Construction and Demolition Waste Utilisation for Recycled Products in Bengaluru: Challenges and Prospects

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API	Application Programming Interface
BBMP	Bruhat Bengaluru Mahangara Palike
BDA	Bengaluru Development Authority
C&D	Construction and Demolition
CDW	Construction & Demolition Waste
CPCB	Central Pollution Control Board
CREDAI	Confederation of Real Estate Developers Association of India
CSE	Centre for Science and Environment
CU	Capacity Utilisation
CUF	Capacity Utilization Factor
DTC	Demolition and Transportation Contractor
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GRIHA	Green Rating for Integrated Habitat Assessment
IISc	Indian Institute of Science
INR	Indian Rupee
HCBM	Hollow Concrete Brick Masonry
IPBM	Integrated Paving Block Manufacturer
IRR	Internal Rate of Return
Km	Kilometres
KHB	Karnataka Housing Board
KPWD	Karnataka Public Works Department
KSCST	Karnataka State Council for Science and Technology
KSPCB	Karnataka State Pollution Control Board
LCV	Light Commercial Vehicle
LEED	Leadership in Energy and Environmental Design
mm	Millimetres
MPa	Mega Pascal
M Sand	Manufactured Sand
MSW	Municipal Solid Waste
Mt	Million Tonnes
NFA	Natural Fine Aggregates
NPV	Net Present Value
NRM	Natural Raw Material
NV	Not Viable
PBM	Paving Block Manufacturers
PWD	Public Works Department
RFA	Recycled Fine Aggregates
RMC	Ready-Mix Concrete
SCU	Stone Crushing Unit
Sq. m.	Square metre
Sq. ft.	Square foot
TIFAC	Technology Information Forecasting and Assessment Council
TPD	Tonnes per Day

1. Introduction

India is currently one of the fastest growing economies in the world and the construction industry alone accounted for approximately 10% of its GDP in 2014 (Centre for Science and Environment, 2014). The Central Pollution Control Board (CPCB) classifies waste generated from the Construction and Demolition (C&D) of buildings and civil infrastructure as construction and demolition waste (CDW). The CPCB has estimated solid waste generation in India to be around 48 million tonnes per annum of which the construction industry accounts for approximately 25% (TIFAC, 2001). However, this estimate of 12-15 million tonnes of CDW is widely considered dated and a significant underestimate; but no updated comprehensive estimate for the country exists. In India, although some valuables are recovered from CDW and some of it is used for filling, most of it gets disposed in landfills or through unauthorised dumping in low lying areas, open spaces, road sides or water bodies creating enormous nuisance and environmental problems (Centre for Science and Environment, 2014). India requires a paradigm shift from a dumping based approach to utilising CDW efficiently. CDW can be recycled to replace natural building material; this is not only beneficial for the environment, but also results in substantial cost and resource savings.

1.1. Scope and Methodology

The study aims to contribute towards creating an ecosystem of CDW recycling in Bengaluru (formerly Bangalore). The analysis explores the status and future outlook of CDW generation and disposal in the city through a combination of literature review, site visits and primary surveys. It reviews the policy landscape and regulations around CDW management and disposal formulated by the municipal authorities. The survey attempts to understand the positions and concerns of various stakeholders including Stone Crushing Units (SCUs), Demolition and Transport Contractors (DTCs), Paving Block Manufacturers (PBM), building developers, and academia around CDW management and recycling for building materials.

A GIS analysis of the sites of waste generation and their potential disposal and utilisation is presented to indicate the logistical requirements for efficiently recycling CDW. Financial analyses of the profitability of venturing into the business of producing CDW-based building materials is undertaken based on the costs of and returns from setting up independent CDW crushing units or integrated paving-block manufacturing units. Next, the case for existing SCUs having significant unutilised capacities to add CDW processing is also examined at different capacity utilisations.

Based on official policy documents and academic literature, ground-level insights from field surveys, and GIS and financial analyses, the study concludes by recommending the way forward for government bodies to facilitate the creation of a business friendly market for CDW-based building products.

2. CDW Generation in Bengaluru: Status and Outlook

Bangalore is the fifth largest urban agglomeration of India and is branded as the ‘Silicon Valley’ of India for leading the growth of Information Technology based companies. Bruhat Bengaluru Mahanagara Palike (BBMP) is the administrative body responsible for civic and infrastructural facilities and it is run by a council. Bangalore Development Authority (BDA) is responsible for principal planning and zoning regulation of the city.

Rapid urbanisation is changing the landscape of the country. Bengaluru is one of the fastest urbanising cities in India; its population has almost doubled within a decade – from 4.3 million in 2001 to 8.4 million in 2011 (Census of India, 2011). Not only has that been accompanied by a boom in new construction, but demolition of shorter buildings to make way for taller ones is also commonplace (GIZ, 2015). The construction boom has placed enormous demands on construction materials. The case of sand is particularly instructive. It has been estimated that around 1 Million tonnes (Mt) of sand per month is being used by the construction industry in Bengaluru (Chitra and Gandhi, 2014), while the total demand for sand in Karnataka was estimated to be 26 Mt in 2014 (Shyam Sunder and Asundi, 2015). Supply shortages and price spikes for natural sand has led to a burgeoning industry for manufactured sand (m-sand) in the region; however, m-sand is being currently manufactured from natural granite (Shyam Sunder and Asundi, 2015). The enormous levels of CDW being generated, if collected and processed, could provide alternatives to depleting sand reserves and offer sustainable alternatives to the construction industry.

Estimates of CDW generation in Bengaluru differ, but different studies have arrived at estimates that are in close range of each other. A study commissioned by the BBMP estimated the CDW generation in Bengaluru at 2,500 Tonnes per Day (TPD) in 2014 (Bharadwaj, 2016). The Karnataka State Council for Science and Technology (KSCST) has estimated CDW generation in Bengaluru city to be more than 2,700 TPD[1]. An article in the *Deccan Herald* newspaper places the CDW generation in Bengaluru at 3,600 TPD, citing estimates from KSCST and the New Delhi based Centre for Science Environment (CSE) (Rajashekhara, 2016).

For this study, we conducted a supply-side analysis of CDW generation based on the stock of built-up area in 2012 [~37 Million Square Meters (MSqm)]. Assuming a 6% compounded annual growth in construction activity, we estimate CDW from demolition, repairs and new construction based on generation coefficients shown in Table 1.

Table 1: Activity-wise CDW generation coefficients

Activity	Rate of Generation (Waste/Area)
Construction	40 kg/ Sq. m
Repair	50 kg/ Sq. m
Demolition	450 kg/ Sq. m

(Source: BBMP, 2016)

Next, 5% and 10% percent of previous year's built-up area is assumed as the repaired and demolished area (respectively) each year. This yields 2,981 TPD of CDW generation in 2012, which is expected to grow to 3,540 TPD by 2016 and 4,118 TPD by 2020.

Figure 1 compares all the above estimates.

[1] Personal communication with Mr. Hemanth Kumar H., Fellow, Karnataka State Council for Science and Technology. April 25, 2016.

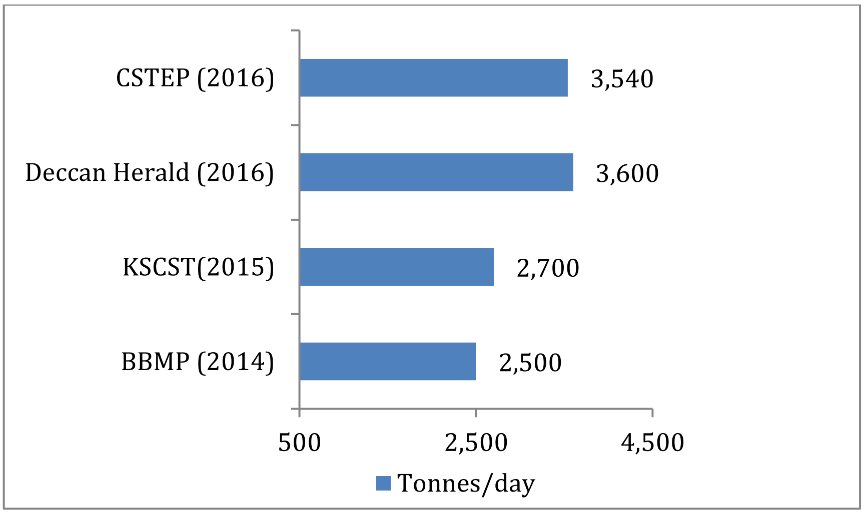

Figure 1: Estimates of CDW generation in Bengaluru (with year)

The typical composition of CDW in India is shown in Figure 2 (TIFAC, 2001).

