetic separation. The quality of the end product in semi-mobile plants is better than that of a mobile unit. Such plants cannot process mixed demolition waste that contains materials such as metal, wood, plastic etc.

Overall, since more C&D waste has to be diverted from landfill, especially in newly developing peripheral urban areas and smaller towns, the challenge of competing project priorities, lack of financial incentives as well as cost and time associated with on-site C&D waste management have to be addressed (Crawford et al., 2017).

1.3.3 C&D Waste Materials and their Reuses

C&D waste is recycled and reused for multiple purposes depending on the composition and characteristics of the waste. The major uses of C&D waste currently are (Development Alternatives, 2017):

Granular Sub Base (GSB) – Crushed C&D waste can be used for the granular sub base layer in construction of roads and pavements.

Manufactured Sand (M-Sand) is crushed C&D waste of sieve size between 0.075mm – 4.750mm and can replace natural sand in non-load bearing structures. Particles of less than 0.075 mm are classified as dust particles.

Recycled Aggregates (RA), which is crushed aggregates of standard size made from a mix of C&D waste materials, can partially replace natural aggregates for construction of non-load bearing structures. According to Indian standards, RA can replace 20% aggregates in plain cement concrete and up to 30% in road construction provided the quality is backed up by laboratory tests. RA is also used for making prefabricated moulded structures like paver blocks, kerb stones, concrete pots and RCC sculptures.

Recycled Concrete Aggregates (RCA) – of standard size can and is replacing natural aggregates in construction processes. According to the 3rd amendment issued to IS-383:2016 by the Bureau of Indian Standards, and IRC-121: 2017 issued by the India Road Congress, RCA could be used in any kind of structural and non-structural applications.

Metal: Almost all scrap metal from C&D waste is reused or recycled to make new products after melting through the smelting process.

Reusing – Materials of reuse value such as wood, unbroken bricks and ceramics are used in the secondary market. Aggregate generated from demolition is used for foundations, and for making mud-concrete blocks while earthen bricks are either reused or recycled. Broken glazed tiles are reused for mosaic flooring, on facades and on ceilings. (Parikh, 2022).

1.4 C&D Waste Globally

36% of the total waste generated globally is attributed to C&D waste and countries have taken initiatives for sustainably managing C&D waste. (Wilson et al., 2015). In 2014, C&D activities generated over 530 MT of waste in the United States (US-EPA, 2018), over 850 MT of C&D waste in the European Union (EU) (Eurostat, 2018) and 1.13 billion tonnes in China (Lu et al., 2017).

1.4.1 European Union - EU

The European Union's umbrella regulation adopted in 2008 is the Waste Framework Directive, which applies to all waste, including hazardous waste, and sets out a waste hierarchy that prioritises waste prevention, reuse, and recycling over disposal. The Waste Framework Directive 2008/98/EC of the European Union set quantitative targets for reuse of C&D waste. The objectives of the Waste Framework Directive is to move the EU as a whole closer to a 'recycling society', avoid waste generation, use waste as a resource, reduce the adverse environmental and health impacts of waste, and move Europe's energy and resource efficiency towards the creation of a 'circular economy. 'The implementation of the regulation is at the discretion of the Member States. (European Commission (DG ENV), 2011)

The Waste Framework Directive is based on the following main principles:

1. **Prevention:** of waste and of the harmful effects of waste. With a life-cycle approach, the waste prevention option is at the top of the hierarchy and is to be applied by Member States while developing their national waste policies. This is to be followed by preparation for the re-use, recycling, energy recovery and disposal of waste.
2. **Polluter-pays**: In accordance with this principle, the costs of waste management is to be borne by the original waste producer or by the current or previous waste holders. This principle is in accordance with the Treaty on the Functioning of the European Union.
3. **The Extended producer responsibility**: aims to strengthen the re-use, the prevention, recycling and other recovery of waste.

Table 6: Waste Generation in Member States of EU (2020)

	Population	% Share of Total Waste by Economic Activities and Households						
		Mining and Quarrying	Construction and Demolition	Energy	Waste Water	Manufacturing	Other Economic activities	House holds
EU	448,387,872	23.4	37.5	2.3	10.8	10.7	5.9	9.4
Germany	84,358,845	1.3	56.3	2.0	12.0	13.7	5.1	9.6
France	68,070,697	0.1	68.5	0.3	8.1	6.0	6.3	10.8
Italy	58,850,717	0.8	37.8	0.9	24.6	15.2	4.1	16.6
Spain	48,059,777	2.3	30.8	0.8	20.8	12.4	11.5	21.3
Poland	36,753,736	36.6	13.0	6.6	13.4	16.1	6.6	7.8
Romania	19,051,562	84.3	0.9	3.1	2.0	4.6	2.2	3.0
Netherlands	17,811,291	0.1	65.4	0.4	7.4	10.6	8.7	7.4
Belgium	11,754,004	0.0	30.5	1.5	31.4	20.9	7.9	7.8
Czechia	10,827,529	0.3	42.9	1.1	15.5	12.1	12.2	15.9
Sweden	10,521,556	76.5	9.3	1.2	4.5	3.1	2.3	3.1
Portugal	10,467,366	0.1	10.7	1.3	22.9	17.8	15.4	31.8
Greece	10,394,055	31.1	18.7	5.2	11.1	12.9	5.4	15.6
Hungary	9,597,085	0.8	27.1	11.2	9.8	15.8	6.1	29.1
Austria	9,104,772	0.1	76.5	0.6	3.5	7.5	5.2	6.7
Bulgaria	6,447,710	81.6	1.6	5.2	2.9	4.2	2.5	2.0
Denmark	5,932,654	0.1	54.8	3.9	7.5	5.4	10.3	18.0
Finland	5,563,970	75.1	11.8	0.8	1.0	8.2	1.0	2.1
Slovakia	5,428,792	1.6	9.0	5.5	8.9	24.0	32.5	18.5
Ireland	5,194,336	9.4	32.6	1.0	12.6	22.4	10.1	12.0
Croatia	3,850,894	11.6	23.8	1.1	16.3	7.5	19.5	20.2
Lithuania	2,857,279	1.0	8.3	2.3	18.4	32.7	16.3	20.9
Slovenia	2,116,792	0.1	6.3	12.1	3.8	17.9	51.4	8.4
Latvia	1,883,008	0.0	9.7	4.1	33.7	17.0	12.9	22.6
Estonia	1,365,884	15.2	9.8	35.0	4.6	24.6	7.4	3.4
Cyprus	920,701	6.9	50.2	0.1	6.5	9.5	9.8	17.0
Luxembourg	660,809	1.1	82.1	0.3	3.5	6.5	4.2	2.2
Malta	542,051	1.3	82.7	0.0	2.9	1.0	5.5	6.5

Sources: Eurostat (env_wasgen) Population - https://ec.europa.eu/eurostat/databrowser/view/DEMO_GIND__custom_7127262/default/table
Share of Waste: Accessed from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics

The construction sector in the EU accounted for about 37% of the total waste generated in 2020. The European Commission identified C&D waste as a priority stream because of the large quantity of the C&D waste generated as well as because of the high potential for reusing and recycling the materials. The EU waste management directive requires

member states to set up a target recovery rate of at least 70% of C&D waste by 2020 (EC, DG-ENV, 2012). The waste policy and regulation recommend that:

1. Waste hierarchy is incorporated in all C&D waste management activities.
2. Waste is diverted from landfill.
3. Increase recycling.
4. Reduction of waste from the economy.
5. Controlling hazardous waste, and
6. Shared responsibility of almost all, including C&D waste users

Table 7: Waste treatment by type of recovery and disposal, 2020

(% share of total waste treatment)	Recovery - Recycling	Recovery - Backfilling	Energy recovery	Disposal - Landfill and other	Disposal - Incineration without energy recovery
EU	39.9	12.7	6.5	40.4	0.5
Italy	83.2	0.2	5.5	10.6	0.5
Belgium	74.1	11.2	7.2	6.3	1.1
Slovakia	64.0	0.6	6.1	29.3	0.1
Latvia	64.0	3.0	8.4	24.6	0.0
Croatia	55.7	4.8	5.1	34.5	0.0
Denmark	55.6	16.6	20.3	7.4	0.0
Spain	54.7	5.1	4.0	36.0	0.1
France	54.2	10.2	7.7	26.4	1.5
Czechia	51.1	33.8	3.9	10.9	0.3
Netherlands	49.4	0.0	7.7	42.0	0.9
Portugal	45.2	8.6	10.9	35.0	0.3
Slovenia	44.5	47.2	2.7	5.0	0.5
Estonia	44.2	14.4	2.2	39.3	0.0
Germany	44.0	26.1	11.8	17.7	0.5
Luxembourg	41.5	32.5	3.1	22.9	0.0
Lithuania	39.5	2.9	10.7	46.9	0.1
Cyprus	37.7	0.8	14.1	47.4	0.0
Malta	37.6	53.3	0.0	9.0	0.2
Poland	36.3	35.3	2.7	25.5	0.2
Austria (1)	34.0	16.1	4.0	44.6	1.3
Hungary	33.7	39.2	6.4	20.4	0.4
Ireland	32.6	2.6	36.2	28.3	0.3
Greece	23.7	9.1	1.8	65.3	0.0
Sweden	11.9	2.7	6.2	79.1	0.0
Finland	9.5	0.9	5.5	83.9	0.1
Bulgaria	7.7	0.0	0.6	91.6	0.1
Romania	5.2	0.9	1.4	92.5	0.1

Sources: Eurostat (env_wasgen)
Population - https://ec.europa.eu/eurostat/databrowser/view/DEMO_GIND__custom_7127262/default/table
Share of Waste: Accessed from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics.

Most member states have introduced the target of recovering 70% of their C&D waste by 2020 in their national legislation, (Di Maria et. al. 2020). Some member states have higher targets ranging from 75% to 90%. The Site Waste Management Plans (SWMP) required in England, Wales, Scotland and Ireland ensure that building materials are managed efficiently, waste is disposed off legally, and material recycling, reuse and recovery is maximised (EPA, 2021).

Giorgi et al (2018) found that many of the EU member states have already achieved the target of recycling 70% waste as a result of both legislative and non-legislative instruments such as criteria of using recycled C&D waste products in public tenders.

In Netherlands, the legislation and market conditions, namely lower cost and Certification as well as quality guarantee from recycling companies are conducive for use of recycled materials (Bhatnagar & Singh, 2020).

1.4.2 USA

The recycling strategy of the US evolved from the decision to incorporate circularity following the 2002 publication of "Beyond Resource Conservation and Recovery Act (RCRA), known as Vision 2020. The Act highlighted the need to shift focus from waste management toward materials management (U.S. EPA, 2003; U.S. EPA, 2023).

In 2018, 600 MT of C&D debris were generated in the US, which contributes 30% of global C&D waste (US EPA, 2018). Demolition waste represented more than 90% of the total C&D debris. Through the implementation of a robust C&D waste management plan, over 75% (455 MT) of C&D debris were directed to next use and less than 25% (145 MT) were sent to landfills. Non-residential demolition generated the maximum C&D waste followed by residential renovation. Aggregate was the main next use for the materials recovered from the C&D debris.

Table 8: USA: Residential/ Non-Residential Construction, Renovation & Demolition Waste

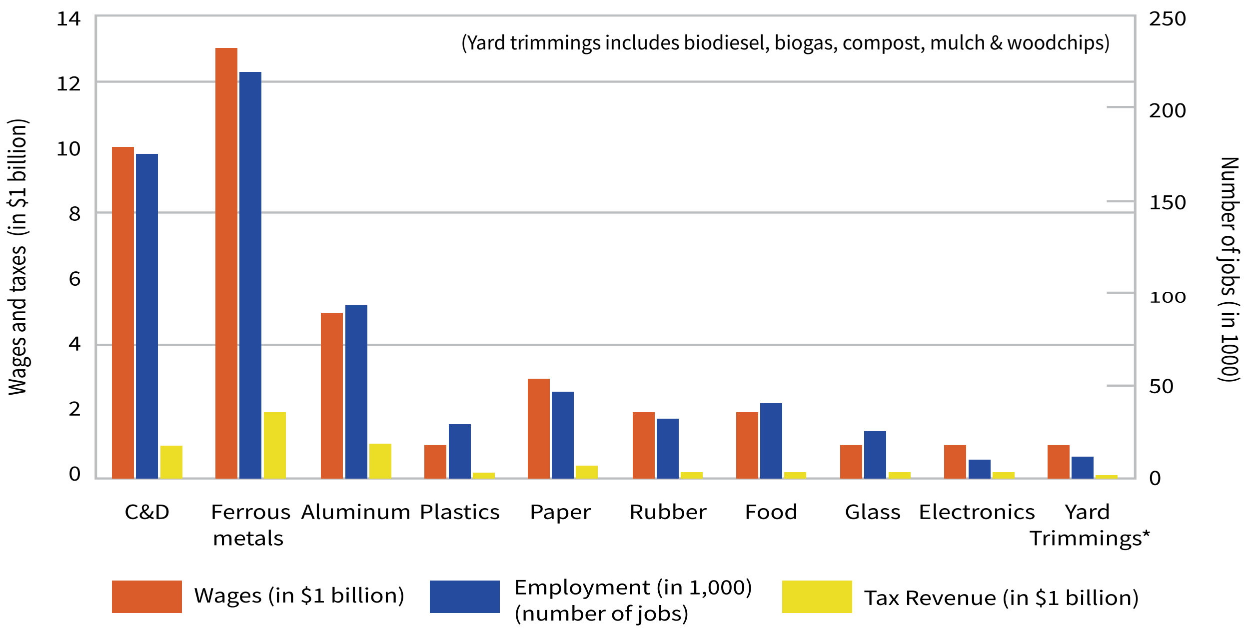
C&D waste Type	Residential	Non-Residential	Total
New Construction	11%	6%	8%
Renovation	55%	36%	44%
Demolition	34%	58%	48%
Total	100%	100%	100%

Source: US-EPA/ BMTPC, 2017

The country's National Recycling Strategy (2021) is focused on MSW recycling systems and the recycling of C&D waste. Further, to encourage the development of an economic market for recycling and monitor progress towards sustainable materials management (SMM), the EPA supported the creation of a national Recycling Economic Information (REI) Project and publishing of the REI Report from 2001.

The U.S. EPA REI Report of 2012 indicates that recycling and reuse activities in the US accounted for approximately 0.5 percent of all employment, 0.6% of wages and 0.8% of all tax revenue (Figure 6). This meant that 1.17 jobs were created for every 1,000 (US) tonnes of recyclables collected and recycled. The ferrous metals industry was the largest contributor to total economic impacts in 2012 followed by C&D sector and the non-ferrous metals industry.

Figure 6: USA: Wages, Taxes and Jobs Attributed to Recycling



Source: U.S. EPA, 2020a

In 2018, about 457 MT of C&D debris were directed to next use and over 143 MT were sent to landfills. The Table below is a summary of the total tonnages of the different materials in the C&D debris intended for varied next uses or sent to landfills (U.S.EPA, 2020a).

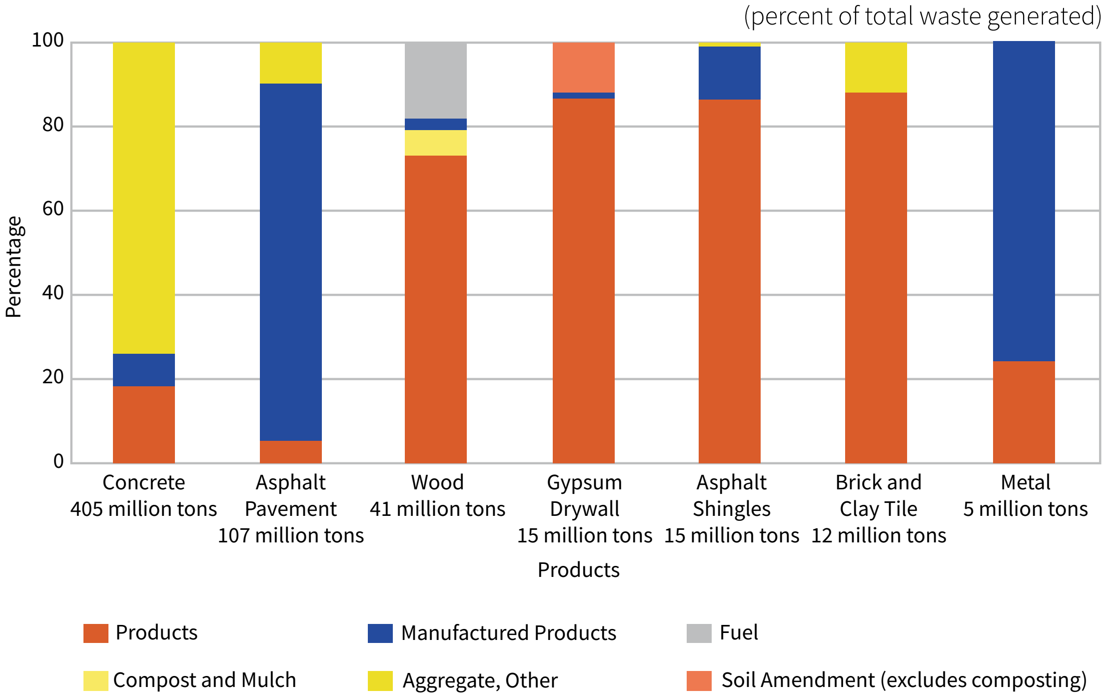
Table 9: C&D Debris Management in US by Material and Next Use, 2018

Material Type in C&D Debris	Landfill	Next Use					Total Next Use
		Compost and Mulch	Manufactured Products	Aggregates, other	Fuel	Soil Amendment	
Concrete	71.2	0	32.8	301.2	0	0	334
Wood	29.6	2.5	1.2	0	7.5	0	11.2
Gypsum Drywall	13.2	0	0.2	0	0	1.9	2.1
Metal	1.1	0	3.6	0	0	0	3.6
Brick & Clay Tile	10.8	0	0	1.5	0	0	1.5
Asphalt Shingles	13	0	2	0.1	0.02	0	2.1
Asphalt Concrete	4.9	0	91.8	10.3	0	0	102.1
Total	143.8	2.5	131.6	313.1	7.5	1.9	456.6

Source: U.S. EPA 2020a

In 2018, aggregate was the main next use for C&D concrete and the next was landfills. The primary destination for wood, asphalt shingles, gypsum drywall, and brick and clay tiles was landfills. The Figure below depicts quantities of the material in C&D debris that went to landfill, for manufacturing of products, fuel, compost & mulch (U.S.EPA, 2020a).

Figure 7: US - C&D Debris Management by Material and Destination, 2018



Source: U.S. EPA ,2020a

Bolden, et. el. (2013) identified the top three reasons given by construction companies for using recycled products in the US as i) reduction in waste disposal; ii) quality of recycled materials with additive materials is higher compared to raw materials, and iii) reduced economic and environmental costs. The responses reflect the fact that the costs that the construction companies would have to incur if they did not recycle the C&D waste are high enough for them to opt for using recycled materials.

1.4.3 China

China, which annually contributes 30%–40% of the global C&D waste, took the first step of the environmental legal system by initiating the Environmental Protection Law (Trial) in 1979, which was officially enacted in December 1989 (Duan et al., 2019). This was followed by several laws, amendments and related organisational arrangements for the prevention and control of pollution of water, air, solid waste, environmental noise and soil. These laws provide a relatively complete environmental legal and regulatory system (Xie, 2019). In August 2008, China was among the first to adopt a circular economy law promoting the recovery of resources from waste (UNIDO, 2017). In addition to this comprehensive policy structure and promotion of circular economy, the strategies of C&D waste management in China are (Aslam et al., 2020):

1. Hefty penalties on the discharge of C&D waste.
2. Appointment of structured supervisory teams for proper discharge of C&D waste,
3. Expenditure of collected penalty for daily operations and subsidies in the particular locality.
4. Incorporation of incentive schemes for successful management of C&D waste.
5. Use of Building Information Modelling (BIM), Global Positioning Systems (GPS), Geographic Information Systems (GIS) and Big Data, Integrated Project Delivery (IPD), Virtual Prototyping, and CAD for improving performance and minimisation of construction waste (Duan et al., 2019).