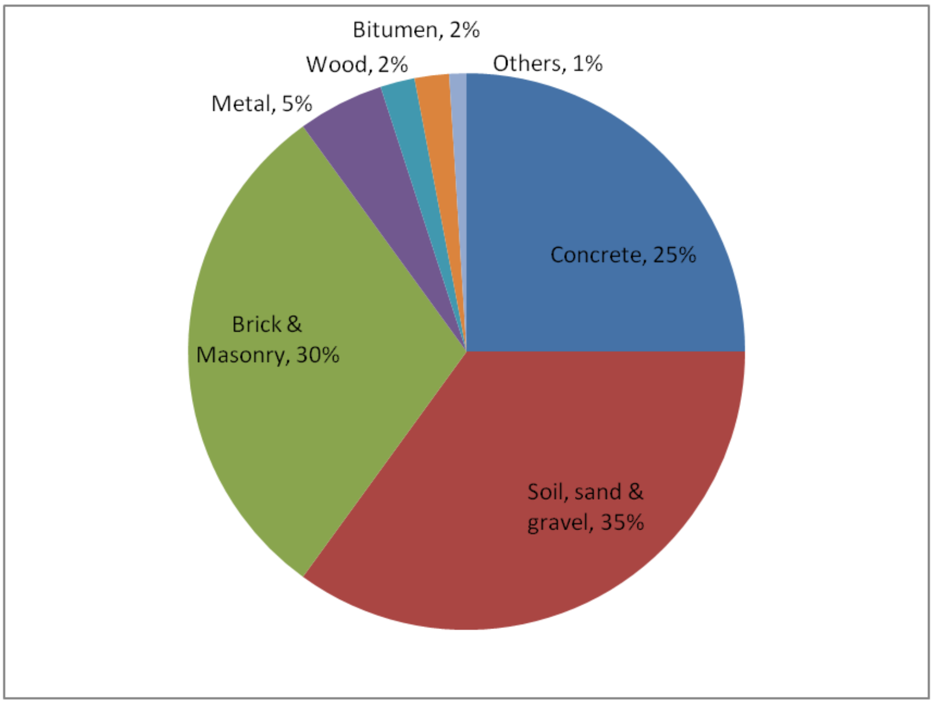

Figure 2: Composition of CDW in India

Of the total CDW generated, approximately 50-60% is easily amenable for reprocessing. This primarily includes concrete, bricks and masonry fractions. These fractions can be crushed and used as coarse or fine aggregates depending on user demand. Soil, sand and gravel can also be reprocessed for productive use as fine aggregates, but with more investment in separation and processing.

3. CDW Disposal in Bengaluru

The BBMP has developed guidelines for CDW management and are in the process of developing a comprehensive management plan. Eight sites have been designated around the city (many of them former stone quarries) for CDW disposal (BBMP, 2016). Further, 3 of these sites – Mallasandra, Anjanapura, and Kannur – have been shortlisted for potential future CDW reprocessing facilities. However, at present, only three out of the eight BBMP designated sites are active. Based on our analysis, it is estimated that 240 TPD of CDW are dumped at the BBMP designated sites (Table 2). Even by most conservative generation estimates, this is only about 10% of total CDW generation in Bengaluru.

Table 2: Total CDW at BBMP designated sites

BBMP Designated Site	Trucks/Day	TPD
Mallasandra	1	10
Anjanapura	8	80
Srinivasapura and Kogilu	15	150

Figure 3 depicts the existing collection, transportation and disposal schematic for Bengaluru's CDW. New construction, remodelling/additional work on existing buildings, and demolition and rebuilding, pavement repairs and other public works all generate CDW.

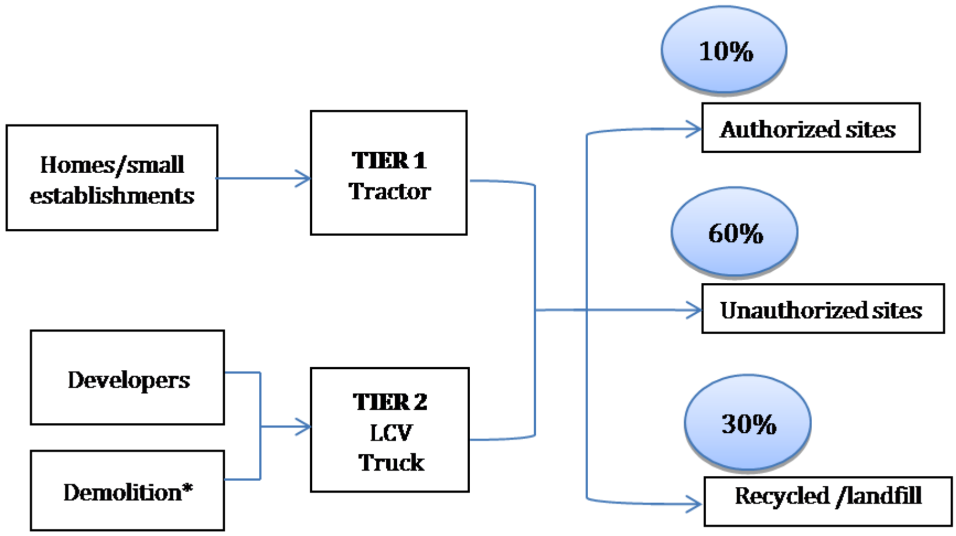

Figure 3: CDW collection, transportation and disposal schematic for Bengaluru

(*refers to the demolition of buildings, road repair works and pavement works)

From our survey, we estimate that approximately 10% of the CDW enters BBMP dumping sites. Based on interactions with the Confederation of Real Estate Developers Association of India (CREDAI) and DTCs, we estimate that roughly 30% of the CDW debris is being used at various sites for levelling low-lying areas and land reclamation for future construction. The remaining CDW is unaccounted for as it is dumped illegally in or around roads and highways, wastelands, old lakes, and valleys.

The BBMP guidelines clearly state that builders need to show the waste disposal plan before remodelling or demolishing a building. No waste can be disposed of in unauthorised areas other than BBMP designated CDW disposal sites. The BBMP-authorised DTCs are expected to pick up the waste from small establishments or generators within 48 hours of receiving a notice from BBMP (BBMP, 2016).

However, the enforcement of these rules has been inadequate. Most of the operating DTCs are private, that is, they have not been authorised by the BBMP for such activities. As a result, their activities are not under regulatory supervision. Smaller builders in the unorganised industry also contribute to the problem of unaccounted waste (Bharadwaj, 2016).

3.1. Status of BBMP Designated Dumping Sites

A field visit to all BBMP-designated dumping sites was undertaken to assess the presence of CDW and to study the operation of the dumping sites. Anjanapura (south Bengaluru) which is not in the online list of BBMP sites was identified as one upon visiting.

There is limited monitoring of CDW transportation and dumping activity at the sites. In most of the dumping sites, the boundary is not clear, and there are no visible markings. It was difficult to verify the information on BBMP dumping sites as listed on their web-page, except in the case of Mallasandra and Srinivasapura. From discussions with BBMP staff, it emerged that Gollahalli (listed on the web-site as an active dumping site) was not actually a designated site. Table 3 provides details on various dumping sites as listed by BBMP (BBMP, 2016).

Table 3: Status of CDW disposal sites designated by BBMP

S. No.	Name of the Site	Address	Area in Acres	Nearby Zone	Status
1	Mallasandra	Sy.No.33,Mallasandra grama, Yeswanthapura Hobli Bengaluru, North Taluk	30	R.R. Nagar/ West	Active
2	Kadu Agrahara	Sy.No.34, Kadu Agrahara grama, Bidarahalli, Bengaluru East Taluk	18	Mahadevpura	Inactive
3	Srinivasapura and Kogilu	Sy.No.15, Srinivasapura and Kogilu grama, Yelahanka Hobli, Bengaluru	10	Yelahanka	Active
4	Gollahalli	Sy.No.58, Gollahalli grama, Uttarahalli Hobli, Bengaluru South Taluk	60	Bommanahalli & South	Inactive
5	Kannur	Sy.No.50, Kannur grama, Bidhrahalli Hobli, Bengaluru East Taluk	50	East	Inactive
6	Guddadahalli	Sy.No.43, Guddadahalli grama, Hesaraghatta Hobli, Bengaluru North Taluk	46	Dasarahalli	Inactive
7	Mittaganahalli	Sy.No.02, Mittaganahalli grama, Bidhrahalli Hobli, Bengaluru East Taluk	10	East/ Mahadevpura	Inactive

3.1.1. Mallasandra

Mallasandra is one of the active dumping sites in the Yeswanthapura Hobli area of north Bengaluru. Spread over an area of 30 acres, the site has a BBMP dry waste collection centre on one side and piles of CDW on the other side.

Here, CDW comprises broken bricks, concrete, clay and mortar bits of varying sizes. This site is relatively well connected with concrete approach roads.