Despite the comprehensive approach, the actual rate for recycling of C&D waste in China is low (Xie, 2019). In 2018, Huang et al. (2018) reported that approximately 75% of Chinese cities were surrounded by large volumes of C&D waste. The regulations and extent of C&D waste management varied widely among cities because only a few municipal governments had detailed the national polices and regulations. Thus, while Shanghai and Shenzhen achieved material recovery rates of more than 15% (Ghisellini et al., 2018), the recovery rate in most Chinese cities was between 3% and 10% (Huang et al., 2018).

1.4.4 UK

Since 2012, the construction industry in the UK has focused on “green initiatives” to meet all the sustainability requirements. Subsequently, the construction industry has made significant efforts in managing the C&D waste as implemented by the UK Sustainable Construction Strategy (Jeffrey, 2011). The actions include:

1. **Diversion of waste from landfill**: based on the waste hierarchy the UK government imposes a restriction on the type and amount of waste that can be disposed of in landfills in England and Wales.
2. **Increase recycling**: UK government’s objective is to create awareness on reuse, repurposing and recycling among many citizens and organisations.
3. **Reduction of waste from the economy:** The amount of C&D waste produced by construction sites around the UK is significantly high. The “Producer Responsibility Obligations (Packaging Waste) Regulations” of 2007 places the responsibility of recovering and recycling a certain amount of packaging waste on the producers of the packaging.
4. **Controlling Hazardous Waste**: Laws impact the way that hazardous waste can be disposed of in England and Wales.
5. **Shared Responsibility**: The UK waste management policies operate on the basis of “shared responsibility” wherein almost everyone including all C&D waste users have responsibilities in preventing waste growth.

The Official UK statistics on non-hazardous C&D waste excludes excavation waste. The recovery rate for C&D waste for England and Wales is calculated as amount of C&D waste generated minus landfill, and for Scotland and Northern Ireland recovery rate is calculated as amount of C&D waste generated minus landfill and incineration (DEFRA, 2023).

1.4.5 Australia

Australia generates 20.4 MT of C&D waste (43% of the total waste generated annually) (Shooshtarian et al., 2019). Based on the Australian national waste report-2020, the C&D waste recycling rate was 76%and recovery rate was 75% (Blue Environment, 2020). In Australia, waste management and resource recovery is dependent on the regulatory framework of a particular State or Territory. Because of this, the approach commonly adopted by the Australian Government is of multi-stakeholder engagement and the introduction of multi-party agreements. The cities of Sydney and Melbourne achieved the reuse and recycling of more than 80% of their C&D waste. Australia charges high fees for disposal of waste in landfills

1.4.6 Korea

Various objectives were laid down in Korea’s second C&D waste management plan (2012-2016) which mainly emphasis on improvement in the waste management information system. Its emphasis is on online record of C&D waste by the contractor and treatment companies, substantial reduction in the amount of mixed waste and implementation of life cycle inventory data on C&D waste (Bansal et al., 2016).

1.4.7 Japan

In 2000, Japan introduced the Construction Waste Recycling Law that specifies the responsibility of demolition contractors for sorting and recycling demolition waste when the total floor area of a building to be demolished is more than 80 Sqm. The contractors are required to separate and recycle concrete (precast plates), asphalt, and wood besides other construction wastes (Ministry of the Environment, 2000). Since Japan focusses on environmental impact, the environmental conservation costs are added to determine the price or quality of the products. Japan defines concrete class based on properties of recycled aggregates. Class H concrete for strength up to 45 MPA which utilises good quality C&D aggregate, Class M concrete which are not exposed to severe environmental condition and finally class L concrete utilising low quality C&D aggregate having high water absorption and used only for backfill and levelling concrete (Bansal et. al 2014; Brito and Saikia 2014).

Table 10: C&D Waste Management Rules in Selected Countries

C&D Waste Management Rules in various countries		
Country	**Regulation**	**Information**
India	CDWM Rules, 2016. MoEFCC	Recover, recycle and reuse of waste, segregating and depositing it to the recycling facilities for collection and disposal paying appropriate charges, as stated by the local authorities.
Romania	Second National waste management plan 92014-2020) (Source: CDWM in Romania V2-September 2015)	Developing recycling technology, waste reduction in landfills. Encouraging reuse of resources, prioritising the efforts of waste management, and separating the collection of waste.
Egypt	The Egyptian Environmental Law No.4 (1994). (Marwa, Salah & Taha, 2004)	Article 41: Segregation and Transporting of C&D Waste. Article 37: Restrict in throwing of any solid wastes except in licensed places. Article 87: Penalty of throwing CDW
China	Recycling Regulation and Disposal of electrical & electronic equipment waste (2011).(Source: Chenyu et. al., 2015)	Realisation of the extended producer, to assist e-waste recycling the organisation for a special fund.
Turkey	The Environment and Forestry Ministry 2004. (Source: Hakan, Nilay & Burcu, 2012)	Administration for waste reduction, and C&D waste collection, storage, recovery, disposal
South Africa	National Waste Management (2011). (Source: Llewellyn van Wyk, 2014)	Ensuring efficient services for waste delivery, Achieving a plan for integrated waste management

1.5 Good Practices

As described earlier, C&D waste can be processed either at a centralised stationery processing plant or mobile or semi-mobile plant in-situ at a project site. In-situ waste processing is suitable for projects that generate more than 0.1 MT of C&D waste while smaller projects can utilise mobile C&D waste crushing and segregation equipment which are available for processing capacities of up to 5 TPD (BMTPC, 2018). Waste generators that generate 20 TPD or 300 tonnes of C&D waste per project in a month are mandated to segregate C&D waste into four parts - concrete, soil, steel/ wood/ plastic, and brick & mortar. Such large waste generators are required to pay for the processing and disposal of C&D waste in addition to storage, collection, and transportation charges (MoEFCC, 2016).

1.5.1 Key Stakeholders Influencing the Use of Recycled C&D Waste Products

Shooshtarian et al.'s (2020) reviewed 31 publications etc. from Australia, China, UK and European countries to identify stakeholders' perceptions, decisions, and motivations for using recycled C&D waste products. The study identified the key areas requiring attention as:

1. Clients' knowledge and expectations about using recycled products.
2. Government and policymakers can promote the use of products made from recycled C&D waste by providing more information and sharing knowledge about recycled materials and by making use recycled product mandatory in construction projects.
3. Recyclers, including manufacturers and suppliers, challenges in selling recycled products in the market can be met by access to technical knowledge and expertise, process improvements and local availability of equipment.
4. Architects and designers who can specify the use of recycled products through construction specifications before work starts in consultation with structural engineers.
5. Structural and Civil Engineers have a significant responsibility in material, application, and specification decisions.
6. Builders' general perceptions about properties of recycled material being inferior and difficulties in applications, relatively high cost to transport compared with the cost of using virgin materials delivered to the construction site via traditional commercial channels.

The review of 2020 in countries where recycling of C&D waste has been ongoing for longer durations than in India, shows that the demand for materials and products made from recycled C&D waste is limited primarily because of concerns about the quality of the recycled material as well as additional cost of transportation for a relatively small volume construction materials from a different location.

Shooshtarian et al.'s (2020) recommendations for overcoming the challenges included increasing awareness about recycled products, promoting product certification and advocating targeted technologies and innovative practices. The recommendations do not address the challenges of additional transportation costs or incentives for using more C&D waste recycled products.

1.5.2 Role of Taxation in C&D waste reduction in different countries:

Tax plays a crucial role in case of C&D waste reduction in many countries. It is experienced in some European countries that a high level of taxation on waste has achieved a significant level of C&D waste reduction. The European Union EU has also supported waste minimisation with on- site recovery and reuse by developing extensive waste management tools and guides. For example, high levels of landfill taxes in Denmark and the Netherlands demonstrated a low dependency on landfill and a high level of waste recovery.

Another interesting case is of Hong Kong which has one of the most aggressive regime of C&D waste fee that was adopted to reduce waste generation. The Construction Waste Disposal Charging Scheme (CWDCS), which regulated that all construction waste must be disposed of at government waste facilities if not otherwise properly reused or recycled, was implemented in 2006. While the CWDCS has significantly improved construction waste management, it has also triggered massive illegal dumping problems for the city. Implementation of the CWDCS did not motivate subcontractors to change their methods of construction and waste handling and hence the reduction could not be sustained (Yu AT et. al., 2013).

Figure 8: India: C&D Waste Management related Studies, Rules & Guidelines

2000

TIFAC Study Report on Composition of C&D Waste in India

First attempt made in India laying focus on the management of C&D Waste.

2014

Guidelines on Reuse and Recycling of Construction and Demolition (C&D) waste, PART IV-CPWD

Focused on collection, transportation and recycling of C&D waste generated at CPWD funded project sites and other applicable similar sites

2015

Resource Efficiency Initiative (India) -European Union

To support India in the implementation of the UN's global Sustainable Consumption and Production (SCP) agenda in business on resource efficiency.

2016

GIZ report on Resource Efficiency in India

Current status of resource efficiency in India with focus on Construction materials and other natural resources.

2016

C&D Waste Management & Handling Rules

To support India in the implementation of the UN's global Sustainable Consumption and Production (SCP) agenda in business on resource efficiency.

2017

Guidelines on Environmental Management of C&D Waste Management in India - CPCB

Provided foundation for C&D Waste Management in India.

2017

Training Manual on Construction and Demolition Waste Management in India for Cities and Towns, GIZ - India

Training manual is to educate and inform the participants on the severity of problem caused C&D waste on the environment and serve as a reference manual.

2018

Strategy for Promoting Processing of Construction and Demolition (C&D) Waste and Utilisation of Recycled Products - NITI Aayog

Provide a framework of implementation of the C&D Waste Management Rules, 2016

2018

BMTPC Guidelines on C&D Waste Recycling

For utilization of recycled produce of C&D Waste to facilitate the stakeholders towards 100% utilization of C&D waste material as envisaged under Swachh Bharat Mission

2019

National Resource Efficiency Policy, MOEFCC

Envisaged to achieve recycling of C&D waste and achieve buffer for securing new supply requirements. This refers to achieving an ambitious national target of 100% recycling of C&D waste by 2025

2019

National Clean Air Programme

Envisages to achieve reductions up to 40% or achieve National Ambient Air Quality Standards for Particulate Matte: 10 concentrations by 2025-26.

2020

15th **Finance Commission**

Air quality linked performance-based grants to urban local bodies increased for large cities as incentives for sustained improvements

2023

Swachh Survekshan

Theme 'Waste to Wealth' and ranking points for C & D waste management increased to 120 points (50 for collection & segregation; 50 for processing and selling of recycled C&D waste & 20 for SBM portal linked digitally maintained Weekly Processing Log Book, Sale Register & Vendor details by ULB)


CAT

C&D Waste in India

2

The construction industry, which provides employment to about 35 million people, is the second largest sector in India in terms of employment after agriculture. It constitutes 40–50% of the country's expenditure on projects in sectors such as highways, railways, airports, irrigation, bridges, housing and townships (Ahuja et al., 2009). It also accounts for 25% of all material demand (Report of the MoEFCC, 2016). The estimated annual consumption of construction materials in 2016 comprised 750 MT of sand, 297 MT of cement, 242 MT of limestone, 2 billion tonnes of stone (aggregate), and 350 million cubic metres of soil (GIZ, TERI & Development Alternatives. 2016).

With the Government's emphasis on improving infrastructure, transportation networks and housing throughout the country, the built-up area in India is expected to increase exponentially due to large-scale domestic and industrial growth (ASCI and NRDC, 2012; CSE, 2011). The construction industry is expected to grow at a rate of 7-8% over the next decade (MoHUA & Niti Aayog, 2018). Further, older buildings are being demolished to make way for high rise buildings (CSTEP, 2016). With an estimated 70 per cent of buildings supposed to exist by 2030 yet to be built in India, the demand for sand for concrete and mortar, soil for clay bricks, stone for aggregates, and limestone for cement is expected to increase significantly (Bhattacharjya & Kapur, 2019). All these activities are escalating the generation of construction waste (BMTPC, 2018). The rapidly developing cities are estimated to contribute 3000 MT of C&D waste annually (Jain et. al., 2020). Thus, the sector will not only have a leading share in the economy but will also be a major emitter of greenhouse gases (GHGs) (Mathiyazhagan et al., 2018b).

Table 11: C&D waste Generation in Indian Cities

City	Population in millions (Census 2011)	Daily C&D waste generation (tonnes/day)	Annual C&D waste generation (MT/ annum)
Mumbai	12.44	2500	0.75
Delhi	16.79	4600	1.38
Bengaluru	8.44	875	0.26
Chennai	6.5	2500	0.75
Kolkata	4.5	1600	0.48
Jaipur	3.47	200	0.06
Patna	2.51	250	0.08
Ahmedabad	6.06	700	0.21
Bhopal	1.92	50	0.02
Coimbatore	2.62	92	0.03

Source- MoHUA and NITI Aayog, 2018

There are significant variations between any co-relations of population and daily C&D waste generation:

In India, the major constituents of C&D waste are concrete, soil, bricks, wood, metal, and asphalt. During demolition, the most important components of waste and its approximate percentage are: bricks & masonry (31%), concrete (23%), soil, sand, and gravel (26%), metal (5%), bitumen (2%) and wood (2%) (TIFAC, 2001).

Table 12: Composition of C&D Waste in India

C&D waste Sub-Streams	India		Delhi		India	Urban areas in North India
	TIFAC, 2001	Study by University of Florida, 2009	MCD survey, 2004	IL&FS Ecosmart, 2005	IIT-B, 2016	BMPTC (2018)
Soil, Sand and Gravel	36%	35%	43%	31%	21.60%	26%
Bricks and Masonry	31%	30%	15%	59%	20.10%	32%
Concrete	23%	25%	35%	0	31.30%	28%
Metals	5%	5%	0	0.40%	0.10%	6%
Wood	2%	2%	0	1.50%	0.50%	3%
Others	3%	1%	7%	7.60%	26.40%	5%
Bitumen	2%	2%	0	0	0	0

Sources CSE, 2020 BMTPC, 2018

The proportion of concrete is estimated as 23% to 35% of total waste. Considering 30% of C&D wastes of 12 MT as concrete, and 50% of the concrete as coarse aggregate, the total available RCA in India is of the order of 1.8 MT annually (CPCB, 2017). .

2.1 C&D Waste and Municipal Solid Waste

Globally, the protection of public health and welfare in urban areas is the responsibility of local governments. This includes all the processes and operations for providing water, health and waste collection services. With rapid urban population growth and increased generation of solid waste in municipal areas, the environmental implications of the growing volume of different types of waste and its safe and cost-effective management gained urgency. Consequently, the local, state and national governments have all been involved in creating the supportive eco-system in terms of policies, rules, regulations etc. for efficient management of MSW. Currently, integrated MSW management systems incorporate a combination of waste prevention, recycling, composting, energy recovery from waste combustion and landfilling.

In India too, the management of MSW is one of the main functions of all urban local bodies (ULBs) as articulated under the 12th Schedule of the 74th Constitution Amendment Act of 1992. ULBs are required to plan, implement and monitor all systems of urban service delivery. However, till 2000, although there were environment related legislation such as Water (Prevention & Control of Pollution) Act, 1974, Air (Prevention and Control of Pollution) Act, 1981, Environment Protection Act, 1986 and rules like Hazardous Wastes (Management and Handling) Rules, 1989 and Biomedical Waste (Management and handling) Rules, 1998, there were no laws or rules dealing with MSW. In September 2000, following the filing of a writ petition before the Supreme Court, the Government of India notified the Municipal Solid Wastes (Management and Handling) Rules, 2000. These Rules provided the overarching framework that governed the management of all solid waste generated and were applicable on every municipal authority responsible for the collection, segregation, storage, transportation, processing, and disposal of MSW. By 2015, the increasing quantities of C&D waste led to greater focus on its management, reuse, and processing, and the Solid Waste Management Rules, 2016 were notified on 8 April 2016 to subsume the 2000 rules and expanded the scope of its application and prescribed the duties of MSW generators for the first time.

As in the US and Europe, C&D waste in India is considered a component of MSW. According to MoHUA (2021), 20 to 25% of the total MSW generated comprises C&D waste. This amounts to an average of 12 MT of C&D waste per year. The high quantity of C&D waste in MSW creates major problems for MSW processing.

The proper management, reuse, and processing of C&D waste has been the focus of various governmental agencies in India since 2010 (BMTPC, 2018). The Ministry of Environment, Forests and Climate Change (MoEFCC – that was called the Ministry of Environment and Forest-MoEF till 2014) notified the Construction & Demolition Waste Management Rules, 2016 on 29 March 2016 that describe the compliance criteria for the management of the C&D waste as well as described what comprises C&D waste.

In terms of the operational aspects, with the launch of the Government of India's - Swachh Bharat Mission (SBM-Urban) in 2014 and the Smart Cities Mission in 2015, there is greater focus on the development of the cities. Under SBM-U, there is greater focus on planning, design, implementation, monitoring and environmental and financial sustainability of MSW management systems. Waste minimisation is the primary focus and material recovery and recycling the first consideration for the management of generated waste. The focus is on segregating waste for viable recycling. Subsequently other forms of treatment and processing are to be considered in accordance to the guidance given by the SWM waste treatment and processing hierarchy. Landfilling of the MSW is the least preferred option. There is emphasis on ensuring financial viability of MSW management systems through revenue generation as well as on Private Sector Participation (PSP) and Public Private Partnerships (PPPs).

Subsequently, the monitoring of C&D waste and of the recycling of the C&D waste products was integrated with the annual competitive monitoring Swachh Survekshan literally (Cleanliness Survey) of the Swachh Bharat Mission. The weightage given for service e level progress has increased from 40% (2021 & 2022) to 48% in 2023 and to 60% in 2024. The specific areas that are monitored for C&D waste management are (SBM-U Toolkit 2019):

- Whether any mechanism is in place to collect & process/ re-use C&D waste as per Waste Management Rules 2016?
- Whether C&D waste collected is processed and sold, and
- Whether the ULB digitally maintains a weekly processing log book, sale register and vendor details (if outsourced) that is linked with SBM portal.

The management of C&D waste stream is therefore integrated with the MSW management systems. This was complemented in February 2019, when MoHUA launched the "Climate Smart Cities Assessment Framework" (CSCAF) to provide Indian cities with a roadmap for adopting and implementing relevant climate actions. The CSCAF consists of 28 indicators across five categories including an indicator on utilisation of RA and RCA derived from C&D waste. This CSCAF indicator on C&D waste captures data regarding collection, processing and reusing of C&D waste, and is aligned to the Swachh Survekshan indicators (NIUA, 2021).

Site Waste-Management Plans: A site waste-management plan, which has estimates of how much C&D debris will be generated on a project and description of how it will be managed, needs to be enforced on each construction site irrespective of its size (Bossink & Brouwers, 1996; Xu et al., 2020). A typical site waste-management plan includes:

1. Detailed description of the project (location, size, details on waste generated etc.).
2. Quantification of the waste generated according to categories.
3. Proposed waste-management options, appropriate tracking and documentation of generated waste.
4. Estimated cost of waste-management.
5. Record of reused materials.
6. Training of the construction crew and
7. Consultation details with local authority, recycling company etc.

With an efficient site waste-management plan, the amount of waste generated can be audited, minimised and some of it prevented. In addition, financial losses can be tracked and quantified.

The key features of C&D waste management include:

i. Availability of satisfactory commercial opportunities for C&D waste products (Akhtar and Sarmah, 2018),
ii. Incentive and reward schemes for zero C&D waste emissions along with higher investments for C&D waste recycling, management, treatment, that is, 7 billion USD (Akhtar and Sarmah, 2018),
iii. Design for deconstruction (demolition as well as product design for disassembly) (US EPA, 2018).

In India, despite the C&D Waste Management Rules 2016 (MoEFCC, 2016), most construction sites lack enforcement of site waste-management plans. This is due to the lack of awareness of the amended rules and regulations on C&D waste and the lack of penalties on illegally disposed construction waste along with misconceptions on waste-management (Illankoon and Lu, 2020). The existing practices dealing with construction waste in India are dumping in empty plots, landfills, water sources or incineration. These methods have to date provided a temporary solution by postponing the problem. Implementing strategies that aim to reduce the amount of waste generated and converting waste material into a new product that is widely used in the construction sector is challenging (Campbell, 2019; Charlson and Hons, 2019; Ghosh and Agamuthu, 2018; Hopkinson et al., 2019).