Figure 4: CDW at Mallasandra site

3.1.2. Srinivasapura and Kogilu

Srinivasapura and Kogilu is a BBMP approved CDW disposal site in Yelahanka spread over 10 acres. The landfill has been an abandoned quarry since 2013. Details of the sites were collected by interacting with the disposal workers. The debris included brick waste, concrete, excavated earth and plastic materials. It was observed that informal waste pickers collect plastic and other useful materials from the CDW debris piles. Small quantities of Municipal Solid Waste (MSW) were also observed at the site.

The site encompasses abandoned stone quarries of more than 10 m depth. The transporters fill the quarry pits with CDW debris from central Bengaluru and other surrounding places.

Figure 5: CDW at Srinivasapura and Kogilu site

3.1.3. Kannur and Mittaganahalli

Kannur and Mittaganahalli are located in north Bengaluru and are spread across 50 acres and 10 acres respectively. The sites encompass abandoned stone quarries and there are no sign boards or well-defined boundaries. Minimal CDW was observed at these sites.

Figure 6: Abandoned quarry at Mittaganahalli

3.1.4. Anjanapura

Anjanapura is not mentioned in the list of BBMP designated CDW disposal sites, but our interaction with BBMP staff revealed that this location is being used for CDW disposal. Large quantities of CDW were observed at this site in south Bengaluru near Gollahalli, which was found to be an inactive site (see Table 3).

Figure 7: CDW dumped at Anjanapura site

4. Stakeholder Mapping

Collection and transportation are known to be key hurdles to CDW processing. Using Geographic Information Systems (GIS), we created a spatial database of the major stakeholders involved in the project who may contribute towards efficient CDW management. The objective of this exercise was to help identify suitable locations for the implementation of CDW recycling projects in Bengaluru.

The following data was used for this analysis:

1. Locations of stone crushing units in and around Bengaluru
2. Locations of paving block manufacturers in and around Bengaluru
3. Locations of designated CDW disposal sites
4. Shape file of the Bengaluru Urban and Rural boundaries
5. Shape file of the BBMP Boundary
6. Shape file of the road network in Bengaluru

4.1. Data Collection

4.1.1. Dumping Sites

BBMP has listed the addresses of designated CDW disposal sites in their Guidelines for Construction and Demolition Waste Management. The location of Guddadahalli (situated in the Bengaluru North taluka) could not be verified. Geographic coordinates of these sites were obtained using Google Earth and field visits.

4.1.2. Stone Crushing Units[2]

Data on the location of SCUs situated in and around Bengaluru was acquired from:

1. Field visits: Visits were made to select few SCUs and their geographic coordinates were obtained.

[2] Detailed lists of SCUs and PBMs in Bengaluru are provided in Appendix IV.

2. Interviews: Discussions with various stakeholders provided important clues for the locations of SCUs.
3. Karnataka State Pollution Control Board (KSPCB): Addresses of 43 SCUs were acquired from the KSPCB website (KSPCB, 2014).
4. Google Earth: All addresses were verified using satellite imagery from Google Earth; 118 SCUs within a radius of 30 km from the centre of Bengaluru were mapped.

4.1.3. Paving Block Manufacturers[3]

Data on the locations of Paving Block Manufacturers (PBMs) was obtained via field visits and telephonic interviews. The locations provided were confirmed by locating them on Google Earth. Coordinates of 26 PBMs within a 30 km radius of the centre were collected.

4.2. Map Generation

4.2.1. Base Layers

OpenStreetMap was used as the base layer along with the shape files for road networks, the BBMP boundary, and the Bengaluru district boundary.

4.2.2. Buffer Layer

A buffer of 30 km was generated from the centre of the city and only stakeholders within the buffer region were mapped.

4.2.3. Stakeholder Mapping

Separate layers were created for:

1. Stone Crushing Units [118 units]
2. Paving Block Manufacturers [26 units]
3. Dumping Sites [7 sites]

4.2.4. Clustering

Individual SCUs and PBMs were grouped into clusters based on the following criteria:

1. Distance from the centre of the city
2. Proximity of nearest neighbour

4.3. Calculating Road Distances

To calculate the road distances between various key entities, Google Maps API (Application Programming Interface) was used with the following specifications:
1. Driving mode was set to heavy-duty vehicles
2. Interior/small roads were avoided.

[3] Detailed lists of SCUs and PBMs in Bengaluru are provided in Appendix IV.

Distances were calculated between:

1. City centre and paving block manufacturing clusters
2. Stone crushing clusters and city centre
3. Stone crushing clusters and paving block manufacturing clusters

4.4. GIS Maps

Figure 8 shows the spatial distribution of BBMP designated CDW disposal sites. It was observed that five CDW disposal sites are located in north Bengaluru and two sites in south Bengaluru.

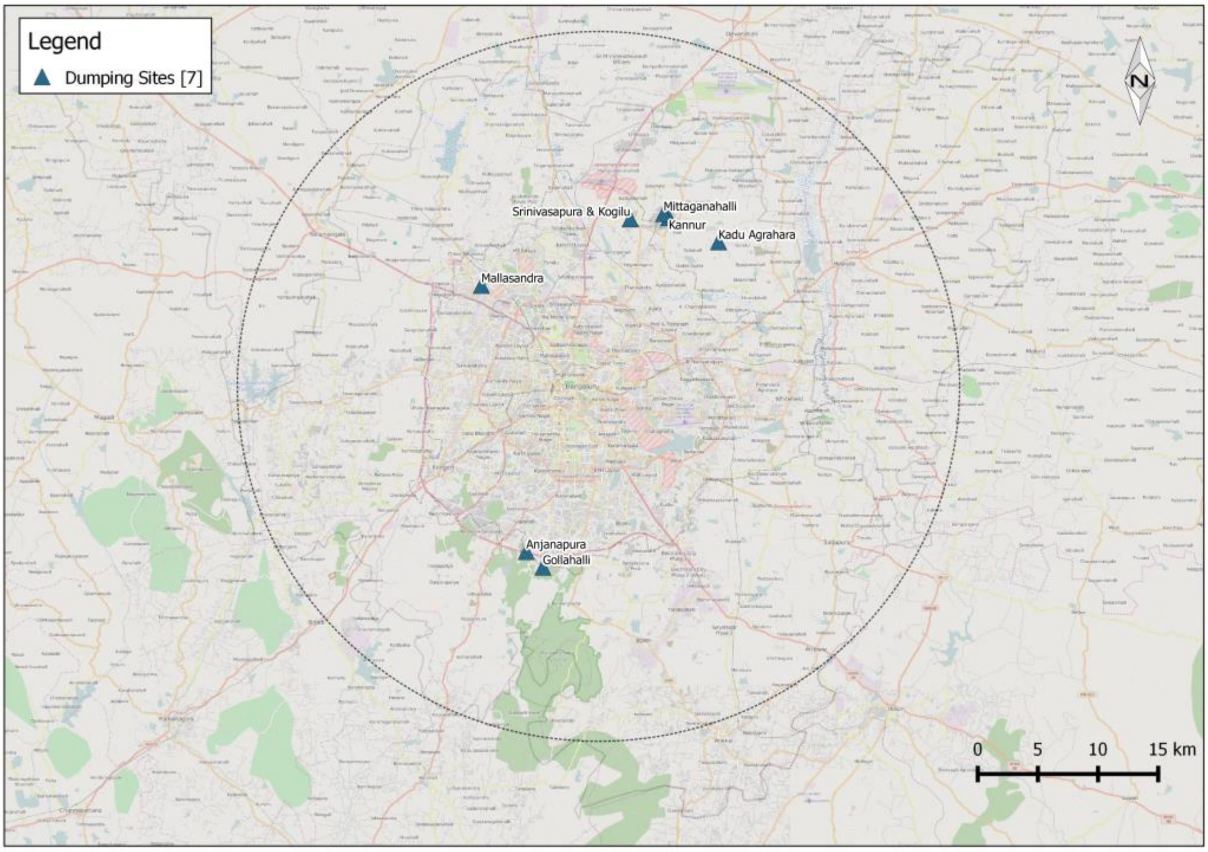

Figure 8: BBMP designated CDW disposal sites

Figure 9 shows the spatial distribution of SCUs within a 30 km radius from city centre. Most units are located in northern Bengaluru.

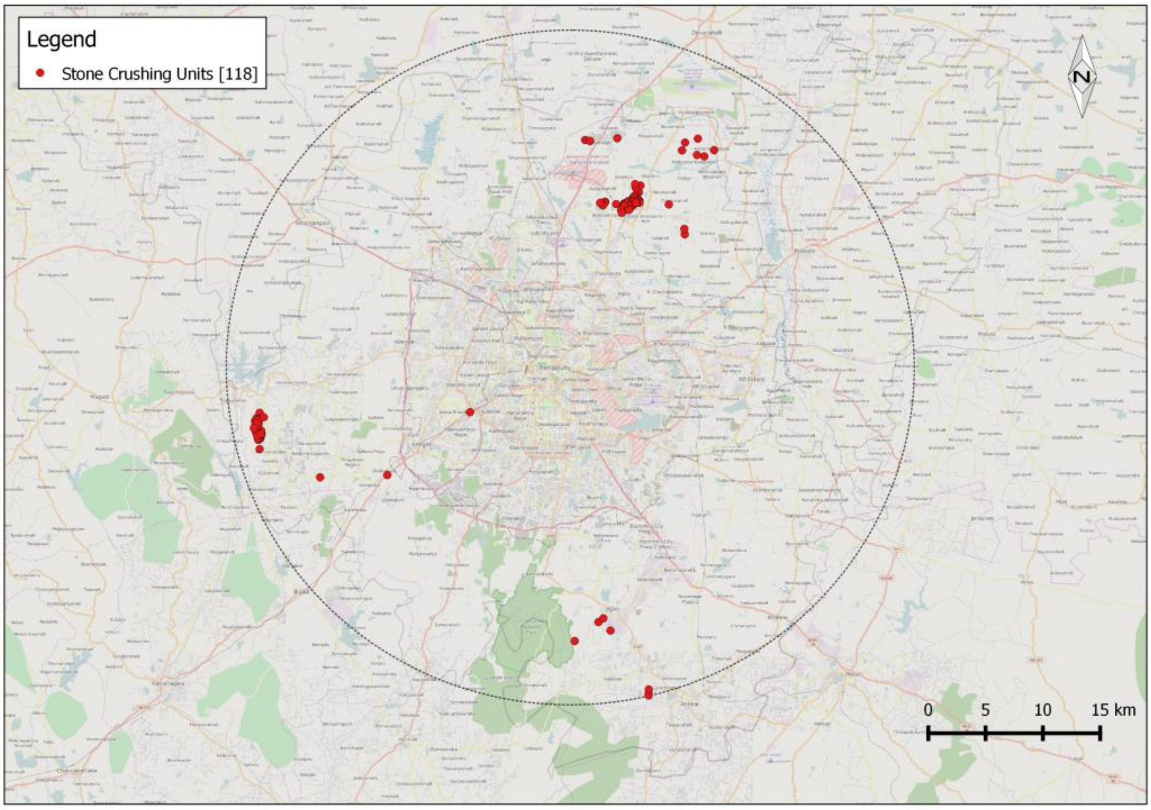

Figure 9: Stone Crushing Units within buffer zone

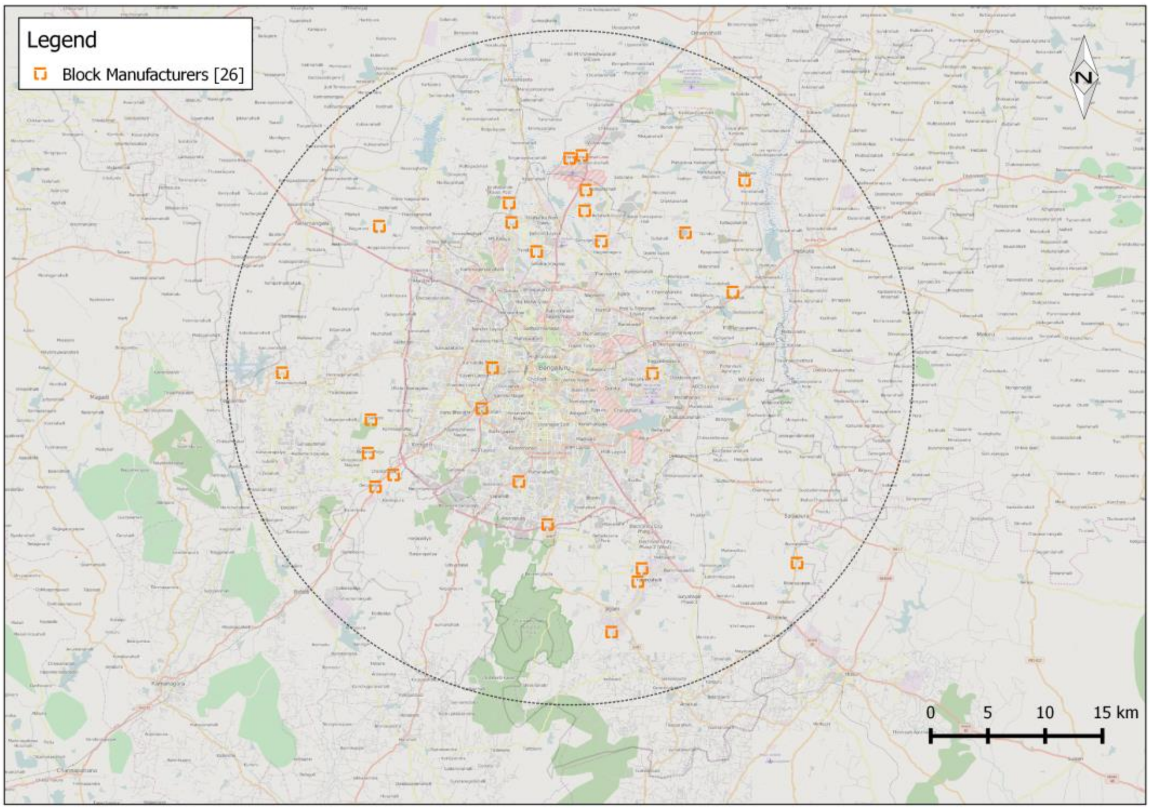

Figure 10: Paving Block Manufacturing Units within buffer zone

Figure 10 shows the spatial distribution of PBMs within a 30 km radius from the city centre. It is observed that PBMs are distributed more or less evenly around the city.

Further, the SCUs are divided into four clusters and the PBMs into three clusters based on the locations of the units. The distances among different clusters are shown in Table 4. Figure 11 shows the spatial distribution of these clusters. PBM cluster 1 has the highest number of units and is nearer to SCU clusters 1 and 2 (Table 4).

Table 4: Distance between SCU and PBM clusters

Distance Matrix (in km)		**Number of Units**	**City Centre (km)**	**Clusters of Paving Block Manufacturers**		
				Cluster 1 [North Bengaluru]	**Cluster 2 [West Bengaluru]**	**Cluster 3 [South Bengaluru]**
				> 8	> 5	> 5
Clusters of Stone Crushing Units	**Cluster 1 [North Bengaluru]**	> 60	22.6	8.6	42.0	46.5
	Cluster 2 [North Bengaluru]	> 7	33.4	15.4	52.6	57.1
	Cluster 3 [West Bengaluru]	> 30	37.5	51.6	12.0	49.6
	Cluster 4 [South Bengaluru]	> 7	34	51.9	38.8	10.3
City Centre				19.4	25.5	24.4