According to a study by Centre for Science and Environment (CSE), India manages to recover and recycle only one per cent of its C&D waste. According to Building Material Promotion Council (BMTPC), India generates 150 MT of C&D waste annually whereas unofficial estimates put the number at three to five times more. With a recycling capacity for about 6,500 TPD, just 1.3 per cent of the total C&D waste generated can be processed and recycled. Following the CDW Rules, 53 cities were expected to set up recycling facilities by 2017 to recover material from the waste. However, only 13 cities have done so as of end-July 2023. There is no uniform method among cities for quantifying and characterising C&D waste. Also, the existing systems do not adequately take into account the new construction materials and construction methods.

Table 13: Functioning C&D Recycling Plants in India

City	Place	Capacity (TPD)
Delhi	Burari	2,000
	Mundka	150
	Shastri Park	500
	Bakkarwala	1,000
	Rani Khera	1,000
Noida	Sector 80	300
Gurugram	Basai	300
Ghaziabad	Ghaziabad	150
Mumbai	Thane, Daighar	300
Mumbai	Vikhroli	100
Indore	Devguradia	100
Hyderabad	Jeetimedla	300
Bengaluru	Chikkajala	1,000
Bengaluru	Kannur	750
Ahmedabad	Gyaspur Pirana	1,000
Tirupati	Tukivakam village	150
Vijayawada	Vijayawada	200
Chandigarh	Industrial Area Phase 1	150
Surat	Surat	300
Pune	Pimpri Chichawad	200
Devas	Devas	8
Kolkata	Rajarhat	500

2.2 Stakeholders in C&D Waste Management

The various stakeholders involved in the field of C&D waste management face varied challenges. The tasks and duties of the key stakeholders that are set forth in the existing legal and administrative framework for India are summarised below (adapted from: NIUA, GIZ. 2020 and Joshi, R., 1999.).

Stakeholders	
Waste generators/ producers	• Owners, builders and contractors of individual properties • Builders association • Architects/ designers (modifications during construction/ renovation) • C&D contractors and transporters • Municipal authorities and suppliers etc. • C&D waste recycling entities such as waste collectors (formal & informal), waste pickers, retailers of recyclable materials and fittings, and wholesalers of recyclable materials. • Other producers of waste.
Waste recyclers	• Private companies • Recycling Units (formal & Informal) • Crushing unit owners / operators • Equipment Manufacturers
Government entities	• Municipal Corporation* • Urban Development Authority • Roads & Building Dept./ PWD • District Collectorate • Central and State Pollution Control Boards/ Committee (SPCBs) • State Urban Development Department • Utility service providers and their contractors • Bureau of Indian Standards/ Indian Roads Congress
End-users of recycled components, materials or products	• Architects, Designers/ • Civil Engineers • Structural Engineers • Contractors • Individuals/ Households
Others	• Cooperative Societies/ • Community bodies • Ward Sabhas/ Committees • CSOs, NGOs, Advocacy Groups, • Entrepreneurs • News Media (Print & AV)

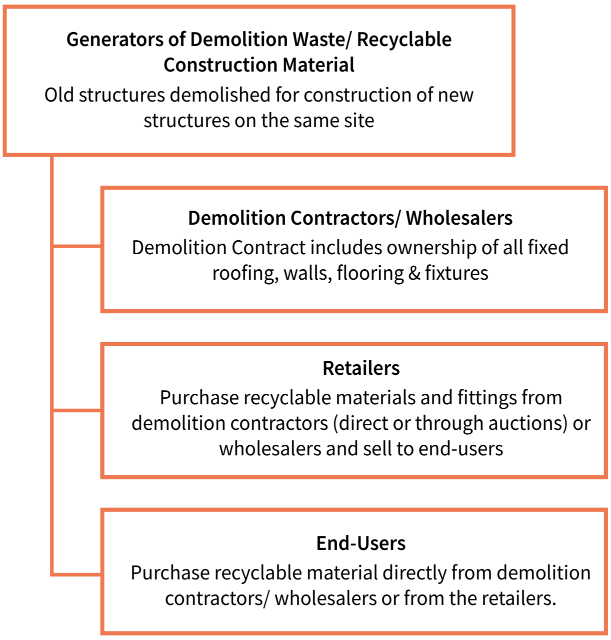
2.2.1 The Informal Waste Recyclers in India

The informal waste sector is the backbone of the recycling industry in India, contributing a lot in terms of environmental sustainability and circular economy. Their contribution in waste collection and recovery of materials from municipal waste is high. The informal recycling reduces the cost incurred in the treatment and disposal of solid waste by extracting recyclables before the mixed waste is haphazardly dumped into the landfills or subjected to any specific treatment. It also contributes enormously in reducing the economic burden of urban local bodies. Waste pickers recover

Approximately 20% of recyclable waste and it is estimated that every tonne of recyclable material collected by the waste pickers saves the ULB approximately INR 24 500 per annum and avoided the emission of 721 kg CO2 per annum (Annepu RK. 2012).

Waste pickers, in the Indian context include persons who informally collect and recover reusable and recyclable solid waste from the sources of waste generation or from dumpsites, and sell the collected waste directly to recyclers or through intermediaries (CPCB, 2017).

Stakeholders for Recycling of C&D Waste



Source: : Joshi, R. 1999.

The key stakeholders in the recycled C&D waste material are demolition contractors, wholesalers and retailers. Once the sale process of an old structure is completed, the buyer, who could be an individual, builder or speculator, issues a contract for demolition of the structure the cost of which includes the demolition of the structure and clearing of the site. As per the contract, the demolisher would own all components of the structure, including salvageable components and materials that can either be resold in their original form (door and window frames and shutters, fittings, rubble etc.) or material salvaged as scrap (steel - including rods from pillars and slabs etc., copper from electric wires, galvanised pipes (plumbing), electrical fittings, taps etc.). In addition, reusable materials like bricks, flooring tiles and plumbing fixtures are also salvaged (Joshi, 1999). The main costs incurred by the demolition contractors are labour and transport of the non-salvageable rubble and debris from the site.

The informal stakeholders in the C&D waste stream are mobile waste-buyers, individuals or associations of waste-collectors, waste-traders involved in secondary sorting, sale and purchase of recyclable materials, and small shop dealers. It also includes waste-pickers at dumpsites and at communal waste collection points, and owners of waste warehouses/ godowns.

2.3 C&D Waste Recycling in Indian Cities

The estimated generation of C&D waste in India in 2013 was 530MT (CSE, 2014). This 750 MT of sand, 123 MT of soil and 2000 MT of stone aggregate (MoHUA & Niti Aayog,2018). Thus, if the estimated C&D waste that is generated is processed, it would only meet 5% of the requirement for construction materials. Since residential buildings comprise 67% coarse and fine aggregates by weight (Devi & Palaniappan 2014), the burden on coarse and fine aggregates will increase substantially. In cities like Bangalore, fine aggregates are transported to distances in the range of 70-100km (Reddy & Jagadish, 2003) due to their shortage. In order to avoid large transportation costs, illegal mining occurs in various parts of the country. Several states in India issued a ban on aggregate mining that caused a severe bottleneck in construction and major infrastructure projects leading to the use of alternate building materials like M-sand extracted from granite.

There are several C&D waste recycling plants in India, some of which are briefly described below.

Delhi

Delhi, which generates about 4,600 tonnes of C&D waste per day, was the first city in India to set-up a processing facility for C&D waste at Burari in North Delhi. The MCD gave around 7 acres of land for a period of 10 years for this plant.

The pilot stationery recycling plant, commissioned in 2009, has a recycling capacity of 500 TPD. MCD collaborated with Infrastructure Leasing & Financial Services Limited (IL&FS) and Environmental Infrastructure & Services Ltd (IEISL) to develop a Design, Build, Operate and Transfer (DBOT) plan for storage and managing of 500 TPD of C&D waste. The DBOT partner was also to develop a test road utilising processed C&D waste with support of Central Road Research Institute, New Delhi.

Air quality monitoring and noise monitoring are important for C&D waste recycling plants. In fact, the Delhi Pollution Control Committee (DPCC) has mandated that monitoring air and noise pollution equipment is placed within the plant premises while issuing consent to operate.

The waste is transported from three designated zones of Delhi, namely Karol Bagh, Sadar, Paharganj Zone and City to a recognised location and then processed and utilised. The rejected material is land-filled at the same location. The following processes are involved in recycling of C&D waste at Burari (Biswas et al. 2021).

- First items like plastic, metal, FRP sheet, rags etc. are segregated mechanically and manually. The remaining waste is segregated into three parts a) whole bricks b) big concrete pieces and c) mixed C&D waste.
- Whole bricks are sold separately and large concrete blocks are broken into smaller pieces (200-400 mm size) using a rock breaker and mechanical hammer. These are then processed and broken into smaller aggregate suitable for making Ready Mix Concrete (RMC), which is used for making non-structural materials like kerb stone, paving blocks, concrete bricks and tiles.

However, initially the products manufactured by the recycling plant found no takers due to lack of information and the absence of support from national legal-instruments like the Indian Standards and National Building Code of India. This changed with the mandatory regulation of the state government to utilise the recycled C&D products for government civil works and projects. In fact, over 16 lakh recycled concrete blocks from the plant have been utilised in the new Supreme Court annex building in New Delhi.

The plant is currently scientifically processing 2,000 TPD of mixed C&D waste and converting it into aggregates, which in turn is converted to ready mix concrete, cement bricks, hollow bricks, pavement blocks, kerbstones, concrete bricks, and manufactured sand, thereby reducing the consumption of virgin construction raw material and minimising the environmental hazard due to C&D wastes. Approximately 450,000 tonnes of C&D waste was collected during 2010–12. The following Table shows the status of off-take of C&D recycled products by Government Departments in Delhi from 1 April 2019 to 31 January 2021.

Table 14: Off-take of C&D Recycled Products by Government Departments in Delhi

S. No	Name of Government Department	FY 2019-20		FY 2020-21		Cumulative for 1 April 2019 to 31st January 2021		
		Annual Off-take Target (MT)	Annual Achievement (MT)	Annual Off-take Target (MT)	Off-take from 1 Apr 2020 to 31 Jan 2021	Total Offtake Target in MT	Total Actual Off-take in MT	%age Achieved
1	North Delhi Municipal Corporation	25,000	73,340	100,000	40,350	125,000	113,690	90.95
2	East Delhi Municipal Corporation	25,000	38,182	50,000	52,333	75,000	90,515	120.69
3	South Delhi Municipal Corporation	50,000	47,327	75,000	20,248	125,000	67,575	54.06
4	Delhi Development Authority (DDA)	50,000	42,530	100,000	175,572	150,000	218,102	145.40
5	Delhi State Industrial & Infrastructure Development Corp. Ltd. (DSIIDC)	100,000	73,344	135,000	65,948	235,000	139,292	59.27
6	Irrigation & Flood Control	200,000	92,757	200,000	9,798	400,000	102,555	25.64
7	New Delhi Municipal Council	10,000	3,539	25,000	6,766	35,000	10,305	29.44
8	Public Works Department (PWD)	100,000	34,419	100,000	42,028	200,000	76,447	38.22
9	Central Public Works Department (CPWD)	15,000	4,663	100,000	7,201	115,000	11,864	10.32
10	NBCC (India) Limited	30,000	1,840	100,000	514	130,000	2,354	1.81
11	Delhi Metro Rail Corporation(DMRC)	1,000	12	10,000	11,375	11,000	11,387	103.52
12	Railway Board	1,000	0	10,000	15	11,000	15	0.14
13	National Capital Region Transport Corporation (NCRTC)	0	0	5,000	0	5,000	0	0.00
14	Delhi Jal Board (DJB)	0	0	5,000	937	5,000	937	18.74
15	Delhi Tourism and Transport Development Corporation (DTTDC)	0	0	5,000	212	5,000	212	4.24
16	Delhi Urban Shelter Improvement Board (DUSIB)	0	0	5,000	117	5,000	117	2.34
17	Delhi Cantonment Board	0	0	5,000	0	5,000	0	0.00
18	Delhi Transco Ltd, BYPL, BRPL, Tata Power Delhi Distribution Ltd & other Govt. Depts of NCT of Delhi	0	0	50,000	568	50,000	568	1.14
	Total (MT)	607,000	411,953	1,080,000	433,982	1,687,000	845,935	0.50
19	NHAI	1,000,000	1,362	500,000	29,746	1,500,000	31,108	2.07
	Grand Total (MT)	1,607,000	413,315	1,580,000	463,728	3,187,000	877,043	27.52

Source: Data provided by Khandelwal, P

The Table below shows the demand from Government Departments in Delhi for different recycled products during 2021. It also shows that in Delhi, M-Sand is the most in demand recycled product from C&D waste recycling.

Table 15: Delhi – Department wise Sales Figures for C&D Products for January 2021

1 January 2021 to 31 January 2021										
S.No	**Name of Government Department**	**RA 3-10 mm**	**RA 10-20 mm**	**RA 20-60 mm**	**RA 60-150 mm**	**M-Sand**	**Soil**	**CC Block**	**CC Block Nos**	**Total in MT**
1	Public Works Department (PWD)	0.00	0.00	50.06	0.00	77.77	0.00	0.00	0	127.80
2	Central Public Works Department (CPWD)	0.00	0.00	0.00	0.00	279.62	0.00	3.750	250	283.37
3	South Delhi Municipal Corporation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
4	North Delhi Municipal Corporation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.000
5	East Delhi Municipal Corporation	0.00	0.00	203.83	0.00	309.78	15,765.970	33.750	2,250	16,313.33
5a	EDMC Contractor	0.00	0.00	203.83	0.00	309.78	1,205.970	33.750	2,250	1,753.330
5b	EDMC Store	0.00	0.00	0.00	0.00	0.00	14,560.00	0.00	0	14,560.00
6	DSIIDC Delhi State Industrial &Infrastructure Development Corp. (DSIIDC)	0.00	0.00	0.00	0.00	132.17	0.00	0.00	0.00	132.17
7	Delhi Development Authority (DDA)	0.00	0.00	497.50	0.00	398.83	20.06		83,950	2,175.64
8	IL&FC	0.00	0.00	100.41	0.00	173.36	0.00	0.00	0	273.77
9	NBCC (India) Limited	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
10	New Delhi Municipal Corporation	0.00	10.150	0.00	0.00	279.07	0.00	0.00	0	289.22
11	Delhi Jal Board (DJB)	0.00	0.00	0.00	0.00	61.51	0.00	0.00	0	61.51
12	National Highways Authority of India (NHAI)	0.00	0.00	0.00	704.19	0.00	0.00	0.00	0	704.19
13	Delhi Metro Rail Corporation (DMRC)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
14	BSES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
	Total (MT)	0.00	10.15	851.80	704.19	1,712.11	15,786.03	1,296.75	86,450 Nos.	20,361.03

Source: Data provided by Khandelwal, P

This was followed by the setting-up of four other plants (3 in North Delhi of 2000 TPD, 150 TPD and 1000 TPD; 2 plants of 1000 TPD each in East Delhi and South Delhi). Despite the capacity of the five plants to recycle 5150 TPD of C&D waste, the city's requirement for collecting and processing 6500 TPD of C&D waste is not met. At present there are 255 C&D waste collection centres in Delhi.

Of 100 tonnes of C&D waste in Delhi, 50% is loose soil, 5% is RCA, 24% is recycled aggregate, 15% is M-sand, 1% are other recyclables and the remaining 5% are rejected. Thus, if C&D waste is recycled, the pressure on landfill sites will reduce by 95%. Based on the learnings of the plants in Delhi, the suggested or viable way forward needs:

- Seamless integration of the process from demolition to processing. A draft tender document was prepared for SBM 2.0 but has not yet been incorporated.
- Separation of concrete waste from non-concrete waste,

- Incentive to waste generator for sale of C&D waste and concession on purchase of recovered materials, including value added products.
- Extra weightage in green building rating, and any other environmental benefits. For example, UAE has included rating systems like LEED, Pearl Rating System for certification and to ensure preparation of plans for waste management, reuse of materials, diverting of waste from landfills for recycling (Hamani, 2011; Eco MENA, 2018).
- IEC activities for wider exposure to availability of recycling options and products made from C&D waste.

Gurugram

Gurugram generates approximately 1,200 TPD of C&D waste. In addition, the areas under the Haryana Urban Development Authority generate a substantial quantity of C&D waste that is illegally dumped. In order to address this challenge, a C&D waste processing facility with a capacity of 300 TPD was established at Gurugram. This plant became functional in 2019 and gradually, the processing capacity of the plant has been increased to 1,500 TPD. Since its setting-up, nearly 1,200,000 tonnes of C&D waste has been collected from unclaimed dumpsites and transported through doorstep collection and enforcement activities. Of this, nearly 350,000 tonnes has been processed (Biswas et al., 2021).

Mumbai Metropolitan Region

According to Maharashtra State Pollution Control Board, 97% of the C&D waste generated by the different urban centres under Maharashtra state are disposed of in low lying areas or landfills. The remaining 3% are processed or recycled. Mumbai generates nearly 89% of the total C&D waste in the state, which is completely disposed of without processing in low lying areas (MPCB, 2022). In March 2022, the government's Mumbai Climate Action Plan (MCAP) concluded that construction activities in Mumbai contribute to 8% of the total emission of particulate matter.

The Mumbai Metropolitan Region was the first in India to come up with a decentralised solution for debris management in Navi Mumbai in 1999. The collaboration was promoted by Youth for Unity and Voluntary Action (YUVA) and the City and Industrial Development Corporation (CIDCO). Although this led to recycling of 1,500 tonnes of C&D waste at the CIDCO YUVA Building Centre, the facility was forced to shut down in 2012 because it failed to receive policy or market support (MPCB, 2022). Currently the city has no official recycling facility. The proposed 2.7 hectare recycling facility at Mulund for recycling 1440 TPD awaits construction (Chatterjee, B., 2020).

Thane

Thane Municipal Corporation (TMC) generates 31,697 MT of C&D waste (MPCB, 2022). It has a C&D processing plant of 300 MT capacity at Daighar. TMC has a policy under which a contractor responsible for generating construction or demolition debris has to pay money to TMC for transferring and treating it at its plant in Daighar. The waste generator has to pay INR 1,089 per MT of waste as transportation charges and if they transport the waste themselves, they have to pay INR 545 per MT. Those who generate debris of less than one MT and are willing to transport it to Daighar themselves are not required to pay anything. A discount of 20% is given to building contractors for C&D waste treatment if they are ready to buy the recycled by-products and re-use them.

Building contractors who are found dumping debris illegally on land, water bodies or mangroves have to pay fines between INR 5,000 to INR 20,000 as well as pay waste transfer and treatment charges (CDE Asia, 2019).

Pune & Pimpri -Chinchwad

Pune and Pimpri-Chinchwad are important real estate centres in Maharashtra. A C&D waste processing plant with a recycling capacity of 200 TPD was installed in the Pimpri-Chinchwad Municipality area in Pune on a Design-Build-Own-Operate (DBOO) Model. It recycles 95% of the water used, and works at 140 KWH power at its peak capacity. Equipped with CDE Asia's cutting-edge wet processing technology, the plant has the ability to convert debris into usable and marketable construction materials such as bricks and manufactured sand of 4 different grades (+20mm, 20mm +8 mm, 8mm +3 mm, 3mm – 0.075 mm) which can again be reused in the growing construction and infrastructure based industries.

Bengaluru
Bengaluru is one of the largest cities in India with a population of more than 8 million. However, it does not have a C&D Waste Management Plan. Rock Crystals is the only fully functional C&D waste recycling plant at Kannur Village in

Chikkajala (East Bengaluru) with a capacity of 1,000 tonnes a day. It started in 2019 and has a contract for 20 years. This plant is functioning at a lower capacity, because they receive 100-200 tonnes of waste every day from the Airport, BBMP sites and a few builders.

According to BBMP, approximately 2,700 TPD of C&D waste was generated in the city in 2014, the Karnataka State Council for Science and Technology estimated that than 2,500 TPD of C&D waste was generated in 2015 and C-STEP estimated that 3540 TPD of C&D waste was generated in 2016 (Ramakrishna, 2023)..

The Center for Study of Science, Technology and Policy (C-STEP) reported that as per a survey conducted by them, approximately 10% of the C&D waste enters the city's dumping site, approximately 30% is used for levelling low-lying areas and land reclamation for future construction, and the rest 60% C&D waste is unaccounted for, that is, it is illegally dumped (C-STEP, 2016).