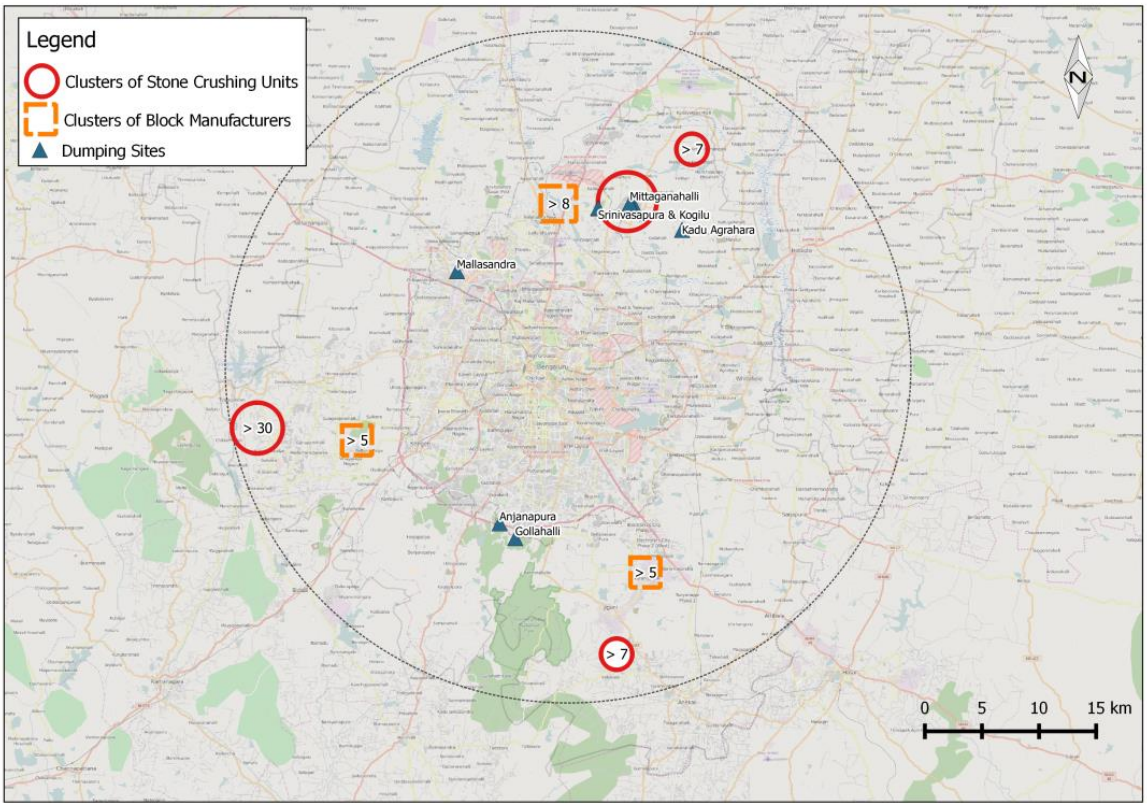

Figure 11: SCU and PBM clusters

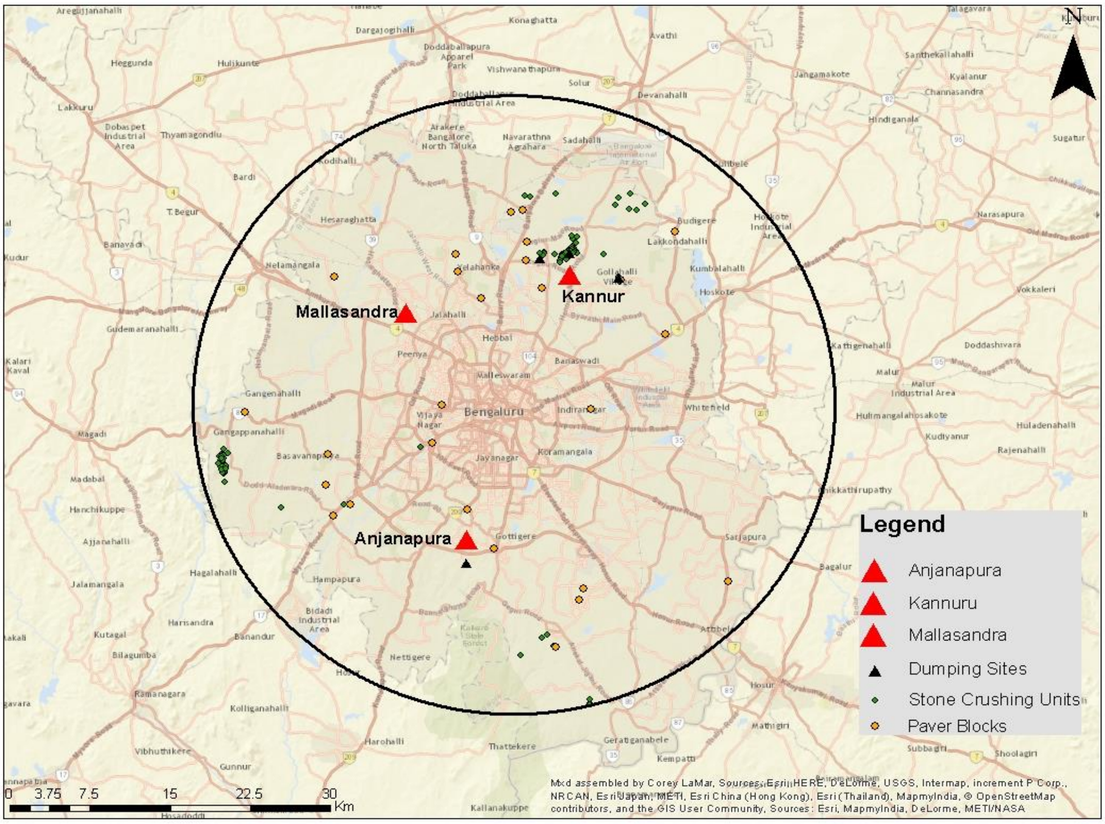

Figure 12: Proposed CDW processing plants

Figure 12 shows the spatial distribution of designated disposal sites and CDW processing plants proposed by the BBMP. It is observed that the proposed sites are located in proximity with SCU clusters.

5. Stakeholder Surveys

The potential market players in CDW processing were interviewed via telephone and at site offices. This section contains the responses from key players identified and interviewed. Academic experts researching CDW generation and recycling were also interviewed for technical inputs.

5.1. Stone Crushing Units

5.1.1. Vinayaka Stone Crushers

Vinayaka Stone Crushers is one of the largest SCUs in Bengaluru and is located at Magadi Road (West Bengaluru). The crushing unit has a capacity of 1,000 TPD and produces multiple products such as M-Sand (4.7 mm) and aggregates of different sizes (12 mm, 20 mm, 30 mm). Dust (<3mm) is a by-product which can be used in the paving block industry.

As per our discussion with the head of the crushing unit, the current sale price of aggregates is in the range of INR 350-400 per tonne. According to *Vinayaka*, the key challenges to profitable CDW-based operations were the high proportion of dust generation (30%), segregation of foreign material and transportation of waste from the generation or disposal site.

Figure 13: Vinayaka Stone Crushers facility

5.1.2. Rock Crystals

Rock Crystals is the only plant in Bengaluru processing concrete waste from Ready-Mix Concrete (RMC) plants and converting it to aggregates and artificial sand (M-Sand) in Bengaluru. They are also empanelled with BBMP as a processor of CDW. At present, Rock Crystals is operating at only 10% of its capacity (1,000 TPD) due to lack of market for CDW-based aggregates and sand. The key challenges for Rock Crystals are CDW transportation, lack of access to assured amounts of CDW, lack of government support and low demand for CDW-based products.

5.1.3. Aishwarya Stone Crushers

Aishwarya Stone Crushers is located in the Kumbalgodu area towards Mysore Road and produces aggregates of different sizes. The plant personnel are aware of CDW processing techniques and mentioned that processing CDW would consume less power than regular stone crushing. The main perceived challenge is the absence of a market for CDW derived products.

5.1.4. Proman Infrastructure Services Pvt. Ltd.

Proman is one of the leaders in supplying complete crusher solutions for the manufacturing of concrete sand and plaster sand. As per our discussion with Proman, CDW can be easily processed at the SCUs after segregating the metal components from the debris.

5.2. Paving Block Manufacturers

5.2.1. Balaji Flooring

Balaji Flooring is located on Magadi Road. As raw materials, the plant uses aggregates of 20 mm size, dust from stone quarries and cement. The plant manufactures 60 mm and 80 mm blocks, which have different applications as shown in the table that follows.

Table 5: Balaji Flooring paving block prices and applications

Block	Price/Sq. ft	Application
60 mm	INR 40	Pedestrian footpath
80 mm	INR 55	Fuel-filling station (heavy load)

Figure 14: Balaji Flooring Paving Block Manufacturing unit

5.2.2. Style Earth Company

Style Earth Company manufactures precast compound walls, drain covers, kerb stones, paving blocks and concrete blocks and is located in north Bengaluru. As per Style Earth personnel, CDW-derived products are not suitable for their compact products.

Figure 15: Style Earth Company manufacturing unit

5.3. Demolition and Transportation Contractors

Typically, demolition activity is undertaken by specialised demolition contractors who use their own demolition equipment and also transport the residual waste. Based on the value of recoverables like steel, wood, glass and pipes, the owners pay a fee to the DTCs.

Interviews were conducted with DTCs to understand the current practice of CDW management and the transportation charges incurred by CDW generators. Many DTCs are not aware of the BBMP guidelines and are dumping the debris illegally. Table 6 shows the key information obtained from the three DTCs interviewed.[4]

Table 6: CDW handling by interviewed DTCs

DTC	Price (INR/Truck)	Radius (km)	CDW Handled (TPD)
A	3,500	Up to 25	150
B	4,000-4,500	20-30	200
C	1,500-3,000	10-25	250

[4] The DTCs chose to remain anonymous.

Figure 16: Vehicles carrying CDW

5.4. BBMP

According to a study conducted by Tide Technocraft Consultancy on behalf of BBMP, the quantity of CDW generated in Bengaluru was about 2,500 TPD in 2014-15 (Bharadwaj, 2016). Based on this finding, BBMP has decided to set up three large scale processing plants of 750 TPD capacity each. The identified zones for CDW processing plants are Kannur, Mallasandra and Anjanapura. BBMP will provide land for the CDW plants, and will solicit tenders from private entities to set up these plants. Our discussions with BBMP officials revealed that a decentralised model of CDW processing consisting of smaller, geographically distributed plants was not considered.

5.5. Academia/Research Institutes

5.5.1. Karnataka State Council for Science and Technology

Mr. Hemanth Kumar, KSCST has assessed the ward-wise CDW generation and disposal mechanisms for Bengaluru in a recent study. In our discussion, he highlighted the importance of developing robust standards for CDW-derived products, and the characterization of CDW. He expressed the possibility of recycling concrete and masonry waste by sorting, crushing and sieving into recycled aggregates.

5.5.2. BMS Engineering College

Prof. Mangala and her team performed analysis of Hollow Concrete Block Masonry (HCBM) made using Recycled Fine Aggregates (RFA) in comparison with the same made from Natural Fine Aggregates (NFA). HCBM prisms were tested as per IS:1905-1987methodology. Both sets of prisms were subjected to uniform incremental load and the corresponding strains were noted using a demountable mechanical strain gauge. The test results are tabulated in Table 7 (Darshan, Mangala and Preethi, 2014).

Table 7: Comparative performance of Hollow Concrete Blocks

Properties	RFA	NFA
Compressive Strength (MPa)	5.03	5.10
Modulus of Elasticity (MPa)	7802.00	6535.00
Masonry efficiency	82.40 %	83.25 %

From the properties of HCBM using RFA, the compressive strength, modulus of elasticity and masonry efficiency were observed to be comparable to those of HCBM prisms made up of NFA.

6. Business Viability Analysis for CDW processing

In order to establish a fully functioning and self-sustaining market for CDW processing, all aspects of the CDW value chain must be strengthened. This requires interventions across regulatory, policy and behavioural aspects in order for CDW-based products to compete with and replace equivalent outputs from natural raw material (NRM) in suitable application areas. Table 8 compares the various costs and risks associated with producing equivalent products from CDW and virgin stone (NRM).

Table 8: Comparison of CDW-based manufacturing against status quo (NRM)

<table>
<tr><th colspan="2">Costs and Risks</th><th>NRM</th><th>CDW</th><th>Remarks</th></tr>
<tr><td rowspan="2">Procurement</td><td>Cost</td><td>Medium</td><td>Low</td><td>CDW cheaper than quarry stone (for optimal collection distance)</td></tr>
<tr><td>Risk</td><td>Low</td><td>High</td><td>Lack of supply chain - institutional support required</td></tr>
<tr><td rowspan="2">Processing</td><td>Cost</td><td>Medium</td><td>Medium-High</td><td>Higher costs owing to manual and automated separation required prior to CDW processing</td></tr>
<tr><td>Risk</td><td>Low</td><td>Medium</td><td>Higher risks owing to technological unfamiliarity; risk of machinery damage due to undesirable substances in waste</td></tr>
<tr><td rowspan="2">Transaction</td><td>Cost</td><td>Medium</td><td>High</td><td>More complex transactions involved in CDW - risks of non-compliance involved since sector is immature</td></tr>
<tr><td>Risk</td><td>Low</td><td>High</td><td>Informality of arrangements in the CDW sector implies the requirement of better enforcement of BBMP norms</td></tr>
<tr><td rowspan="2">Social/ Environmental</td><td>Cost</td><td>Medium</td><td>Negative</td><td>The social costs of virgin stone quarrying need to be internalised by appropriate institutional and behavioural changes</td></tr>
<tr><td>Risk</td><td>Medium-High</td><td>Low</td><td>CDW procurement and processing is socially risk-less compared to quarry operations</td></tr>
</table>

Table 8 indicates that although CDW based product manufacturing and use has positive social (and sustainability[5]) implications, the associated tangible private costs and risks around CDW processing setup are high in the current scenario. To have a well-functioning and competitive market for CDW processing, BBMP and state departments have to address these costs via appropriate policies and enforcement mechanisms.

6.1. Current Ecosystem for CDW Processing

Figure 17 maps out the CDW value chain starting from a construction or demolition site (CDW generator) and ending at either disposal sites (designated and undesignated) or being recycled back into the construction industry. BBMP's current CDW disposal regulations govern mainly the CDW generators and DTCs; however we have found that much of the CDW goes unaccounted for or is dumped at illegal sites by private DTCs. To facilitate CDW recycling, BBMP will need to ensure that maximum CDW reaches the recycling units, implying some mechanism for DTCs to either transport it directly from the generation site to recycling plants or from the disposal sites. The DTCs could also be provisioned to offer segregated CDW at additional charges to the user. It is apparent that BBMP has not been able to fully enforce the CDW norms in their existing shape. Therefore, in order to facilitate a functioning CDW supply chain, it will have to significantly step-up enforcement. If successful in doing so, BBMP can effectively free itself up from expending significant resources in CDW disposal.

The products from CDW processing in Bengaluru must have a market to facilitate their diffusion and uptake as building materials. Given the scale of expected construction activity in Bengaluru over the next 5-10 years, the demand for building materials already exists locally. To compete against conventionally produced building materials, CDW-based products will require not only certification from appropriate testing and certifying authorities, but also to be demonstrated as cheaper substitutes without compromising on strength and other important aspects. The two functions can also be performed within the city boundaries, for example Bengaluru University and Indian Institute of Science (IISc) contain facilities to test and certify products from CDW; institutions such as CREDAI, Karnataka Public Works Department (KPWD), Karnataka Housing Board (KHB), Bengaluru Development Authority (BDA), etc. can significantly help promote CDW-based building materials by using these for the numerous non-structural applications where they can easily replace conventional products. This can be done via institutional purchase mandates, white-papers, awareness campaigns, etc.

[5] Many Green Building rating systems (e.g., LEED, GRIHA, etc.) incorporate the recycling of construction waste as building materials. According to Mr. Hemant Kumar of KSCST, in the best cases, this can reduce the demand for conventional materials (which are scarce and costlier to extract) by up to 25%.

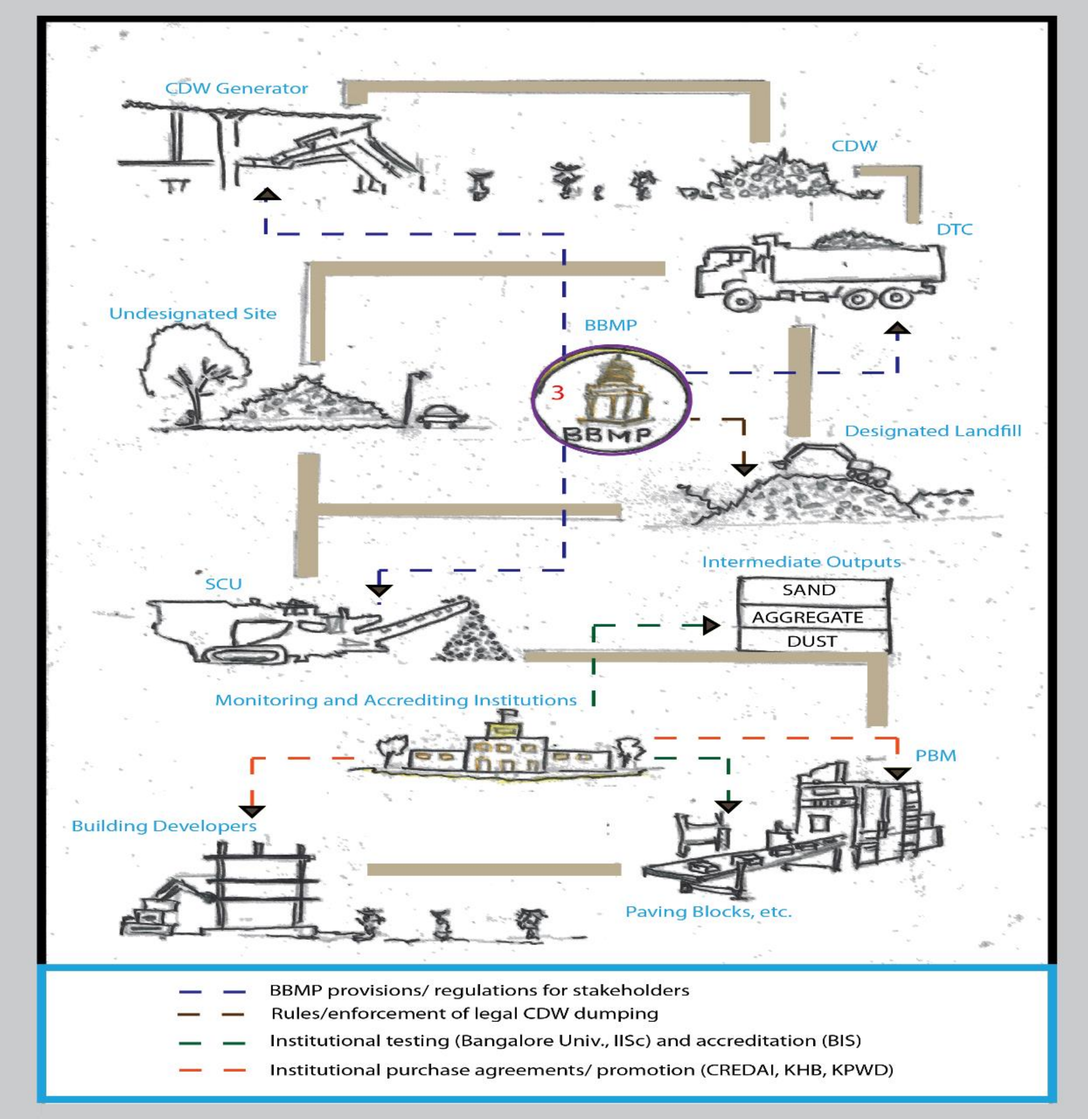

Figure 17: CDW disposal and processing ecosystem in Bengaluru

6.2. Financial Modelling of SCUs and IPBMs

6.2.1. Data and Methodology

Although no functioning models of entirely CDW-based manufacturing units exist in Bengaluru, site visits to SCUs, PBMs and equipment suppliers, and the CDW processing plant in Ahmadabad has thrown some light on the investment costs for setting up CDW processing units. Figure 18 shows these costs for SCUs and Integrated PBMs (IPBMs) that produce aggregates, m-sand and dust, or paving blocks from CDW.