Bengaluru recently set-up a door-step pick up mechanism in South Bengaluru for C&D waste free of cost in association with Saahas – an NGO. Saahas collects concrete, brick, metal, ceramic, plastic, wood, glass and wires. Being an intensive logistic initiative, Saahas is planning to introduce a subsidised cost model after the pilot period (Mathew, 2022).

Hyderabad
In Hyderabad, the Municipal Corporation collects the waste in its own trucks and transfers it to the plant – so sometimes the quantity of waste is less than the processing capacity and at other times it is more. Consequently, the excess C&D waste that could not be processed was collected and dumped on a part of the site where the plant was to expand in the future. Consequently, a huge volume of legacy waste was accumulated and the company was asking the Municipal Corporation of Hyderabad for money to transport the accumulated waste from one part of the plant to another. This mismatch in the plant operation and the collection and supply network has disrupted a lot of businesses. Thus, it is necessary to have an integrated business model where the processor collects the amount of waste according to the plant's processing capacity.

2.3.1 Challenges and Roadblocks

The Table below lists the challenges and roadblocks identified in the literature for C&D waste recycling in urban areas as well as challenges of actually running the recycling plants and limited demand for C&D recycled materials.

Table 16: Summary of Challenges and Roadblocks

Stakeholder	Actions
Municipal bodies/Local authorities	• ULBs appear to be the weakest link hindering rapid adoption of initiatives and face several challenges. Even if the collection, transport and processing is actually contracted out to a private entity, the ULB is ultimately responsible for the overall performance of the management scheme
	• Cities are not convinced how the business case would work in their circumstances, and are apprehensive about the model being a drain on their budget • C&D waste management is considered a low priority (the public is more concerned about MSW), especially in the absence of strong coordination/facilitation by state-level agencies.
	• Land shortage • Lack of monitoring capacity/resources and experience in C&D waste management • Concern about finances and business case • Lack of urgency/priority.
	• Make arrangement for collection of C&D waste • Ensure transportation of C&D waste at appropriate site • Minimum 2-acre land to be provided for setting up of 50-100 TPD C&D waste wet processing plant. For every additional 100 TPD C&D waste, an additional 1-acre land for C&D waste recycling plant. • Examine and approve waste management plan of generators • Establish C&D waste generation database • Device appropriate measures for management/ processing of C&D waste and use of recycled products and provide incentive/s for use of products made with recycled C&D waste
Private sector/ Construction industry	• Lack of awareness and concern • Dominance of the unorganised sector in demolition • Lack of confidence in recycled products • Poor economic viability of recycled products (aggregates are taxed at 5% and manufactured products are taxed at 18% making the use of recycled products economically unviable for customers.)
State government agencies/ Departments	• Low involvement of state urban departments. • Low engagement by public construction agencies • Web-Portal Creation • Quantification of C&D waste • Utilisation pattern of C&D waste-based aggregates and products
Secondary data on the numbers of plants currently running in India is not available.	

Source: MoHUA, 2018

2.3.2 Recommendations and Actions

The summary of recommendations and actions for enhancing C&D waste recycling in India are (MoHUA, 2018; 2021):

i. Essential to take inventory of and characterise the C&D waste for the different cities as well as areas within a city, such as older parts, newer rapidly developing areas, areas being redeveloped etc.

ii. Provide handholding support/ planning assistance for cities that are ready to set-up C&D waste management facility.

iii. Accelerating state level facilitation by recognising the efforts made for C&D waste recycling.

iv. Conduct sustained outreach in construction industry through interaction with industry associations.

v. Promote standardisation, research and utilisation of C&D waste recycled products

vi. Engage with stakeholders such as CPWD/ PWDs, BIS, GRIHA/ IGBC, BMTPC, etc. for facilitating more extensive use of products made from recycled C&D waste.

In order to promote C&D waste circularity (from secondary literature):

- Building design and construction: reduce the use of virgin materials. Use 20% secondary materials in new building construction and 40% in roads and highways.
- Building products and materials with secondary resources should be given tax rebates.
- Reduction in the overall waste generation by setting dismantling standards and SOPs
- Transparency in FAR, demolition plan, data on construction material and declaration of life span of the building from the planning phase.
- Cluster based C&D Waste recycling plants, at least one in cities with >10 lakh population
- Mobile-based data collection system on types of C&D waste being generated.
- Define green building standards on C&D waste utilisation,
- Waste generators must pay charges for collection, transportation, processing, and disposal as notified by the concerned authorities.
- Municipal Corporations/ULBs should ensure buy-back of the recycled material from the processing plants through building permit system.
- Reduction of GST on C&D waste processed products from present applicable rate of 18% to 5%.
- The utilisation of the C&D waste incentivised through reduced GST and or other fiscal incentives.
- Exemption of Green tax on C&D Recycled products and transportation.
- The intent of the national level policy for achieving resource efficiency in the construction sector needs to be translated to a roadmap for action at the State and city level.
- All construction projects – both buildings and infrastructure should prepare demolition plans and segregation plans for C&D waste management as part of building plan approvals submitted to the municipality/ competent authority, as applicable.

Looking at Challenges of C&D Waste

3

Although research on C&D waste management in Asia has been extensively conducted, little attention has been paid to standard practices of C&D waste management in other geographic areas. The knowledge of C&D waste management developed in one geographical area is not easily adapted and applied to other areas without considering their contextual differences (Lu W, 2010). This research aims to study the prevalent C&D waste management strategies and practices in three cities.

The cities selected for the detailed study are Surat, Ahmedabad and NOIDA. Surat was selected since it is the best performer in the area of C&D waste management. Ahmedabad was taken up since it was started before the C&D Waste management guidelines were issued while NOIDA was taken up because of the scale of recycling of C&D waste it had to take up following the demolition of the twin towers.

3.1 Surat Green Precast Private Ltd.

The C&D recycling plant in Surat was selected for the study. Surat produces 2200 MT of solid waste daily. The per capita waste generation is more than 450 grams per capita per day. Collection and transportation was 2150 M.T. per day (Average of 01/01/18 to 31/12/18). Municipal Solid Waste collected through the primary collection system reaches the Semi closed body transfer station of the respective zone from where it is being sent to the Khajod Disposal transported through a close body container in a mechanically compacted way. The integrated MSW treatment process of Surat Municipal Corporation is to find the best possible technology and scientific solution for resolving the garbage disposal problem in the city.

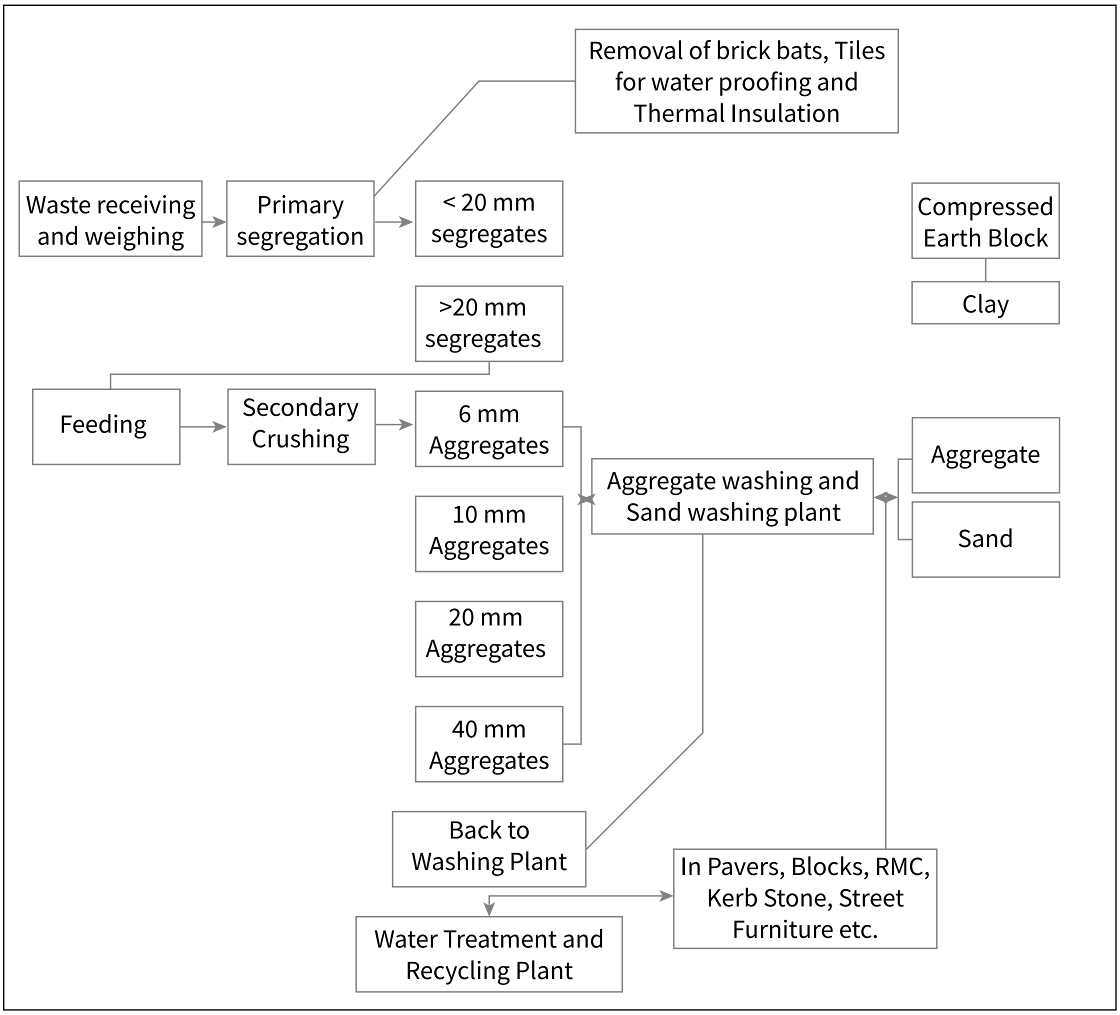
- The integrated treatment technology promoted by Saurashtra Enviro Projects Private Ltd. Surat was selected as the most appropriate technology for treatment of MSW.
- The agency has installed the facility on a BOOT basis for a concession period of 02 years.
- The quantity agreed for agency is minimum 600MT per day subjected to maximum treatment of 500,000MT for treatment.

Surat Green Precast Private Ltd (SGPPL) is managing and processing all C&D waste in the city. The C&D waste recycling plant was commissioned in February 2019 on PPP mode with a 20 years concession period. The recycling plant is located on 3 acres of land at Kosad and receives waste from 10 designated dumping sites. Each trip covers on an average about 15-17 km distance. SGPPL capital investment for this project is more than 12 Crore.

Transportation of waste is done by trucks owned by the company. SGPPL is responsible for transporting the C&D waste from the collection points to the processing facility, whereas the waste generators are supposed to dump the C&D waste at any of the 10 designated dumping locations. The plant handles 300 tonnes of C&D debris per day (TPD). SGPPL charges SMC INR 160/tonne for less than 5 tonnes and INR 333/tonne tipping fee to pick up waste from any of the 10 designated dumping sites accumulated from the 8 administrative zones in the city. While SGPPL collects collection charges directly from users/ generator agency and deploys GPS based vehicles for efficient monitoring, SMC has made it compulsory for utilisation of 20% recycled products in all of the tenders as per the guideline of SBM.

As in other parts of the country, C&D waste material streams of immediate market value such as metals, wood frames, etc. are recovered for the secondary market, usually by the informal sector, while the rest of debris and waste is left behind. The debris are collected from the designated collection centres from all 8 administrative zones. While a small fraction of this debris is used for backfilling and as daily landfill cover, most of it is not utilised which cannot be taken into the consideration of recycling process for C&D waste management facility.

Figure 9: Process Flowchart - C&D Waste at SGPPL



Source: Fieldwork

SGPPL charges SMC ₹ 160/ton for less than 5 tonne and ₹ 333/tonne tipping fee to pick up waste from any of the 10 designated dumping sites from over the 8 administrative zones in the city.

3.1.1 Life Cycle Inventory

Normally the plant receives 0.5% of mixed waste per day. Sometimes by composition, the plant can get 10% of plastic too. The first step is to remove large/ oversize debris from the mixed C&D waste during which even brick-bats, tiles used for water-proofing and thermal insulating materials are removed. Next is the scrubbing process where clay adhering to the debris is removed. This is followed by removal of light weight impurities. This is followed by the sieving process to separate aggregates (6mm, 10mm, 20mm and 40mm) from the debris. Thereafter, the debris is fed into the crushing machine for secondary crushing, and sieved to separate different sized aggregates that are washed. The aggregates and M-sand are sold as well as used in the manufacture of kerbstones, paver blocks, blocks for manholes, interlocking tiles, toilet blocks, and concrete brick blocks.

Soil is recovered from the sludge resulting from the washing process. The water used in the plant is recycled at the sewage treatment plant using non-polluting processes. The present analysis for LCI considered the process from start to the secondary crushing and separation of the aggregates.

In the present case, 1 tonne of waste is considered as the functional unit for the analysis. This facility was found to be consuming per day about 100 KWH of electricity sourced from Gujarat based hard coal electricity and 50,000 litres of water sourced from SMC for processing of waste in the plant (considering gate-to-gate system boundary). The Table below represents data used for transportation of C&D waste from site to recycling plant.

Table 17: Data used for Transportation of C&D Waste from Dumping Sites to Recycling Plant

Variables	Input/ Output materials	Quantity per day	Units	Remarks
Fuel	Input	64.5	KG	1 litre of diesel = 0.86 kg
Truck type, capacity and distance travelled	Input	3750	TKM	10 Tonne*375 Km
Brick and masonry	Input	69.055	TPD	As per break up of composition shared 31%
Sand, rock, gravel	Input	80.194	TPD	36% is sand, rock, and gravel but excluded soil
RCC - secondary materials	Input	149.25	TPD	Used as a concrete blocks

Calculation: To break up the data of bricks, mixed soil, sand, rock, and gravel consider 67% as 100% and the results are as given in the table below.

Table 18: Data used for Manufacturing of Recycled Aggregates

Variables	Input/ Output materials	Quantity per day	Units	Remarks
Electricity	Input	100	KWH	Gujarat based hard coal electricity used
Fuel	Input	43	KG	Diesel
Water	Input	50000	m3	Unspecified natural origin of Gujarat state.
Chemicals	Input	0.25	KG	Used aluminium sulphate instead of ferric chloride
Recycled aggregates	Output	238.8	TPD	
Silt	Output	61.2	TPD	Considered as inert also added Residual to it
Atmospheric pollutants- PM 2.5	Output	70.68	micro gms	
Atmospheric pollutants- PM 10	Output	107.3	micro gms	
Atmospheric pollutants- NO2	Output	17.42	micro gms	Converted PPB to microgram
Atmospheric pollutants- SO2	Output	19.31	micro gms	Converted PPB to microgram

Method: ReCiPe 2016 Midpoint (H) V1.07 / World (2010) H

Indicator: Characterisation

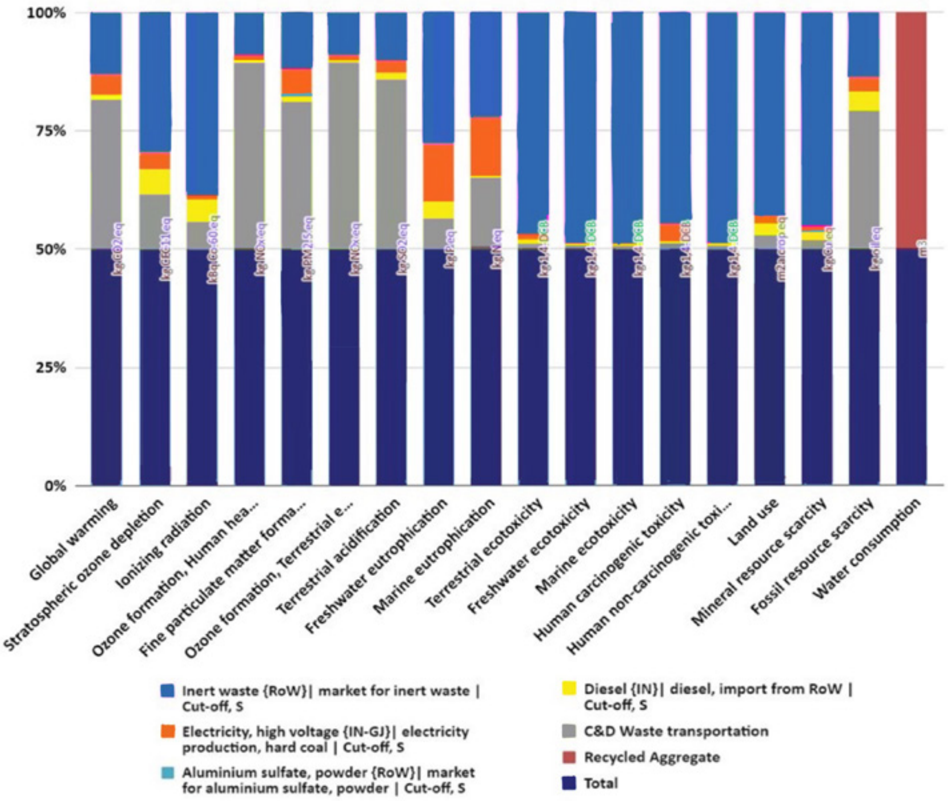
Atmospheric pollutant data is an important requirement for LCA of C&D waste, which is not available inside the processing plant. Taking that into account, we have collected air pollutant data from the nearest Air Quality Monitoring station, which is located very close to the SGPPL. Data collected on a daily basis for a month period (25th February 2023 to 26th March, 2023) and then the monthly average is taken into account. Four indicators such as Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Particulate Matter size equal to or less than 10 micron (PM_{10}) and Particulate Matter having an aerodynamic diameter less than or equal to 2.5 micron ($PM_{2.5}$) have been collected for the present study.

3.1.2 Life Cycle Impact Assessment

The primary data collected from SGPPL in Surat city were compared and analysed using midpoint categories for LCA. For impact assessment in LCA, databases and factors are considered as important input and output variables in order to study its environmental impacts. In the present case 18 environmental impacts are studied under LCIA. The LCA result shows that the inert waste, that is, non-biodegradable material in waste is found as a major contributing factor responsible for global warming and impacts on other 16 environmental parameters more or less.

It is majorly responsible for various kinds of toxicity like ionising radiation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human carcinogenic toxicity, human non-carcinogenic toxicity, land use, mineral resource scarcity, stratospheric ozone depletion, freshwater eutrophication, terrestrial acidification etc. Second major contributing factor found is transportation of C&D waste which is majorly responsible towards global warming, stratospheric ozone depletion, ozone formation, human health, fine particulate matter formation, terrestrial ecosystems, fossil resource scarcity, fine particulate matter formation, terrestrial ecosystem, terrestrial acidification, marine eutrophication etc. High voltage electricity, diesel are also contributing factors to some extent also recycled aggregate having an impact on water consumption. In this life cycle analysis, inert waste is having the highest impact on the environment followed by transportation of C&D waste, and the use of high voltage electricity and diesel.

Figure 10 : LCA result of Surat C&D Waste Recycling Plant



3.1.3 Interpretation of the Findings

The interpretation of LCA analysis is based on its predefined goals and scopes. The scope of the LCA studies is limited due to inaccuracy of data as C&D waste data is complex and heterogeneous by nature. It is found from the LCA result that C&D waste has harmful effects on the environment, ecological resources and on various life forms including human beings. C&D waste is potentially responsible for the increase in air pollution, water pollution and soil pollution as well as human health. Its components like inert waste due to its non-bio-degradable nature followed by transportation of waste needs to be addressed as these two factors are having a major threat for the environment.

3.2 Ahmedabad Enviro Projects Private Limited

4000 MT of solid waste is generated daily in Ahmedabad. The per capita waste generation for the city is more than 700 grams. The Ahmedabad Municipal Corporation (AMC) has an annual budget of over INR 4000 million for solid waste management, employs 13000 health and conservancy staff and has more than 1600 vehicles for collecting and transporting waste (Mehta, 2020).

Before 2012, C&D waste in Ahmedabad was disposed of without any treatment. On 18 March 2012, AMC issued an Expression of Interest for a C&D waste processing plant on a PPP mode on a Design, Build, Finance, Own and Operate basis for 30 years. Of the six companies that responded, AMC issued a work order to DNP Infrastructures Private Ltd. to set-up the Ahmedabad Enviro Projects Private Ltd. (AEPPL) for processing 300 TPD of C&D waste on 5 acres of land allocated by AMC. AEPPL was established in October 2013 and commenced phase wise operations from December 2013, and became fully operational from June 2014. AEPPL's capital investment for this project is more than INR 70,000,000. Thus, the C&D waste treatment facility was commissioned before MoEF announced the "C&D Waste Rules" in March 2016. The AEPPL currently handles 1000 TPD of C&D waste.