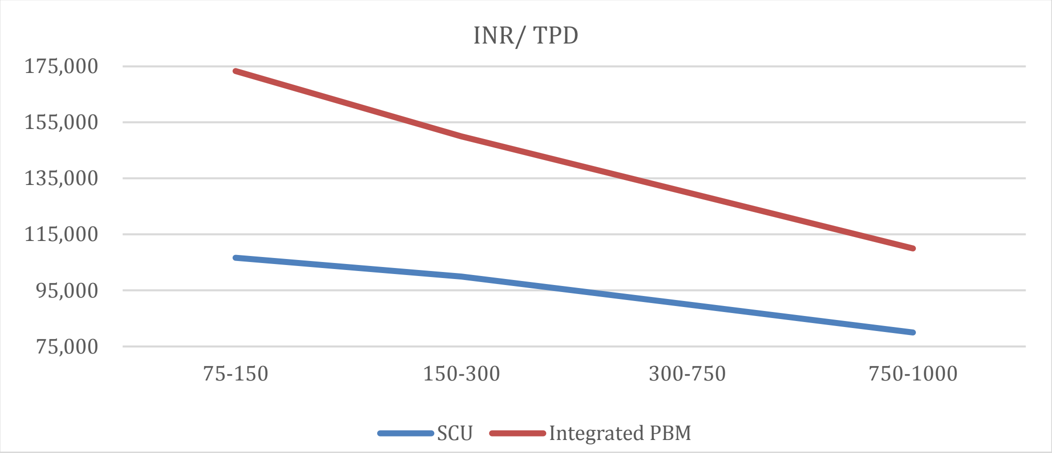

Figure 18: Investment costs vs size for CDW processing plants

(Source: Authors' analysis)

From Figure 18, the scale economies for such units become apparent. However, given the current situation of dispersed and largely unregulated CDW generation and disposal, there is a trade-off between size and feasibility of operations, which pertains to supply linkages. Therefore, it may seem attractive to go for larger sized units, but they may not be able to perform as efficiently as a number of smaller dispersed units due to reasons of transportation and existing logistical arrangements for CDW.

Figure 19 provides a component break-up of the investment involved in setting up an SCU. This data was obtained from Shyam Sunder and Asundi (2015) and has been modified to account for additional investments in machinery and equipment for a CDW-based processing unit.

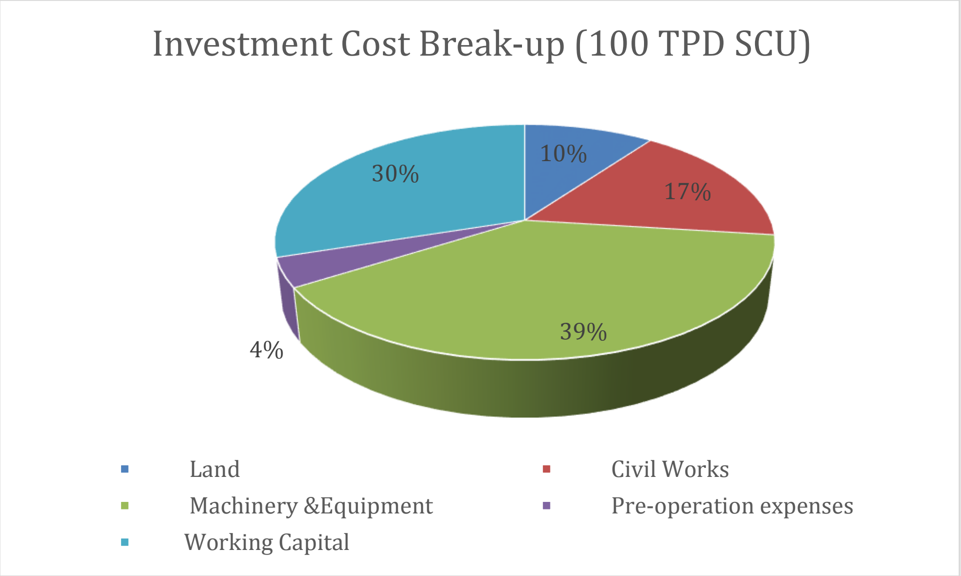

Figure 19: Break-up of investment costs for a 100 TPD SCU

(Source: Authors' analysis)

The average life of a plant is assumed to be 25 years. Real and financial costs have been taken into account for this model. Interest on borrowed capital is assumed at 17% per annum. Depreciation of 5%, 10% and 20% on buildings, machinery and office equipment respectively is assumed. The working capital represents a third of the annual operating costs comprising personnel/labour, consumables, utilities and contingent expenses, as the experience during CSTEP's M-Sand study (Shyam Sunder and Asundi, 2015) has shown. In addition, CDW handling (segregation, transportation and storage) costs are taken as INR 150/tonne[6]. Investment composition and CDW handling costs vary with the size of the plant, but only the latter has meaningful effect on the plant's profitability. Higher CDW handling costs for larger capacity plants are assumed owing to lack of CDW aggregation and well-defined supply channels for recycling.

For the purpose of this analysis, taxation and asset salvage values are not considered.

A key advantage of using CDW-based products is that they turn out to be cheaper than products made from Natural Raw Materials (NRM). Figure 20 shows this comparison[7]. The prices were obtained from interviews at site, via telephone or email, or from the manufacturers' websites. In general, experts and SCU's have maintained that CDW products are likely to be 10-20% cheaper than their NRM counterparts.

Figure 20: Prices of CDW and NRM based building materials

The cheaper cost is an important factor for CDW-based products to make inroads into urban construction projects by replacing conventional building materials.

6.2.2. Cases Examined

The following mutually exclusive cases were examined:

1. Two kinds of firms - SCUs and IPBMs
2. Five cases of size - 100, 250, 500, 750 and 1000 TPD
3. Three cases of product configuration (Table 9 and Table 10)

[6] This information was obtained from the DTCs who were asked the labour costs of segregating a truck of CDW and transportation charges to different sites for levelling. Transportation costs are around 65% of the handling charges.

[7] The price for NRM and CDW based aggregates, sand and dust were obtained from SCUs. Prices of CDW based Paving Blocks are calculated based on the assumption that they are 10-20% cheaper than NRM based blocks (Table 5).

Table 9: Product configuration for SCUs

	Aggregates	M-Sand	Dust
Case I	40%	30%	30%
Case II	30%	40%	30%
Case III	35%	35%	30%

Table 10: Product configuration for IPBMs

	60 mm Paving Blocks	80 mm Paving Blocks
Case I	60%	40%
Case II	50%	50%
Case III	40%	60%

4. Five cases of Capacity Utilisation (CU)

Table 11: Different cases of Capacity Utilisation

Case A	Case B	Case C	Case D	Case E
50%	60%	70%	80%	90%

Given that CU is influenced by market demand, raw material supply linkages, and policy and regulatory environment, the different cases of CU can otherwise be understood as scenarios of market maturity.

Therefore, 150 cases in total were examined under this study for green-field CDW processing projects.

6.2.3. Results and Discussion

Table 13 and Table 14 show the Internal Rates of Return (IRR) for 75 cases each of SCUs and IPBMs. Table 12 provides the legend for interpreting the IRR values.