The AMC pays a transportation fee INR 228.99 for 300 TPD and 218.09 for 700 TPD currently (with a 5% increment every year). The plant authority is responsible for transporting the C&D waste from the 16 designated dumping sites to the processing facility, whereas the waste generators are to dump the C&D waste at any of the designated dumping locations. The debris at dumping sites is collected by JCB and transported through 7 trucks with 22MT capacity that cover an average distance of 25 km to bring the waste to the plant. The waste is dumped in piles at the plant and is segregated as RCC waste, mixed waste and low-quality waste.

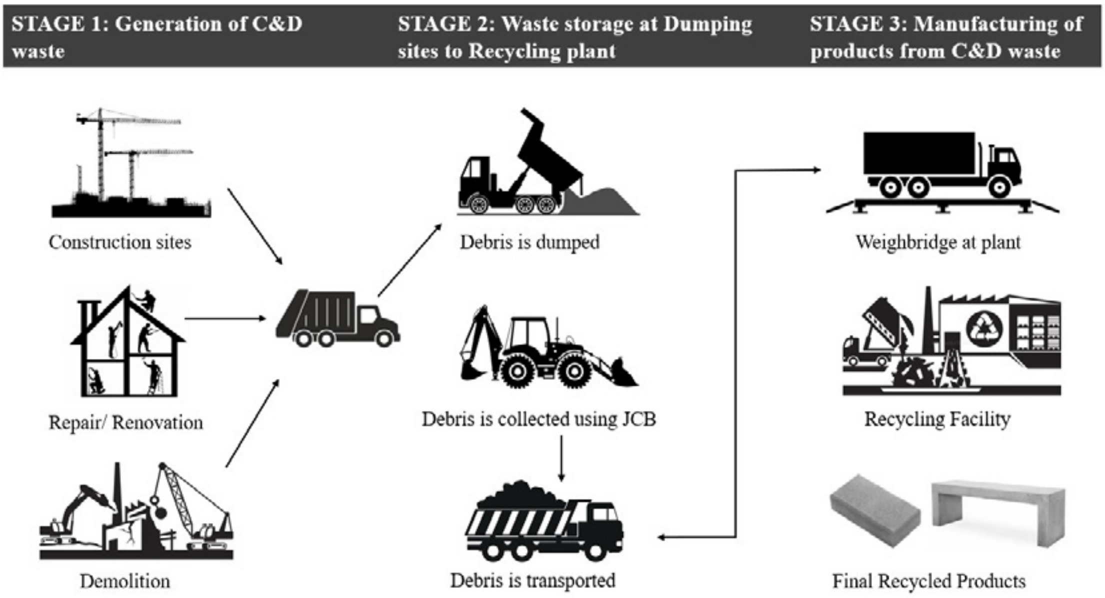
The transportation service for C&D waste is provided by AEPPL. AMC pays INR 178 per tonne as tipping fee for transportation of waste from the collection points to the recycling plant. AMC also provides doorstep pickup service for collection of C&D waste that can be availed by paying a fee that is based on approved rates. Ahmedabad residents can avail this service by registering a request/ complaint for collection of C&D waste by calling the AMC operated Comprehensive Complaint Redressal System. The door-to-door service is also contracted out to AEPPL. To make collection of small quantities (less than one tonne) economically viable, such requests are mapped and scheduled so that four to five spots can be covered in a single trip.

Table 19: Transportation and Processing Fees charged by AMC

Weight	Per Tonne	Per Trip
Less than 1 tonne of waste	-	INR 200
For 1-5 tonnes of waste (minimum quantity)	INR 225	INR 675
More than 5 tonnes of waste (large quantity)	INR 212.5	INR 1700

Source: AMC, 2018

Figure 11: AEPPL - Process overview of Ahmedabad C&D Waste Recycling Plant



The waste goes through the following process for manufacturing the products.

- Feed Systems → The collected waste goes through feed systems in the plant and prepares for screening.
- Primary Screening → This phase prepares the material for primary crushing; after this stage, the material remains of equal size.
- Magnet separator → It removes all the metal from the waste.
- Primary Crusher → The primary crusher can crush bigger particles into smaller ones and ensure that these particles remain in the compressed form.
- Secondary Crushing → It converts smaller particles into finer particles or a powder form. It is an important stage as it provides the manufacturing unit with raw materials.
- Aggregate and Wash Sand → Materials for producing aggregates and sand pass through the washing process before manufacturing
- In the running plant they use a fogger machine (at crusher, sieving process) to settle down the waste dust.

AEPPL has a laboratory which tests the product quality, safety and durability. The plant manufactures a variety of value added products, including Precast RCC, precast concrete box culverts and manholes, RCC fencing pole, door frame, grill, kerb stones and ferro covers, road edge stones, paving stones, granite, interlocking paving blocks, bitumen-bound materials, concrete blocks, frames, paver blocks, benches and kerb stones, pipe bedding, hydraulically bound mixtures for sub-base and base, unbound mixtures for sub-base, capping, embankments and fill. The C&D waste products are sold under the brand name NUEarth and are ICMQ Certified and GRIHA Accreditation

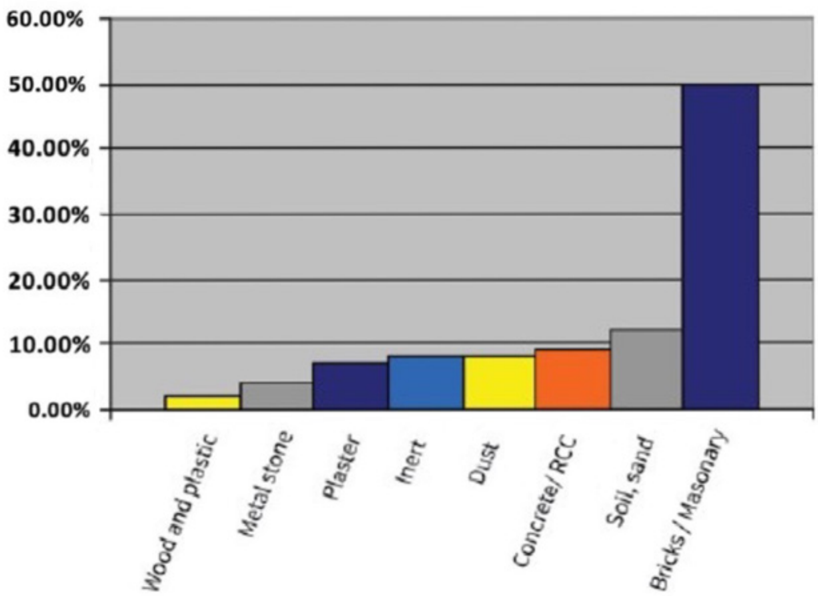
To provide the necessary boost to recycled building products, AMC has adopted a preferential procurement policy under which respective government departments/ projects are to procure 50% of requirements for paver blocks and kerb stones, and 25% of requirements for manhole covers (without frame) from AEPPL. AMC also specified that the rates should be as per the existing rates of AMC approved tender and/or rates as per the schedules of rates (SOR), whichever is less. AMC has also approved a policy of procuring pre-cast/ pre-stressed wall panels from AEPPL to build compound walls for AMC's properties. AEPPL has recycled 1,672,000 MT of C&D waste in Ahmedabad.

Ahmedabad's integrated business model where the processor also collected waste from the dumping site and hence can ensure that only the quantity of waste they could process was collected. In contrast, in Hyderabad, the Municipal Corporation collects the waste in its own trucks and transfers it to the plant – so sometimes the quantity of waste is less than the processing capacity and at other times it is more. Consequently, the excess C&D waste that could not be processed was collected and dumped on a part of the site where the plant was to expand in the future. Consequently, a huge volume of legacy waste was accumulated and the company was asking the Municipal Corporation of Hyderabad for money to transport the accumulated waste from one part of the plant to another. This mismatch in the plant operation and the collection and supply network has disrupted a lot of businesses. Thus, it is necessary to have an integrated business model where the processor collects the amount of waste according to the plant's processing capacity.

The challenges of running the plant is selling the products made from recycled C&D waste, transportation of the waste, electricity, manpower, processing capacity and internal transportation. Government support is needed for expanding the market for goods made out of recycled C&D waste. In addition, AMC needs to establish dumping sites in areas such as Naroda, Bopal and others where major development is ongoing and C&D waste is being illegally dumped.

3.2.1 Life Cycle Inventory

Figure represents the composition of waste, where bricks and machinery (50%) are half of the total waste, soil and sand (12%), concrete/RCC (50%), inert and dust each (8%, metal, stone (4%), wood and plastic (2%).



Source: AEPPL

Mixed C&D waste debris are sorted and then processed to obtain output as M-Sand, dust and granular sub-base, pavement block, kerb stone, concrete block, bricks, aggregates of 5 mm, 10 mm, 20 mm and 40 mm. Under the cut-off criteria, processing till aggregates is being considered for the present LCA study. The process overview of the existing system in Ahmedabad is shown in the figure-3 below.

In the present case, 1 tonne of waste is considered as the functional unit for the analysis. This facility was found to be consuming about 288 KWH of electricity per day and 25000 L of water per day for processing of waste in the plant (considering gate-to-gate system boundary).

Table 20: Data used for Transportation of C&D waste from Dumping Sites to Recycling Plant

Variables	Input/ Output materials	Quantity per day	Units	Remarks
Fuel	Input	129	KG	1 liter of diesel = 0.86 kg
Truck type, capacity and distance travelled	Input	23,000	TKM	20 tonnes*1150 KM
Brick and masonry	Input	298	TPD	As per break up of composition shared 31%
sand, rock, gravel	Input	346	TPD	36% is sand, rock, and gravel but excluded soil
RCC - secondary materials	Input	276	TPD	Used as a concrete blocks Formula: To divide number of tonnes of RCC by 2.4 to get value in cub ic metres.

Calculation: To break up the data of bricks,mixed soil, sand, rock, and gravel consider 67% as 100% and the results are as given in the table below :

Table 21: Data used for Manufacturing of Recycled Aggregates

Variables	Input/ Output materials	Quantity per day	units	Remarks
Electricity	Input	288	KWH	Gujarat based hard coal electricity used (per hour=36 kw multiplied by 8 hours)
Fuel	Input	43	KG	Diesel (1 litre of diesel = 0.86 kg)
Water	Input	25000	m3	Unspecified natural origin of Gujarat state.
Chemicals	Input	10	KG	Used aluminum sulphate instead of ferric chloride
Recycled aggregates	Output	874	TPD	Added all
Silt	Output	101.14	micro gms	
Atmospheric pollutants- PM 2.5	Output	196.89	micro gms	
Atmospheric pollutants- PM 10	Output	102.72	micro gms	Converted PPB to microgram
Atmospheric pollutants- NO2	Output	34.57	micro gms	Converted PPB to microgram
Atmospheric pollutants- SO2	Output	126	tonne	Added sand, clay and residual.

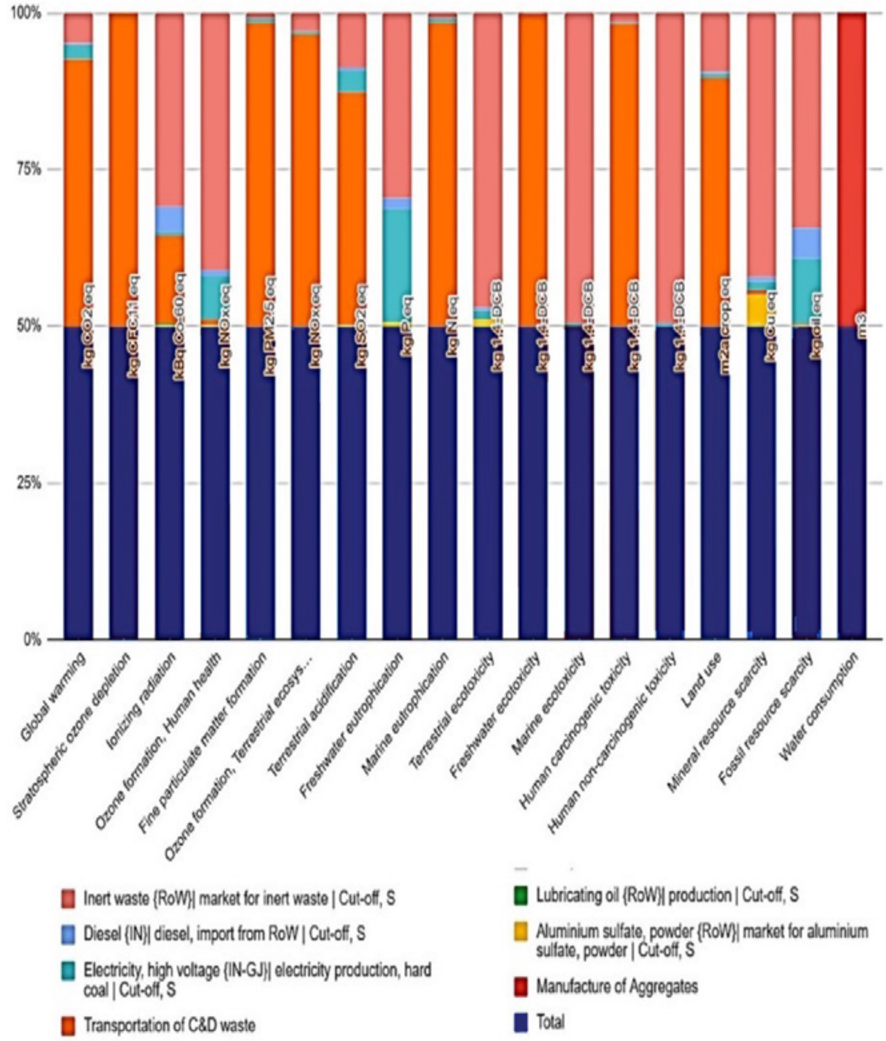
Method: ReCiPe 2016 Midpoint (H) V1.07 / World (2010) H
Indicator: Characterisation

Atmospheric pollutant data is an important requirement for LCA of C&D waste, which is not available inside the processing plant. Taking that into account, we have collected air pollutant data from the nearest Air Quality Monitoring station, which is located very close to the SGPPL. Data collected on a daily basis for a month period (25th February 2023 to 26th March, 2023) and then the monthly average is taken into account. Four indicators such as Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Particulate Matter size equal to or less than 10 micron (PM_{10}) and Particulate Matter having an aerodynamic diameter less than or equal to 2.5 micron ($PM_{2.5}$) have been collected for the present study.

3.2.2 Life Cycle Impact Assessment

Data were compared and analysed for LCA using midpoint categories for its impact assessment.For impact assessment in LCA, databases and factors are considered as important input and output variables in order to study its environmental impacts. In the present case 18 environmental impacts are studied under LCIA. The result shows that the transportation of C&D waste is considered as a major contributing factor for global warming followed by inert waste and high voltage electricity. Transportation of waste found to be responsible towards stratospheric ozone depletion, fine particulate matter formation, ozone formation, terrestrial ecosystem, marine eutrophication, freshwater ecotoxicity, human carcinogenic toxicity, land use, ionising radiation etc. Inert waste, that is, non-biodegradable material, which is majorly responsible towards ozone formation and human health, terrestrial ecotoxicity, marine ecotoxicity, human non-carcinogenic toxicity, mineral resource scarcity, fossil resource scarcity, freshwater eutrophication, ionising radiation etc. High voltage electricity is also responsible for freshwater eutrophication, fossil resource scarcity, ionising radiation etc. Diesel and aluminium sulfate powder are also responsible to some extent. Manufacturing of aggregates has an impact on water consumption. Transportation of waste is having the highest impact on the environment followed by inert waste and high voltage electricity.

Figure 12: LCA result of Ahmedabad C&D Waste Recycling Plant



3.2.3 Interpretation of the Findings in Ahmedabad

The interpretation phase of the present study in AEPPL evaluates the results of the life cycle inventory analysis and the impact assessment based on its pre-defined goals and scope to find various environmental parameters. In the present study primary data collected from the Ahmedabad processing plant (AEPPL) and secondary data collected from nearby Air Quality monitoring centre used for the analysis of the life cycle of C&D waste reveals that transportation of C&D waste is a major contributing factor towards the various indicators of environmental pollution followed by inert waste. High voltage electricity, Diesel and aluminium sulfate powder are responsible for less environmental impact on few indicators.

3.3 Noida: C&D Waste Recycling Plant

Noida, which is managed by the New Okhla Industrial Development Authority, came-up as a special economic zone (SEZ) in Uttar Pradesh under the UP Industrial Area Development Act of 1976. It is a part of the National Capital Region and covers an area of 203 km² and had a population 642,381 in 2011 (Census of India, 2011). Noida, and specifically its SEZ area, is a hub for software, education and mobile app development companies that have led to the city having the highest per capita income in the Uttar Pradesh. The city's district administrative headquarter is in Greater Noida (380 Sq.Km., Population 2011 - 107,676), which was created as an extension to Noida.

Noida is one of India's greenest city with nearly 50% green cover. In the 2022 Swachh Survekshan ranking for cities with a population of 100,000 to 1,000,000, Noida was the fifth cleanest city in the country and cleanest city in Uttar Pradesh.

Following the notification of the Solid Waste Management Rules, 2016, the Urban Development Department of Government of UP notified the Uttar Pradesh State Solid Waste Management Rules, 2016. According to the Rules, every waste generator is required to store C&D waste separately when generated in their own premises, while the ULB should dispose-off the separately stored C&D waste as per the C&D Waste Management Rules, 2016. The bulk generators are required to segregate the C&D waste at the project premises, into four separate streams, namely concrete; soil, wood and plastics, and bricks and mortar.

Prior to the commencement of construction or demolition activities, every bulk waste generator, service providers or their contractors are required to submit a plan indicating the provisions made for the collection and segregation of C&D waste of different streams, the C&D waste likely to be generated, and the period of project construction or demolition. The plan is to include the actions that the bulk waste generators/ service provider proposes to adopt on the completion of the project and final clean-up of the project premises

Waste Collection Mechanism

In 2017, the NOIDA authority conceived a project to deal with C&D waste and on 5 March 2019, entered into a PPP contract with Hyderabad-based ReSustainability and Recycling Private Limited (formerly known as Ramky Reclamation and Recycling Private Limited) for setting-up a C&D waste recycling plant at Noida. According to the contract, the firm set up a 800 TPD capacity plant (in two shifts) spread across five acres of land in Sector 80 with a capacity to process a minimum of 300 TPD. The INR 220 million plant envisages the collection, transportation, processing, and management of C&D waste. The initial concession agreement is of 15 years during which time ReSustainability would pay an annual rent of INR 20,000 (@INR1/ Sqm). The plant was commissioned on 15 October 2020.

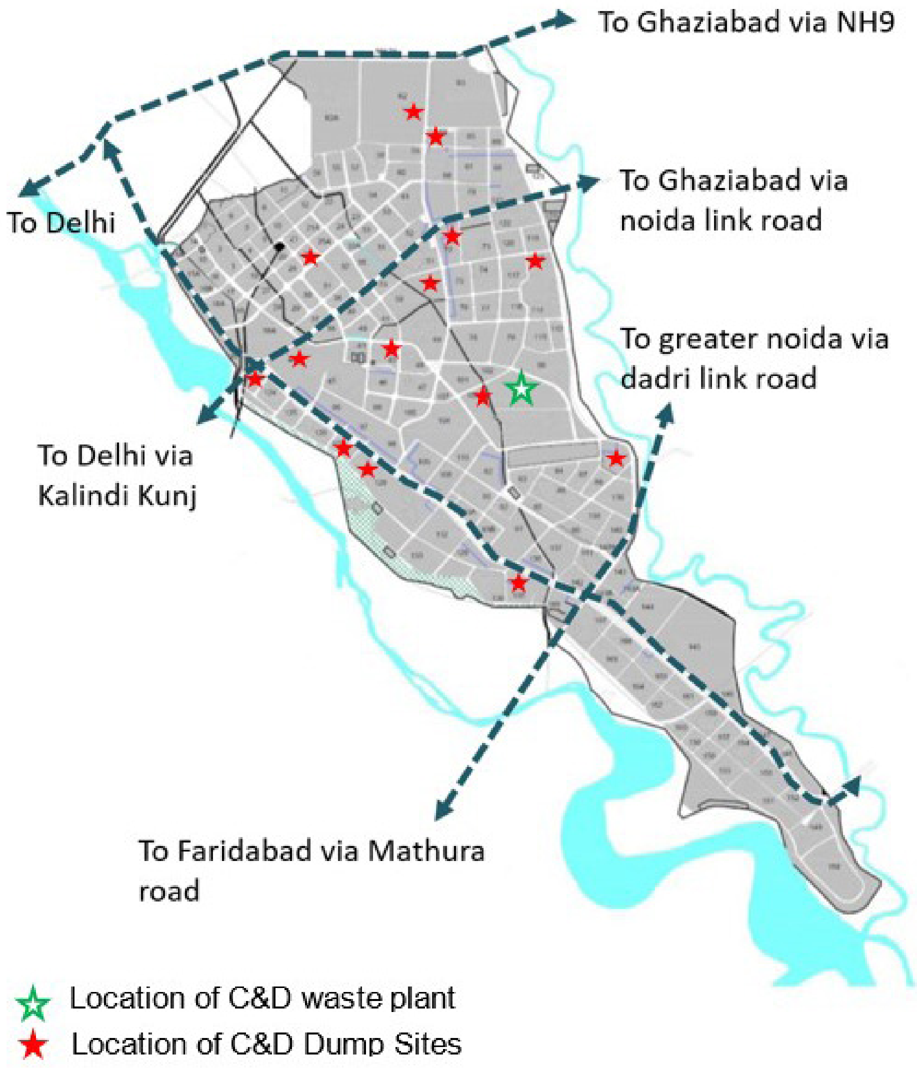
The recycling plant receives waste from 14 designated C&D waste dumping sites of approximately 400 to 500 Sqm. each. The collection centres are located within a 20kms of radius of the plant. The plant authority is responsible for transporting the C&D waste from the collection points to the processing facility, whereas the waste generators are supposed to dump the C&D waste at any of the designated dumping locations. The truck drivers, who ferry the waste from the collection sites, are trained to identify the waste composition while picking up the waste from the site, in order to ensure that the composition of the waste to be processed does not have a higher soil content. If the truck drivers are not able to share the composition details, the waste is denied receipt in order to ensure that the truck drivers carry out the necessary due diligence at the collection site.

Around 400-450 TPD of C&D waste is recycled daily at the plant during operational time of 6 hours per day except for Sundays when electricity supply is not available due to load shedding. The volume of C&D waste is highest during the festive season, that is, from September to October. The lowest volume of waste is received from November to January due to National Green Tribunal restrictions (?).

15 workers are engaged for working on the plant. Of these, 5 are engaged in sorting the waste brought in from the dumping sites and 10 are engaged in production of products. Contract labour is engaged in production of pavers. 2 workers and 1 labourer live on-site.

As per the concession agreement, NOIDA authority pays INR 495 per tonne for processing waste to ReSustainability. This includes INR 347 to be paid as transportation cost and INR 148.50 per tonne as processing fees to the agency. In the case of individuals, the cost will be borne by individual C&D waste generators. An individual, who is generating more than 20 tonnes of C&D waste everyday would be allowed to avail the facility on payment of processing fees. It said that individuals may drop the waste at processing sites for recycling on payment of INR 148.50 per metric tonne.

Figure 13: Locations of C&D Waste Dumping Sites



The plant received about 18 truckloads of waste every day. Each truck load weighs about 20 tonnes. The trucks entering the plant are weighed at the weighbridge. Post the weighbridge the drivers of the truck sprinkle the waste in the truck with water till the time water starts dripping from the truck. This is done to prevent dust pollution on site. Post this, the waste is segregated (refer the flow diagram). The plant uses wet waste processing technology for which the 75,000 litres of water used for the plant per day is taken from the nearest STP facility. The washing water is recirculated so only about 20-30% additional water is required for every reuse.

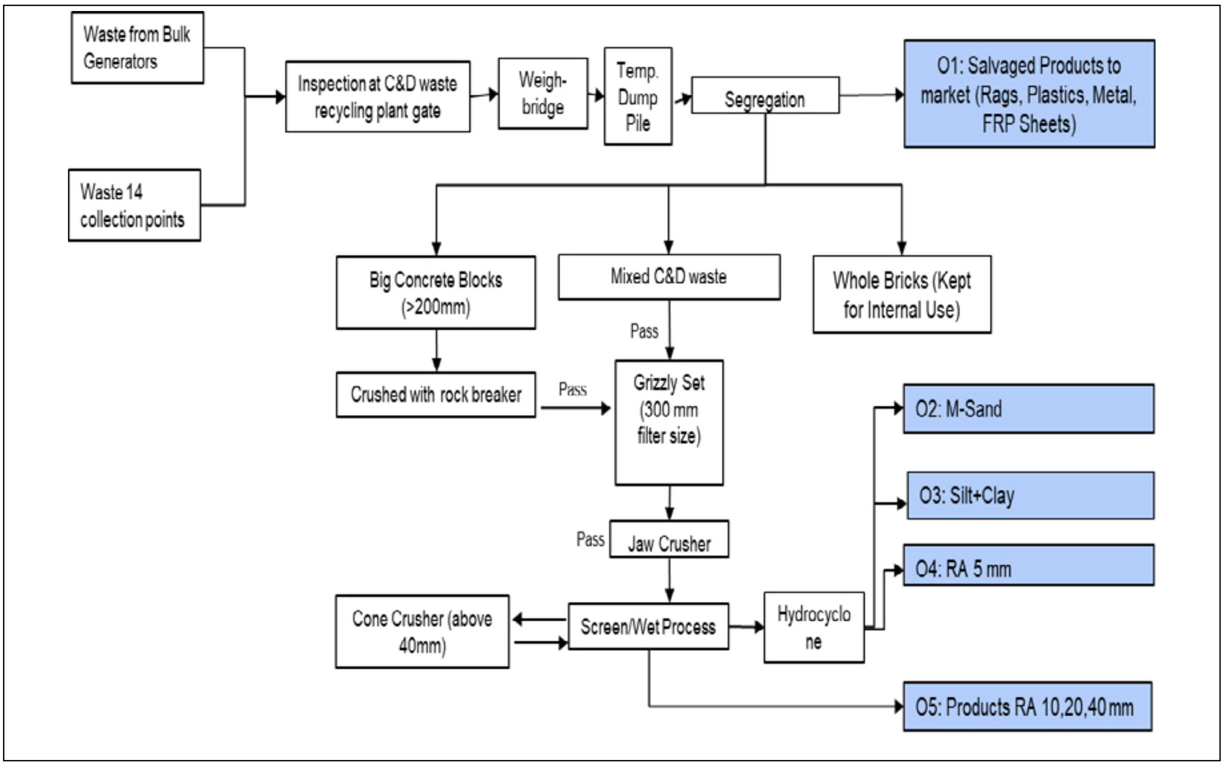
Waste Composition

Composition of waste (excluding twin towers): Up to 3% MSW mixed with C&D waste per day. Brick to concrete (stone) received in either 60:40 or 70:30 ratio.

The truck drivers, who ferry the waste from the collection sites, are trained to identify the waste composition while picking up the waste from the site. This is done to ensure that the composition of the waste to be processed does not have a higher soil content. Soil content clogs the grizzly filters and renders the line non- operational for at least 2-3 hours; time required for cleaning. If the truck drivers cannot share the composition details, the waste is denied receipt at the plant and the truck drivers are penalised for the same. This ensures that the truck drivers carry out the necessary due diligence at the collection site.

Figure 14-: Noida C&D Waste Recycling plant

Figure 15: Process flow of C&D Waste Recycling Plant, Noida



Provided by Re Sustainability

Waste received from Twin Tower demolition site (as on 3 November 2022)

Plant was set to receive 30,000 MT of demolition waste over a period of 3 months. By end of October 2022, 6000 MTs of demolition waste had been received and processed. The waste comprised recycled concrete aggregate (RCA) of very good quality that had the potential to be used in PCC (up to 25%), RCC (up to 20% only up to M25 grade) and in lean concrete (100%). The recycled products have been supplied to Jewar Airport for on-site utilisation. The plant was awaiting the go ahead from Noida authority to resume the waste processing from Twin Tower

Plant Maintenance

The plant is operational for 8-9 hours in a day. Out of this, 2-3 hours are devoted to greasing, cleaning and general plant maintenance. Every 3 months, the plant is shut down for 2-3 days for equipment maintenance.

Health and Safety of Plant Operators

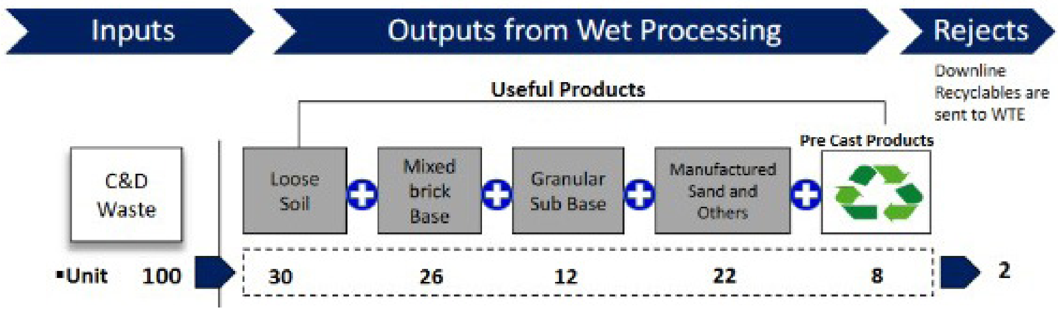
All plant operators wear a PPE while on the floor. Plant operators are trained to maintain sufficient distance while waste is being dumped into the plant. This is done to prevent dust inhalation. Also, the plant operators are given jaggery as a daily supplement to cleanse the air passage.

Use of Recycled Material

The recycled materials are sold for road construction, drain construction and other related works. At present the coarse aggregate is sold for INR 250/tonne and fine recycled aggregates are sold for INR 750/tonne. Ramky also supplies recycled aggregates to RMC, construction companies and other interested parties who wish to choose recycled products for civil and interior works. In addition to this, paver blocks of M25-M30 strength are manufactured on site and sold through Ramky's dedicated marketing channels. Recycled waste is also provided to local manufacturers to produce concrete blocks which may be used as substitutes to bricks (non-structural purposes). Recycled C&D waste products are transported up to a distance of 60-100 kms. (farthest point is Noida International Airport also known as Jewar Airport). M-sand, dust and granular sub-base are sold as construction material. Pavement Block, Kerb Stone, concrete block, bricks are sold in the open market.

According to ReSustainability, the processing of C&D waste can reduce waste to landfill by 98% as shown in the Figure below.

Figure 16: Value Addition after Processing C&D Waste: Noida



Provided by ReSustainability

Table 22 : NOIDA – Summary of C&D Waste Recycled (2018 to 2023)

Financial Year	Collection & Transportation	Processing & Disposal		Sale		
	in Tonnes	in Tonnes	% of collected waste	in Tonnes	% of processed waste	Sale of Tiles in Pieces
2018-2019	0	0	0	0	0	0
2019-2020	109,773	0	0	0	0	0
2020-2021	70,122	40,313	57.49	24,096	59.77	0
2021-2022	174,996	131,542	75.17	114,985	87.41	88,215
2022-2023	146,734	131,739	89.78	142,019	107.80	178,297
1 April 2023 to 30 June 2024	36,478	36,358	99.67	37,659	103.58	32,804
Total	**538,103**	**339,952**	**63.18**	**318,759**	**93.77**	**299,316**

Provided by ReSustainability

Table 23: NOIDA – Rates of Products made from C&D Waste

S.No.	Item Name	Thickness	Rates in INR + 18% GST		
			Grey	Red	Yellow
1	Zig Zag Tile	60 mm	11.00	12.00	12.00
2	Dumble Shape Tile	60 mm	11.50	12.50	12.50
3	Milano	60 mm	11.50	12.50	12.50
4	Zig Zag Tile	80 mm	12.50	13.50	13.50
5	Dumble Shape Tile	80 mm	12.50	13.50	13.50
6	Paver Block	80 mm	12.50	13.50	13.50
7	CC Block (400/ 200/ 100)	INR 32/ piece			

Table 24: NOIDA – Rates of Materials from Recycled C&D Waste

S.No.	Item	Rate in INR + 5% GST Extra
1.	Recycled Aggregate 10 mm	370
2.	Recycled Aggregate 20 mm	350
3.	Recycled Aggregate 40 mm	300
4.	Recycled Aggregate 5 mm	750
5.	M-sand	850

Transportation cost, loading and unloading charges are extra. No loading charges for aggregates and sand. Tiles and blocks are manufactured according to the orders received.

3.3.1 Life Cycle Inventory

Composition of waste consists of up to 3% of MSW mixed with C&D waste per day. Brick to Concrete (stone) received in either 60:40 or 70:30 ratio. Mixed C&D waste debris are sorted and then processed to obtain output as M-Sand, dust and granular sub-base, pavement block, kerb stone, concrete block, bricks, aggregates of 5,10,20 and 40 mm. Processing till aggregates is being considered for the present study.

In the present case, 1 tonne of waste is considered as the functional unit for the analysis. This facility was found to be consuming per day about 33 KWH of electricity sourced from Noida grid and 75,000 litres of recycled water from the STP being managed by the same organisation for processing of waste in the plant (considering gate-to-gate system boundary).

Atmospheric pollutant data is one of the important requirements for LCA of C&D waste, which is not available inside the Noida processing plant. Taking that into account, we have collected air pollutant data from the nearest Air Quality Monitoring station, which is located very close to the Noida processing plant. Data collected on a daily basis for a month period (27th January 2023 to 26th February, 2023) and then the monthly average is taken into account. Four indicators such as Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Particulate Matter size equal to or less than 10 micron (PM_{10}) and Particulate Matter having an aerodynamic diameter less than or equal to 2.5 micron ($PM_{2.5}$) have been collected and used for the present analysis.

Table 25: Data used for Transportation of C&D waste from Dumping site to Recycling Plant

Variables	Input/ Output materials	Quantity per day	Units	Remarks
Fuel	Input	86	KG	1 litre of diesel = 0.86 kg
Truck type, capacity and distance travelled	Input	81000	TKM	22 tonne*270KM
Brick and masonry	Input	97.164179	TPD	As per break up of composition shared 31%
sand, rock, gravel	Input	112.835820	TPD	36% is sand, rock, and Gravel but Excluded Soil
Concrete blocks	Input	90	TPD	

Table 26: Data used for Manufacturing of Recycled Aggregates

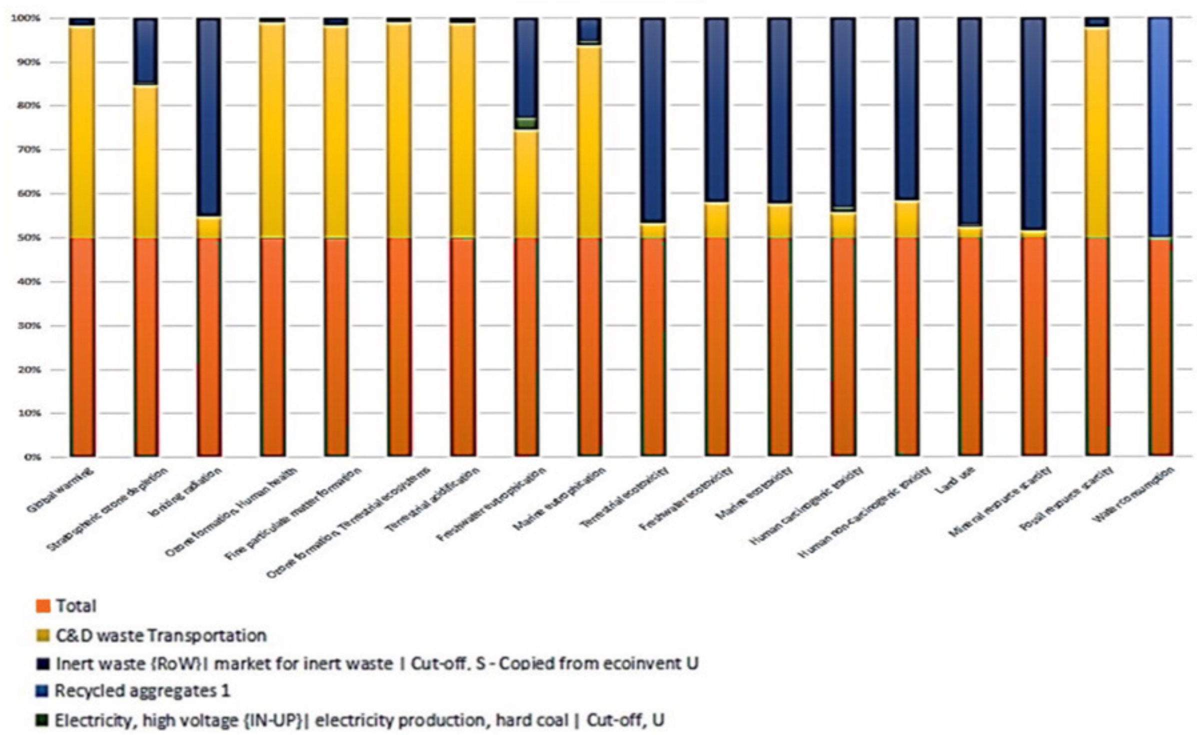
Variables	Input/ Output materials	Quantity per day	units	Remarks
Electricity	Input	33	KWH	NOIDA grid (coal based)
Water	Input	75000	KG	Recycled water from STP
Recycled aggregates	Output	205.8	TPD	
Soil	Output	94.2	TPD	Considered as inert also added residual to it
Atmospheric pollutants- PM 2.5	Output	87.18	micro gms	
Atmospheric pollutants- PM 10	Output	199.76	micro gms	
Atmospheric pollutants- NO2	Output	40	micro gms	Converted PPB to microgram
Atmospheric pollutants- SO2	Output	14	micro gms	Converted PPB to microgram

Method: ReCiPe 2016 Midpoint (H) V1.07 / World (2010)
**Indicator: Characterisation*

3.3.2 Life Cycle Impact Assessment

Due to the lack of C&D waste data for LCIA in Noida city, they were compared and analysed in LCA using midpoint categories. For impact assessment in LCA, databases and factors are considered as important input and output variables in order to study its environmental impacts. In the present case 18 environmental impacts are studied under LCIA. The result shows that the Transportation of C&D waste is considered as a major contributing factor having an impact on air pollution, water pollution and human health. It is responsible for an increase in global warming, stratospheric ozone depletion, ozone formation, human health, fine particulate matter formation, ozone formation, terrestrial ecosystem, terrestrial acidification, fossil resource scarcity and marine eutrophication. Followed by Inert waste, that is, non-biodegradable material, which has a major impact on human health. It is responsible for an increase in various kinds of toxicity like Ionising radiation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human carcinogenic toxicity, human non-carcinogenic toxicity, land use and mineral resource scarcity etc. High voltage electricity is responsible for having a small impact on freshwater eutrophication and recycled aggregate having an impact on water consumption. Transportation of waste is having the highest impact on environment pollution followed by inert waste.

Figure 17: LCA Result of Noida C&D Waste Recycling Plant



3.3.3 Interpretation of the Findings in NOIDA

The interpretation phase of the present study evaluates the results of the life cycle inventory analysis and the impact assessment based on its pre-defined goal and scope to find various environmental parameters. In the present study primary data collected from the Noida processing plant used for the analysis of the life cycle of C&D waste reveals that, for all impact categories, transport, sorting and landfilling make a net contribution to the environmental pollution. C&D waste is potentially risky for environment pollution as air pollution, water pollution as well as to human health. Transportation distance of C&D waste and its inert substances, that is, non-biodegradable are majorly responsible for environmental pollution. Therefore transportation distance of C&D waste needs to be addressed by the concerned local bodies in order to reduce its environmental impacts.

Comparing the Case-Studies

4

The results from the LCA of the C&D waste management initiatives in the three cities show that the environmental impacts of the recycling initiative, primarily (because of the transportation of the C&D waste) are higher than the benefits arising from recycling of the debris.

1. Each of the recycling plant has the capacity to recycle very small proportion of the C&D waste generated in the respective cities. This is also reflected in the literature.
2. The plants are not running at full capacity so the quantity of C&D waste that can be recycled is higher than the difference between the quantity of C&D waste generated and the capacity of the C&D plants.
3. Despite the limited recycling of C&D waste, the uptake of recycled material is very low.
4. Transportation of the C&D waste from place of origin to the dumping sites (not accounted for in the LCA), from the dumping sites to the recycling plant is the most energy consuming and environmentally polluting activity. This finding is in line with other studies, especially Borghi et.al.'s (2018) sensitivity analysis that verified that transportation of C&D waste causes the highest environmental impacts. As per this study in the Lombardi region of Italy, recycling is preferable to landfilling when the transportation distance from generators of C&D waste and recycling facility is within 30 km (Penteado and Rosado 2016), and if uncertainties in data are considered, the transportation distance reduces to only 6.5 km in order for off-site recycling to have benefits over landfilling (Vossberg et al. 2014). Thus, recycled aggregates cause lower impacts than natural aggregates (except non-carcinogens) only if recycled aggregate transportation distance is 20 km more than of natural aggregate (Rosado et al. 2017).

Overall, in the case-study cities, the distance to which the C&D waste is transported during different stages is high and therefore landfill maybe a better solution environmentally.

Table 27: Comparing Surat, NOIDA and Ahmedabad Plants

Recycling plant			Surat			NOIDA			Ahmedabad		
C&D Waste Generated			2100 MT/ Day solid waste which includes 280 MT/ Day of C&D Waste			MT/ Day solid waste which includes MT/ Day of C&D Waste			4000 MT/ Day solid waste which includes 1000 MT/ Day of C&D Waste @ 25%		
	Variables	**Input/ Output materials**	**Quantity per day (300 TPD)**	**Units**	**Source**	**Quantity per day (300 TPD)**	**Units**	**Source**	**Quantity per day (1000 TPD)**	**Units**	**Source**
Input	Fuel (Tractor, Truck)	Input	75	Litres of diesel	0	100	Litres (diesel truck of 22 Tonne capacity)	0	150	Litres of diesel	0
	Fuel used in JCB	Input	50	Litres of diesel	0	0	No additional fuel used in the plant	0	50	Litres of diesel	0
	Electricity	Input	100	KW	SMC	33	KW	NOIDA grid (coal based)	360	KW	AMC
	Water	Input	50000	litres	SMC	75000	Litre	recycled water from STP	25000	Litre	AMC
	Lubricant oil used	Input	0	0	0	0	0	0	0.67	Litre	0
	Chemicals	Input	0.25	kg/day (floc used to settle the sludge)	0	0	No additional chemicals added during processing	0	10	kg/day (floc used to settle the sludge)	0
	Bricks, Mixed soil, s and, rock, gravel	Input	149.25	TPD	0	210	TPD	0	644	TPD	0
	Concrete blocks	Input	0	0	0	90	TPD	0	276	TPD	0
	RCC - secondary materials	Input	149.25	TPD	0	0	0	0	0	0	0
Out put	Recycled aggregates-1 (40mm)	Output	0	0	0	102.9	TPD	0	506	TPD	0
	Recycled aggregat e-2 (20 mm)	Output	238.8	TPD	0	102.9	TPD	0	230	TPD	0
	Recycled aggregate -3 (10 mm)	Output	0	0	0	0	0	0	138	TPD	0
	Sand	Output	0	0	0	0	0	0	41.4	TPD	0
	Clay	Output	0	0	0	0	0	0	4.6	TPD	0
	Soil	Output	0	TPD	0	88.2	TPD	0	0	0	0
	Silt	Output	59.7	TPD	0	0	0	0	0	0	0
	Residual	Output	1.5	TPD	0	6	TPD	0	80	TPD	0

Recycling plant			Surat			NOIDA			Ahmedabad		
C&D Waste Generated			2100 MT/ Day solid waste which includes 280 MT/ Day of C&D Waste			MT/ Day solid waste which includes MT/ Day of C&D Waste			4000 MT/ Day solid waste which includes 1000 MT/ Day of C&D Waste @ 25%		
	Variables	**Input/ Output materials**	**Quantity per day (300 TPD)**	**Units**	**Source**	**Quantity per day (300 TPD)**	**Units**	**Source**	**Quantity per day (1000 TPD)**	**Units**	**Source**
	Atmospheric pollutants- PM 2.5	Output	70.68	micro gms/ m3		87.18	micro gms/ m3		101.14	micro gms/ m3	
	Atmospheric p ollutants- PM 10	Output	107.37	micro gms/ m3		199.76	micro gms/ m3	Readings taken from AQI monit oring station situated in Sector 116	196.89	micro gms/ m3	Readings taken from AQI mon toring station situa ted in Pirana
	Atmospheric pollutants- NO2	Output	9.11	parts per billion (PPB)	Readings taken from AQI mon toring station situated in Dabhol	21.26	parts per billion (PPB)		54.64	parts per billion (PPB)	
	Atmospheric pollutants- SO2	Output	7.26	parts per billion (PPB)		5.29	parts per billion (PPB)		0	parts per billion (PPB)	
	Atmospheric pollutants- O3	Output	0	micro gms/ m3		0	micro gms/ m3		34.57	micro gms/ m3	

4.1 Financial Viability

The Table below is being redone – see part Table given under 6.3 for highlighting raw material replaced

Table 28: Daily Outputs from C&D Waste Recycling Plants at Surat, NOIDA and Ahmedabad

Recycling plant	Surat	NOIDA	Ahmedabad	Total in Tonnes per Day
Variables	**Quantity per day (300 TPD)**	**Quantity per day (300 TPD)**	**Quantity per day (1000 TPD)**	
Recycled aggregates-1 (40mm)	0	102.9	506	608.9
Recycled aggregate-2 (20 mm)	238.8	102.9	230	571.7
Recycled aggregate-3 (10 mm)	0	0	138	138
M-Sand	0	0	41.4	41.4
Clay	0	0	4.6	4.6
Soil	0	88.2	0	88.2
Silt	59.7	0	0	59.7
Residual	1.5	6	80	87.5

Survey Data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Research Findings

5

India's C&D waste composition is different from that of Europe and the US because most of the recyclable wastes (various types of plastics, paper, newspaper, cardboard, glass, heavy and light metal products, wood, brick-bats, etc.), including from demolition-sites, are purchased directly by informal and formal recyclers from the waste generators. Thus, the Municipal Solid Waste (MSW) has a higher proportion of wet-waste and the C&D waste is of low-quality.

Currently, local Governments are providing land of 3 to 5 acres to private entities to run the C&D waste recycling plants. In some instances, the land is provided adjacent to the STP (sewage treatment plant) of the city, which the same private sector entity is managing. The benefit is that the waste treatment facilities are in close proximity and the recycled water from the STP can be used for the recycling and processing of the C&D waste. In addition, dumping sites for the C&D waste are identified on ULB owned plots in different parts of the city. The plant operator is required to collect the C&D waste only from the designated sites.

However, because of the distance of the designated sites from areas where substantial C&D work is ongoing, the C&D waste continues to be dumped illegally at other locations while the designated plots are under-utilised. The study indicates that the highest contribution of GHG for the recycling of C&D waste comes from transportation of the waste from the dumping sites to the plant and internal transportation. It is essential to have easy to access dumping sites for C&D waste close to the areas where a lot of building, construction or demolition activities are ongoing. The dumping sites cannot be 'permanent' sites within well-developed urban areas because that would entail longer distances for dumping of waste as well as collection of C&D waste for recycling.

5.1 Local Government Response to C&D Waste Rules

Monitoring of city-level MSW has improved under the Swachh Bharat Mission 2.0 (vision is to make all cities 'Garbage Free' and ensure grey and black water management). Cities are now monitored for progress on MSW collected and processed. The indicators monitored include:

i. Any mechanism in place to collect and process/re-use C&D waste as per C&D Waste Management Rule, 2016
ii. Provisions made for use of raw C&D waste in municipal/ government/ municipality approved construction activities in non-structural applications or used by private agencies for lower layers of road pavements, inner colony roads, filling of plinth and basement etc. OR
iii. Provisions made for use of material made out of C&D Waste in municipal and/or government construction activity (if available) or used by private agencies in kerb stones, structural concrete as manufactured aggregate, paving blocks, bricks etc. Processing also covers C&D waste re-used for non-constructional applications – filling of plinth & basement etc.
iv. From 2019 onwards, Weekly Processing Log Book, Sale Register & Vendor details (if outsourced) digitally maintained (e.g. excel le) by ULB are linked with SBM portal (SBM-U Toolkit 2019).

5.2 Life Cycle Assessment

C&D activities pose a significant threat to the environment and their adverse impacts include increased pollution, global warming, land deterioration and resource scarcity etc. Therefore, recycling of C&D waste has been a better alternative. Moreover, an increase in the percentage of recycling will reduce the pressure on the use of virgin materials as well as reduce environmental impacts. The present research used the LCA method to study its environmental impacts. Due to unavailability of proper landfill data, the study used only primary data collected from 3 different recycling plants

The recycling capacity of the Noida plant and Surat plant are 300 TPD whereas the Ahmedabad plant is 1000 TPD. All three plants do not have their air pollution monitoring units inside their plant premises. Therefore for LCA, Air Quality data from nearby AQI stations of each location has been used for the analysis. The composition of C&D waste is more or less similar in 3 plants, as it is construction debris mixed with some materials like plastic, soil etc. Under the cut-off criteria, processing till aggregates is being considered for the present LCA study.

For impact assessment in LCA, databases and factors are considered as important input and output variables in order to study its environmental impacts. The limitation of the present LCA analysis is inaccuracy of data as C&D waste data is very complex and heterogeneous by nature. In the present analysis, 18 environmental impacts are studied under LCIA. The LCA result of the Noida and Ahmedabad plant shows that the Transportation of C&D waste is considered as a major factor having impacts on air pollution, water pollution and human health etc. It is responsible for an increase in global warming, stratospheric ozone depletion, ozone formation, human health, fine particulate matter formation, ozone formation, terrestrial ecosystem, terrestrial acidification, fossil resource scarcity and marine eutrophication. The second major factor is inert waste, that is, non-biodegradable material, which has a major impact on human health. It is responsible for an increase in various kinds of toxicity like Ionising radiation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human carcinogenic toxicity, human non-carcinogenic toxicity, land use and mineral resource scarcity etc. High voltage electricity, manufacturing of aggregates, and diesel are responsible for having a small impact on a few indicators. Transportation of waste is having the highest impact on environment pollution followed by inert waste. High voltage electricity, Diesel and aluminium sulfate powder are responsible for less environmental impact on few indicators of global warming. Whereas the LCA result of Surat shows that the Inert waste as the major contributing factor responsible for global warming and having impacts on other 16 environmental parameters more or less.

It is majorly responsible for various kinds of toxicity like Ionising radiation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human carcinogenic toxicity, human non-carcinogenic toxicity, land use, mineral resource scarcity, stratospheric ozone depletion, freshwater eutrophication, terrestrial acidification etc. The second major contributing factor found as transportation of C&D waste which is also having impacts on global warming, stratospheric ozone depletion, ozone formation, human health, fine particulate matter formation, terrestrial ecosystems, fossil resource scarcity, fine particulate matter formation, terrestrial ecosystem, terrestrial acidification, marine eutrophication etc. High voltage electricity, manufacturing of aggregates and diesel are also having very minimum impacts on a few parameters. In this LCA, Inert waste is having the highest impact on the environment followed by transportation of C&D waste, high voltage electricity and diesel.

It is found from the LCA result that C&D waste has harmful effects on the environment, ecological resources as well as on human health. Transportation of C&D waste and its inert nature are potentially risky for the environment as it is responsible towards air pollution, water pollution as well as to human health, increasing various kinds of toxicity, land use and resource scarcity. Therefore transportation of C&D waste needs to be addressed by the concerned local bodies in order to reduce its environmental impact. Similarly, its inert waste is also another major responsible factor having major impacts on our environment which needs to be sorted probably by on site segregation.

5.3 Environmental Impact of C&D Waste Recycled

The impact that can be confidently stated is the amount of C&D waste recycled and the volume of materials and products from the plant that actually replace the use of raw materials. While the precise volumes/ quantities are not known, the total materials replaced are as follows:

Table 29: Quantities of Recycled Materials per day

Recycling plant	Surat	NOIDA	Ahmedabad	Total
Variables	Quantity per day (300 TPD)	Quantity per day (300 TPD)	Quantity per day (1000 TPD)	
Recycled aggregates-1 (40mm)	0	102.9	506	608.9
Recycled aggregate-2 (20 mm)	238.8	102.9	230	571.7
Recycled aggregate-3 (10 mm)	0	0	138	138
Sand	0	0	41.4	41.4
Clay	0	0	4.6	4.6
Soil	0	88.2	0	88.2
Silt	59.7	0	0	59.7
Residual	1.5	6	80	87.5

Survey Data

5.4 Local Initiatives for Reuse of C&D waste

The Kesarjan Building Centre, located near Ahmedabad on Rajkot highway, started with fly-ash products, using fly-ash, sand and cement and lime. However, since the Centre wanted to replace use of sand with debris, the Centre started purchasing typical construction waste with varied types of aggregate from the contractors transporting such waste. The waste is manually segregated, debris are crushed and sieved but not washed. The recycled aggregate, including the cost of transportation and crushing, is costlier than the natural aggregates. They also get brick bats from brick kilns, industrial waste, fly ash and ceramic tile waste. The products made include bricks for exposed load-bearing brick walls. These different sized bricks from the normal bricks are also of higher quality. The Centre also produces different coloured bricks. In terms of the process, the plant gets mixed debris, including industrial waste and segregated waste. The bricks, which are used in regular construction, comprise 95% recycled material and 5% cement. The Centre does not formally market its high-end products, which are in demand amongst architects. The Centre is developing lime mortar using lime water.

The capacity of the Centre can be scaled-up to 300 tonnes or for producing around 100,000 bricks per day. For this support in terms of C&D waste material being sent by the generators to the Centre and pay the transport cost that is currently an expenditure incurred by the Centre

5.5 Observation and Recommendation

From the above LCA of C&D waste, we found that Transportation of waste is a major contributing factor towards global warming. As our cities have a limited number of processing plants, which lead to more disposal activity and increasing the volume of inert waste and ultimately responsible for negative impact on our environment. Transportation of waste from source site to the processing plant on an average covers 20-30 kms of distance per trip, which is quite high and requires more fuel and energy. Inert waste is another major factor responsible for environmental impacts. Inert waste, that is, non-biodegradable material such as concrete, plaster, metal etc. are also responsible for rise in environmental pollution, toxicity etc. In order to reduce environmental impacts the following steps are recommended:

1. C&D waste generated on large scale projects should be processed and recycled on site (as per the regulations) and the products and materials used on-site to the extent possible to minimise requirements for dumping sites to reduce transportation cost as well as requirements for landfill.
2. Close scrutiny and monitoring of C&D Waste Management Plans of projects, including actions taken for minimising quantity of materials used and waste generated (design and technology).
3. To find superior technological solutions for decentralised recycling of C&D waste that addresses concerns about air and noise pollution. A number of builders working in close proximity too could set-up small recycling plants. For example, CREDAI, which got a few builders to come together to set-up a batching plant, can facilitate mobile or semi-mobile C&D waste recycling facilities near the batching facility.

4. Provide incentives to private C&D waste recyclers such as Kesarjan and other Building Centres to promote C&D waste recycling and innovations for enhancing quality of final products.
5. Close monitoring of all Government organisations and their tendered projects (as available for Delhi) to ensure that contractors not only transfer the C&D waste generated to the closest recycling facility but also use the mandated percentage of recycled materials on projects.
6. Data uploaded on SBM-Urban platform for MSW and C&D waste (as required under Swachh Survekshan) should be available publicly for further transparent monitoring and research.

Newspaper reports for Ahmedabad highlighting the challenges for C&D waste recycling plants.

AMC allots 15 more plots for debris disposal

TIMES NEWS NETWORK

Ahmedabad: The city civic body on Thursday allotted 15 more plots in various parts of the city for disposal of construction debris. The Ahmedabad Municipal Corporation (AMC) already had 10 such plots, thus the total number is now 25.

The AMC has also resolved that if a citizen or construction company wants the civic body to remove debris from their site, the service will be provided at a cost of Rs 200 per haul.

The standing committee of AMC on Thursday also decided to charge a deposit per shift apart from the rental for the hire of party plots or community halls. Earlier, the civic body charged a deposit for the entire day even if the facility was rented only for one shift.

The AMC rents these facilities in three shifts. Now, people will have to pay Rs 25,000 as deposit per shift apart from the rent.

The standing committee also approved a project to collect flower waste from various places in the city and give it to a startup to make incense from it. The committee also approved the closure of the Amraiwadi public library and its conversion to an anganwadi.

Times of India,
Ahmedabad Edition
22 September 2023

Political pressure? Plant to process C&D waste will come up in Gyaspur, not Gota

TIMES NEWS NETWORK

Ahmedabad: In a volte-face, the Ahmedabad Municipal Corporation (AMC) has scrapped its plan to build a construction and demolition (C&D) waste processing plant in Gota, following mounting political pressures and concerns regarding dust pollution raised by upcoming residential societies.

Just four months after allotting 23,000 sq m of land in Gota's TP Scheme 56 for the plant, the standing committee has laid a resolution in its January 4 agenda to relocate the plant.

The new proposed site, Gyaspur, is already home to one such facility. While the official reason cited by the AMC is "residential areas around the plot," whispers of political pressure are also doing the rounds. To be set up on 5 acres of land in Gyaspur, the plant was designed to process 300 to 500 metric tonnes of C&D waste every day, from which items, including paver blocks, were to be manufactured and used.

The existing Gyaspur C&D plant, situated in the eastern part of the city, struggles to handle the ever-increasing construction and demolition debris generated by construction projects.

The Gota plant was proposed to ease this burden, especially of the western areas that generate considerable amount of waste.

Experts warn that transporting construction and demolition (C&D) waste across the city to Gyaspur plant will only exacerbate air pollution along the route

Experts warn that transporting C&D waste across the city to Gyaspur plant will only exacerbate air pollution all along the transportation route, negating the benefits of waste processing. "The AMC had strategically decided to install a processing plant in Gota for the western areas," said a senior AMC official.

Times of India,
Ahmedabad Edition
3rd January 2024

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LCA Results of Cases-Studies

LCA results of SGPPL

Impact category	Unit	Total	Recycled Aggregate	C&D Waste transportation	Diesel {IN}| diesel, import from RoW | Cut-off, S	Aluminium sulphate, powder {RoW}| market for aluminium sulphate, powder | Cut-off, S	Electricity, high voltage {IN-GJ}| electricity production, hard coal | Cut-off, S	Inert waste {RoW}| market for inert waste | Cut-off, S
Global warming	kg CO2 eq	6.409715689	0	4.066643462	0.09368773883	0.0008689256955	0.5853427468	1.663172816
Stratospheric ozone depletion	kg CFC11 eq	0.0000015636 27197	0	0.000000358934 2463	0.0000001715575 706	0.000000000328131 0972	0.000000110866483	0.000000921940 766
Ionising radiation	kBq Co-60 eq	0.0586373 6466	0	0.006721689133	0.005553919034	0.00004892722319	0.0009192401655	0.04539358911
Ozone formation, Human health	kg NOx eq	0.0625730 6737	0.00000000029 47588568	0.04942556684	0.0005491751808	0.000002967991868	0.001346825608	0.01124853145
Fine particulate matter formation	kg PM2.5 eq	0.0137038 8357	0.00000000043 20550852	0.008564870208	0.000312402797	0.000003041941825	0.001530875277	0.00329269291
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.0631437 6606	0	0.0497359724	0.000572935222	0.000003002703763	0.00135788704	0.01147396866
Terrestrial acidification	kg SO2 eq	0.0351556 6319	0	0.02514145809	0.0009391182734	0.000007637219841	0.001956064854	0.007111384677
Freshwater eutrophi cation	kg P eq	0.001198 5367	0	0.0001547508158	0.00008553873419	0.00000066211 94604	0.0002901399681	0.000667445062

Impact category	Unit	Total	Recycled Aggregate	C&D Waste transportation	Diesel {IN}| diesel, import from RoW | Cut-off, S	Aluminium sulphate, powder {RoW}| market for aluminium sulphate, powder | Cut-off, S	Electricity, high voltage {IN-GJ}| electricity production, hard coal | Cut-off, S	Inert waste {RoW}| market for inert waste | Cut-off, S
Marine eutrophication	kg N eq	0.000070461 21721	0	0.00002118395706	0.000000586152066	0.0000000240404188	0.00001753775301	0.00003112931465
Terrestrial ecotoxicity	kg 1,4-DCB	17.06404253	0	0.3694551928	0.3016217746	0.01769977387	0.3716880638	16.00357773
Freshwater ecotoxicity	kg 1,4-DCB	1.43192747	0	0.02269128128	0.0009125855619	0.0001853078947	0.009387239877	1.398751055
Marine ecotoxicity	kg 1,4-DCB	2.010168659	0	0.03101009036	0.001631961817	0.0002447472747	0.0131184037	1.964163456
Human carcinogenic toxicity	kg 1,4-DCB	0.3327761652	0	0.006859386027	0.003187848806	0.0003679652745	0.02535171281	0.2970092523
Human non-carcinogenic toxicity	kg 1,4-DCB	72.77071765	0	1.195608536	0.0289160258	0.003850543327	0.5179686656	71.02437388
Land use	m2a crop eq	0.1825124445	0	0.01072769786	0.008746667463	0.00002831343597	0.006254437694	0.1567553281
Mineral resource scarcity	kg Cu eq	0.005585437298	0	0.0002087529771	0.0001781138539	0.00003107613716	0.0001140899475	0.005053404382
Fossil resource scarcity	kg oil eq	2.637211802	0	1.543458977	0.2113121543	0.0002210153731	0.1578462023	0.724373453
Water consumption	m3	209.405884	209.3802345	0.001464079816	0.0000800777347	0.00001149214579	0.001019391769	0.02307442461

LCA results of AEPPL

Impact category	Unit	Total	Manufacture of Aggregates	Aluminium sulphate, powder {RoW}| market for aluminium sulphate, powder | Cut-off, S	Lubricating oil {RoW}| production | Cut-off, S	Transportation of C&D waste	Electricity, high voltage {IN-GJ}| electricity production, hard coal | Cut-off, S	Diesel {IN}| diesel, import from RoW | Cut-off, S
Global warming	kg CO2 eq	9.128719012	0	0.008663836	0.000831286	7.759241344	0.447252109	0.023283379
Stratospheric ozone depletion	kg CFC11 eq	2.797121087	0	0.00000000522848	0.000000000899424	2.797120182	0.000000133564	0.0000000563142
Ionising radiation	kBq Co-60 eq	0.176307526	0	0.000940177	0.000224455	0.050010945	0.001871828	0.014184558
Ozone formation, Human health	kg NOx eq	0.007713511	0.000000000 47483	0.0000324374	0.00000522159	0.000138412	0.001059807	0.000150049
Fine particulate matter formation	kg PM2.5 eq	0.103663197	0.000000000 170726	0.0000332456	0.00000191592	0.100485822	0.001204634	0.0000853567
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.107610684	0	0.0000328167	0.00000691484	0.099891503	0.001068511	0.000156541
Terrestrial acidification	kg SO2 eq	0.02291713	0	0.0000834676	0.00000458663	0.017032938	0.001539213	0.000256592
Freshwater eutroph ication	kg P eq	0.000635562	0	0.00000723634	0.000000521941	0.000000668826	0.000228309	0.0000233715
Marine eutrophica tion	kg N eq	0.001002499	0	0.00000026274	0.0000000165083	0.000970749	0.0000138003	0.000000160153

Impact category	Unit	Total	Manufacture of Aggregates	Aluminium sulphate, powder {RoW}| market for aluminium sulphate, powder | Cut-off, S	Lubricating oil {RoW}| production | Cut-off, S	Transportation of C&D waste	Electricity, high voltage {IN-GJ}| electricity production, hard coal | Cut-off, S	Diesel {IN}| diesel, import from RoW | Cut-off, S
Terrestrial ecotoxicity	kg 1,4-DCB	10.29999514	0	0.207920087	0.004482158	0.00711293	0.314687617	0.08888657
Freshwater ecotoxicity	kg 1,4-DCB	314.128062	0	0.002034657	0.0000426358	313.3298409	0.00740485	0.000266693
Marine ecotoxicity	kg 1,4-DCB	9985.978741	0	9.253303477	0.228212202	0.281574385	73.89933064	2.627140739
Human carcinogenic toxicity	kg 1,4-DCB	301.1822476	0	0.290641214	0.003556621	289.5400022	1.410938427	0.059760172
Human non-carcinogenic toxicity	kg 1,4-DCB	8945.514429	0	7.423877889	0.190992694	0.044524606	68.65962451	2.071581118
Land use	m2a crop eq	0.464508856	0	0.000309439	0.0000440313	0.368665165	0.00492157	0.002389822
Mineral resource scarcity	kg Cu eq	0.003366437	0	0.000339633	0.00000379479	0.0000418993	0.0000897765	0.0000486654
Fossil resource scarcity	kg oil eq	0.592956346	0	0.002415491	0.000944821	0.000173611	0.124207985	0.05773609
Water consumption	m3	28.65864799	28.60411899	0.000125598	0.00000759892	0.040591825	0.000802152	0.0000218794

LCA results of NOIDA

Impact category	Unit	Total	Recycled aggregates	C&D waste Transportation	Electricity, high voltage {IN-UP}| electricity production, hard coal | Cut-off, U	Inert waste {RoW}| market for inert waste | Cut-off, S - Copied from eco-invent U
Global warming	kg CO2 eq	90.17020807	0	86.92393033	0.2758033646	2.970474377
Stratospheric ozone depletion	kg CFC11 eq	0.000005570722324	0	0.000003871876092	0.0000000522336018	0.00000164661263
Ionising radiation	kBq Co-60 eq	0.09037018142	0	0.008864410337	0.0004315178166	0.08107425327
Ozone formation, Human health	kg NOx eq	1.097252455	0.0000000007852283771	1.076527714	0.0006345405812	0.02009019993
Fine particulate matter formation	kg PM2.5 eq	0.1890566342	0.0000000006002915452	0.1824544531	0.0007213364521	0.005880844004
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.10392401	0	1.082791428	0.0006397446056	0.02049283726
Terrestrial acidification	kg SO2 eq	0.5494337641	0.0000000001129251701	0.5358110494	0.0009215774578	0.01270113714
Freshwater eutrophication	kg P eq	0.002602791548	0	0.00127401792	0.0001366975931	0.001192076035
Marine eutrophication	kg N eq	0.0005111774192	0	0.0004473164019	0.000008263167974	0.0000555978493
Terrestrial ecotoxicity	kg 1,4-DCB	30.78891375	0	2.031942107	0.1741226268	28.58284902
Freshwater ecotoxicity	kg 1,4-DCB	2.975614113	0	0.4729929929	0.004411580444	2.498209539

Impact category	Unit	Total	Recycled aggregates	C&D waste Transportation	Electricity, high voltage {IN-UP}| electricity production, hard coal | Cut-off, U	Inert waste {RoW}| market for inert waste | Cut-off, S - Copied from eco-invent U
Marine ecotoxicity	kg 1,4-DCB	4.152239508	0	0.6380210422	0.00616614795	3.508052318
Human carcinogenic toxicity	kg 1,4-DCB	0.6130023693	0	0.07062435024	0.01191097648	0.5304670426
Human non-carcinogenic toxicity	kg 1,4-DCB	152.551719	0	25.45622273	0.243926153	126.8515701
Land use	m2a crop eq	0.2967421777	0	0.01382775398	0.002944912624	0.2799695111
Mineral resource scarcity	kg Cu eq	0.0093535539	0	0.0002763156941	0.00005171291273	0.009025525293
Fossil resource scarcity	kg oil eq	30.12992015	0	28.76179194	0.07437644424	1.293751762
Water consumption	m3	364.4733111	364.4314869	0.0001327264323	0.0004798737214	0.04121160131

Srinagar

The ACfS has identified Srinagar as a city of interest based on primary consultations with key city stakeholders. An overview of waste management provisions in Srinagar is presented in subsequent sections. Also, priority action areas for the city required for sustainable development have been highlighted.

Actions taken towards implementation of C&D Waste Management Rules, 2016 [2]

i. The Policy and Strategy for Management of C&D Waste (Jammu-Kashmir)-2020 was notified on 20 February 2020. The objectives of the J&K Government for C&D Waste Management Policy are:

ii. To ensure that no C&D waste is dumped in open spaces by 2022,

iii. To ensure segregation of C&D waste at source level,

iv. To ensure establishment of C&D waste recycling facility within stipulated time period (six months from notification of policy,

v. To ensure procurement of by-products of recycling (10% to 20%) in Municipal/ Government contracts subject to strict quality control and standards prescribed by BIS.

vi. To ensure that adequate preventive measures be taken by bulk waste generators to avoid any dust of C&D waste handling at construction site during storage and unloading a mandate under CPCB guidelines, 2017.

vii. To ensure that at least 50% of C&D waste is reused or recycled by 2022.

Most importantly, the recommendation to all ULBs for notifying secondary storage of C&D waste is to preferably identify a location in each of the zones and in a manner that non-bulk generators would not have to transport small quantities of C&D waste to a distance of more than 2.5 to 3.0 Kms.

Specific dumping sites for C&D waste have been identified by eight local bodies. The Directorate of Urban Local Bodies, Kashmir has already notified three locations at Uranhall Anantnag, Shalkhud Sumbal and Sopore in Kashmir Region for dumping of C&D waste in compliance to the directions of the National Green Tribunal (NGT) and Solid Waste Management Rules, 2016.

Environmental cells have been set up by Jammu Municipal Corporation and Srinagar Municipal Corporation with issuance of public notice for general public to comply under Byelaws and directions issued by corporations.

Status of Solid Waste Management and C&D Waste

Srinagar constitutes around two-third of the state's urban population. It is considered as the largest urban centre and rapidly growing city amongst all Himalayan urban centers.

Srinagar Municipal Corporation is planning to implement a holistic solid waste management plan with a vision to make Srinagar litter, dust-bin, dust and pollution free. This Action Plan has a significant step forward in assessing the existing situation of SWM as well as laying out clear guidelines for making Srinagar a safe, resilient and litter-free city. This involves various aspects of the MSW operations viz. source segregation, door-to-door collection, primary & secondary transportation, intermediate waste storage & transfer, scientific processing and final disposal as per SWM Rules, 2016. Some of the major interventions of the proposed action plan are as below:

1. Fleet upgradation and additional deployment of hoppers/compactors/bins for achieving the 100% collection & transportation system.
2. Provision for setting-up C&D waste processing facility in compliance to C&D Management & Handling Rules, 2016.
3. SMC has proposed GIS based integrated waste management system which will have following features like Fleet Management System, Geo-fencing and Geo mapping, biometric staff management system and Radio Frequency Identification (RFID) based house numbering.

2 (Source: http://jkspcb.nic.in/Content/ConstructionDemolitionWastManagement.aspx?id=10479)

Table 30: Quantification of Waste in Srinagar

S.No.	Particulars	Quantity
1	Average Per Capita of MSW	0.40 kg/person/day
2	Total MSW generation in the city (Year-2021) (quantity of waste has been estimated based on the survey done by Srinagar Municipal Corporation. Accordingly, Average Per Capita is calculated at 0.40 kg.)	620 tonnes per day (August 2021 – 450 MTPD according to monthly Progress Report to National Mission for Clean Ganga)
3	Projected Waste Generation in 2025	690 tonnes per day
4	Construction & Demolition Waste Generation	100 tonnes per day
5	Domestic Hazardous Waste Generation	5 tonnes per day
6	Quantity of E-waste Generation	2 tonnes per day
7	Poultry Waste Generation	6 tonnes per day
8	Animal Carcasses (average)	1 tonne per day

Table 31: Break-up of MSW Generated in Srinagar Municipal Corporation

S. No.	Sources MSW Generation	Percent	Quantity of Waste (TPD)
1	Households	55%	341
2	Shops & Establishments	20%	124
3	Street Sweeping	8%	49.6
4	Lakes	1%	6.2
5	Markets	4%	24.8
6	Hotels/ Restaurants	10%	62
7	Others	2%	12.4
		100%	620

Table 32: Srinagar Municipal Corporation: Characterization of MSW

S.No	Sources MSW Generation	CPCB-NEERI	ERA	SMC	Average
1	Biodegradable Waste	61.77%	58.50%	41.19%	53.82%
2	Recyclable Waste	17.76%	10.30%	19.54%	15.87%
3	Inert Waste (Combustible & Non-combustible)	20.47%	31.20%	39.27%	30.31%
4	Moisture Content	61%	25.88%	-	43.44%
5	Calorific Value	1264 kcal/kg	1579 kcal/kg	-	1421.5 kcal/kg

Source for table 31,32,33: Government of Jammu & Kashmir Forest, Ecology & Environment Department. Monthly Progress Report by States/ UTs, pursuant to the Hon'ble NGT Order Dated 24.09.2020 in the matter of OA.No.673/2018 for the Month of August 2021.

Due to rapid urbanization, the development in the city both in terms of new construction as well as demolition of old buildings are happening at a rapid pace. But the waste generated by new construction, renovation and demolition is a challenge. Due to the unavailability of C&D waste processing plants in Srinagar jurisdiction, these wastes are dumped illegally near river belts. Srinagar has four polluted river stretches. As per Revised Action Plan for Integrated Solid Waste Management system in Srinagar, C&D waste estimated to be 100 TPD.

An environmental cell has been set up within Srinagar Municipal Corporation with issuance of public notice for general public to comply under Byelaws and directions issued by corporations.

Currently, SMC produces 33 TPD of C&D waste daily and most of the generated C&D Waste is used for filling of low lying areas. However, some Municipal Councils dispose C&D waste by filling sanitary landfills. Currently, the waste is collected unsegregated through trucker trollies.

Most of the C&D waste generated is being reused by the locals for filling of low lying areas. However, some ULBs dispose off C&D waste by filling sanitary landfills. The SMC is contemplating to set up a 100 TPD capacity C&D Waste Processing Plant in Saidapora, Achan. The DPR is under process (August 2021). C&D waste collection centre at dumping site Achan, Srinagar has already been notified.

Priority Action Areas for Srinagar City

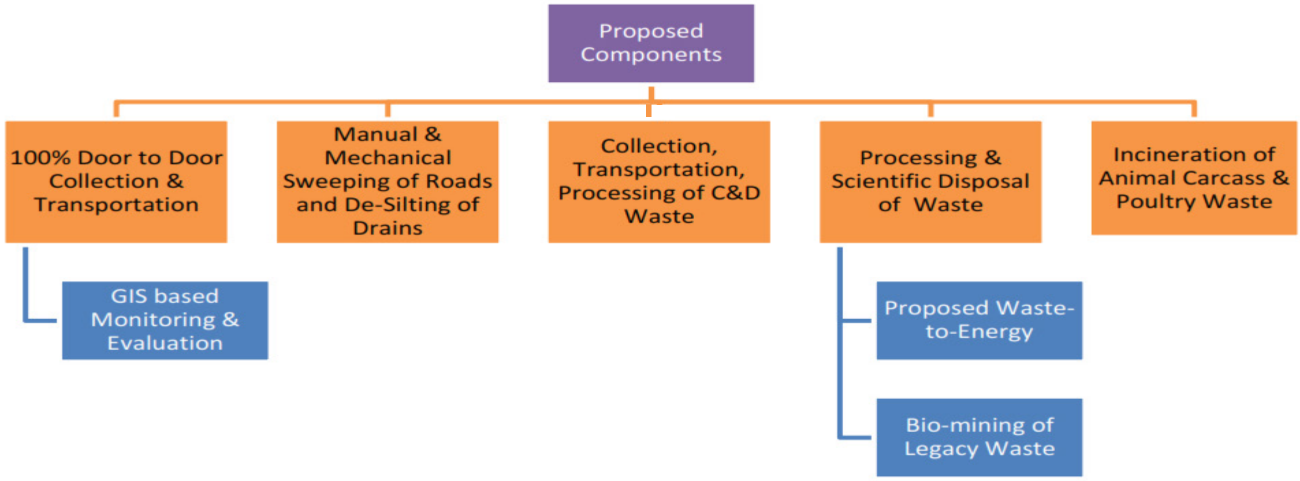
1. Immediate approach is to propose for a C&D recycling plant inside the city as per the C&D Rule, 2016.
2. Proper estimation of C&D waste in the city.
3. In order to stop illegal dumping, strictly impose a penalty on it.
4. Efficient Management of C&D waste by Srinagar Municipal Corporation.
5. Formulation of better policy and strategy for the efficient management of C&D waste in Srinagar.
6. Specific guidelines need to be issued for Contractors/ builders/developers with respect to segregation of construction and demolition waste in Srinagar.

Table 33: Composition of Waste from Generators

	Concrete	Brick	Glass	Wood
Bulk Generator	40	40	10	10
Residential	60	30	5	5
Dumpsite	-	-		-

Table 34: Mode of Implementation for the Management of C&D Waste

Model	This activity to be outsourced to the Private Operator on Design, Build Finance, Operate & Transfer (DBFOT) Model on PPP mode (viz. Delhi, Ahmedabad, Thane)
Payment Mechanism	SMC shall pay the Tipping Fee on per tonne basis
User Fee	Citizens shall pay the user charges for C&D waste collection and disposal on per tonne basis.
Fines	Penalty shall be imposed to the People for illegal or open dumping of C&D waste



SMC has data on numbers of building permissions issued from 1 April 2018 onwards. However, status of whether demolition permissions are required or not is unknown.

Srinagar Municipal Corporation List of Building Permission (Residential/ Commercial) Cases w.e.f. 1st April 2018 to 28 December 2022 (with OBPS - October 2021 to December 2022)			
S.No.	Month	Residential	Commercial
1	April 2018 to December 2022	3008	463
2	OBPS (Online Building Permission Service) Cases	1015	26
Total Building Permissions granted from 1 April 2018 to 28 December 2022		4023	489

Any waste generator, irrespective of whether it is government or semi government institutions, business units or individual persons, if found depositing and throwing the C&D Waste on roads, streets, lanes, bye lanes, drains, rivers, river banks, parks or any other place, they are to be levied with penalties in accordance with current rules and regulations.

Further, vide Order no. 269 of 2020 dated 11.02.2020, the Commissioner, Srinagar Municipal Corporation has mandated that the Joint Commissioner (Planning), SMC is to collect a deposit of INR. 25000/- instead of INR.5000/- as "Mulba Security Deposit" from prospective applicants seeking the building permissions in order to enforce the permittee's to deal with the debris in accordance with the C&D Waste Management Rules, 2016.

8.2.2 Mode of Implementation for the Management of C&D Waste

Model	This activity to be outsourced to the Private Operator on Design, Build, Finance, Operate & Transfer (DBFOT) Model on PPP mode (viz. Delhi, Ahmedabad, Thane)
Payment Mechanism	SMC shall pay the tipping fee on per tonne basis
User Fee	Citizens shall pay the user charges for C&D waste collection and disposal on per tonne basis.
Fines	Penalty shall be imposed to the people for illegal or open dumping of C&D waste

Items Description	Capex Requirement in 1st Year in INR (FY-2021-22)	Capex Requirement in 2nd Year in INR (2022-23)	Total Capital Cost in INR	Capital Cost (in Crore) INR
Capital Cost for Setting up of C&D waste processing facility (Capacity- 100 TPD)	-	128,710,054	128,710,054	12.87

Abbreviations

AEEE	Alliance for an Energy Efficient Economy
AEPPL	Amdavad Enviro Projects Private Limited
AMC	Ahmedabad Municipal Corporation
BIM	Building Information Modelling
BMTPC	Building Materials and Technology Promotion Council
C&D	Construction and Demolition
CSE	Centre for Science and Environment
EPA	Environmental Protection Agency
EU	European Union
GIS	Geographic Information System
GRC	Generation Rate Calculation
GSB	Granular Sub Base
IVAR	Infomerics Valuation And Rating Private Limited
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MoEFCC	Ministry of Environment, Forests and Climate Change
M-Sand	Manufactured Sand
MSW	Municipal Solid Waste
MT	Million Tonnes
PPP	Public Private Partnership
RA	Recycled Aggregates
RCA	Recycled Concrete Aggregates
REI	Recycling Economic Information
SBM-U	Swachh Bharat Mission - Urban
SGPPL	Surat Green Precast Private Ltd
SWMP	Site Waste Management Plans
TIFAC	Technology Information, Forecasting and Assessment Council
TPD	Tonne Per Day

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