Table 12: Legend for interpreting IRRs

Not Viable (NV)	IRR<0%
Not Attractive	0%<IRR<=10%
Moderately Attractive	10%<IRR<=25%
Highly Attractive	IRR>25%

Table 13: IRRs for SCUs

SCUs	100 TPD	250 TPD	500 TPD	750 TPD	1000 TPD
Case IA	NV	NV	NV	NV	NV
Case IIA	NV	NV	NV	NV	NV
Case IIIA	NV	NV	NV	NV	NV
Case IB	NV	NV	NV	NV	NV
Case IIB	NV	NV	1%	3%	4%
Case IIIB	NV	NV	NV	NV	NV
Case IC	NV	NV	8%	8%	8%
Case IIC	NV	7%	16%	17%	17%
Case IIIC	NV	3%	12%	13%	13%
Case ID	4%	11%	21%	21%	21%
Case IID	13%	20%	30%	31%	32%
Case IIID	9%	16%	25%	26%	26%
Case IE	15%	23%	34%	34%	34%
Case IIE	24%	33%	45%	46%	47%
Case IIIE	20%	28%	39%	40%	41%

100 TPD SCUs become viable only if they operate at 90% CU throughout, whereas 250 TPD SCUs offer moderate returns from 80% CU onwards. Larger units offer moderate-to-good returns at 70% or higher CU, which can be considered a threshold for the SCUs. At 60% or lower CU, it becomes difficult to justify the investment. Therefore, market assurance and organisation will play a critical role for a profitable CDW reprocessing business.

Table 14: IRRs for IPBMs

IPBM	100 TPD	250 TPD	500 TPD	750 TPD	1000 TPD
Case IA	NV	NV	NV	NV	NV
Case IIA	NV	NV	NV	NV	NV
Case IIIA	NV	NV	NV	NV	NV
Case IB	NV	NV	NV	NV	4%
Case IIB	NV	NV	NV	NV	5%
Case IIIB	NV	NV	NV	1%	5%
Case IC	NV	NV	17%	19%	23%
Case IIC	NV	NV	17%	19%	24%
Case IIIC	NV	NV	17%	20%	24%
Case ID	NV	16%	35%	37%	43%
Case IID	NV	16%	35%	38%	43%
Case IIID	NV	17%	36%	38%	44%
Case IE	12%	31%	54%	57%	64%
Case IIE	13%	32%	55%	58%	64%
Case IIIE	13%	32%	55%	59%	65%

For IPBMs, the story is very similar to that of the SCUs, except the returns are much better at higher capacities and utilisation factors. Conversely, the returns at smaller capacities (e.g., 100 TPD) are worse than those of the SCUs.

6.2.4. Financial Modelling of Existing SCUs

Owing to the existence of several SCUs in Bengaluru, it is useful to consider whether these units can add CDW processing to their operations and analyse the returns on the same. For plants with idle crushing capacity, we conducted an analysis of the marginal cost and benefits of adding a unit of CDW processing capacity. This analysis differs from the earlier cases in that the CU can be planned much better based on the historical experience of the SCUs. CDW can be used to blend with virgin material to improve the CU of existing units and offer cheaper recycled products.

The additional investment cost for CDW handling and processing (pre-crushing) is taken to be INR 6,400/TPD[8]. The CDW handling costs (operational expenses) are variable according to the planned CU. It is assumed that own capital is invested owing to the small size of investment, and depreciation is not considered. The average annual revenues were adjusted to account for the value addition from the marginal CDW processing capacity. Five cases of capacity utilisation were examined - 30%, 40%, 50%, 60, and 70%, Figure 21 shows the payback period in each case.

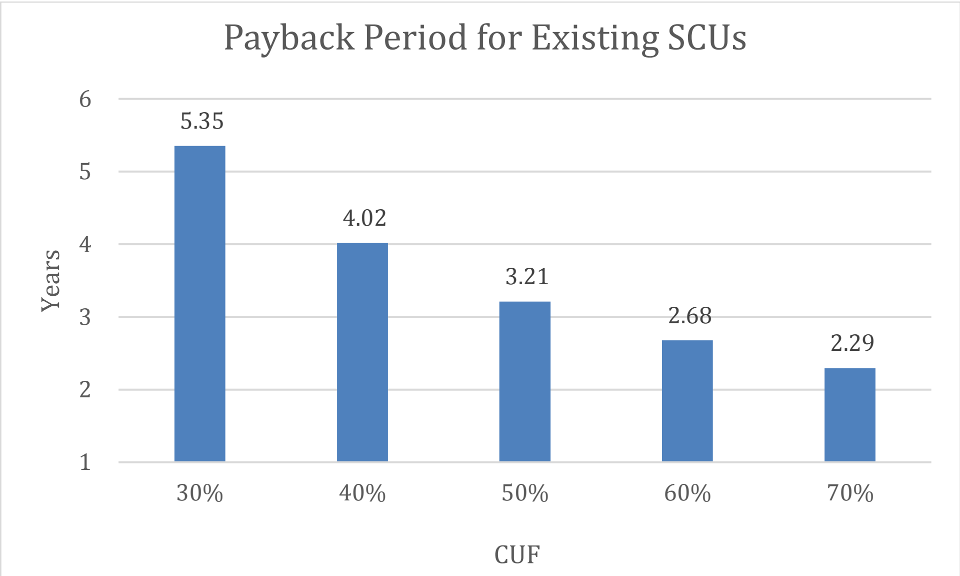

Figure 21: Payback Period for Existing SCUs with CDW Processing

CDW-based investments in existing SCUs have relatively short payback periods at 30% or higher capacity utilisation factor (CUF). This is because the additional investment is small relative to net surplus generated annually, and operating expenses can be managed more effectively in existing SCUs. Decision on such expansion must therefore carefully consider the health of existing operations and the anticipated market growth for building materials.

[8] This figure is based on expert consultation and is roughly 6% of total investment cost for setting up a CDW processing SCU (see Figure 18).

7. Conclusion and Recommendations

This study examined the status and outlook for CDW generation and management in Bengaluru. Though estimates vary from 2,500 TPD to 3,600 TPD, our own assessment indicates that CDW generation has grown from 2,981 TPD in 2012 to 3,540 TPD in 2016, and is likely to reach 4,118 TPD by 2022. Around 60-80% of this waste is fit to be recycled back into new construction with some pre-processing. This provides BBMP an opportunity to process this waste more sustainably than current practices indicate. A major fraction of the CDW is dumped along roads, highways and next to water-bodies, and most of BBMP's designated CDW disposal sites are either inactive or under-utilised. With the expected growth in construction activity, the current CDW disposal practices will become environmentally unsustainable.

The monitoring mechanism for CDW disposal is weak and most DTCs are unregulated. The only SCU utilising CDW currently is operating at unviable CU due to lack of demand for its products. Other SCUs have also cited the absence of proper market mechanisms, regulations and standards for CDW-based products. One PBM observed that CDW cannot be utilised in paving blocks, kerb stones or pothole covers from a technical aspect, but much academic literature indicates otherwise. All this indicates that there is much scepticism among the market players as regards to CDW recycling in the immediate future. This stems in part from low capacity of BBMP in implementing its CDW guidelines, as well as lack of awareness among potential market players regarding CDW utilisation.

The GIS mapping shows how CDW generation, disposal and potential utilisation sites are clustered across the southern, north-western and north-eastern parts of Bengaluru. It will therefore make sense to develop adequate processing capacities near or within these clusters to ensure that overhead costs are minimised. This is what BBMP is proposing; however, setting up 750 TPD capacity may result in low utilisation in the initial few years due to lack of a proper supply chain. BBMP may be better served to start with lower capacities, and ramp them up as the supply linkages become more streamlined.

On the other hand, the prevalence of scale economies is felt quite strongly in building material manufacturers, as investment costs per unit capacity decline with higher planned capacities. Machinery and equipment costs are around 40% of total capital costs, with crushers making up almost 60% of these costs. Investment in automated segregation equipment (such as magnetic belts), though considered optional, is recommended to prevent damage to equipment from alien material that may be present in CDW even after initial segregation. Despite these additional investments, market surveys showed that CDW-based products are on average 10-20% cheaper than conventional products. It was not entirely clear whether the cheaper prices are due to lower overall (input) costs or a strategy by manufacturers to lure potential procurers away from the status quo.

Financial modelling of green-field projects indicates that CDW processing plants of smaller sizes (100, 250 TPD) are viable only at very high Capacity Utilisation Factors (80-90%), whereas the larger plants (500, 750 and 1000 TPD) may be viable at about 70% CUF. Therefore, market assurance will play a key role, at least in the incipient stage of CDW processing in Bengaluru. For existing SCUs with substantial idle capacity, it makes a good case to invest in CDW processing as the additional investment can be recovered within 6 years, even at relatively low levels of utilisation.

In view of the above, the key **recommendations** from the study are as follows:

- Regulate, monitor and enforce the collection and disposal of CDW: This will help ensure an orderly disposal mechanism, and lead to credible data generation and monitoring for CDW management and planning.

- Bring all DTCs under purview and facilitate engagement between DTCs and SCUs: In order to maintain control over CDW activities and check informal arrangements and illegal dumping of CDW that can be re-processed, the operations of DTCs must be regulated and monitored.

- Demarcate the CDW designated sites and provide better road access: This will ease the transport bottlenecks, which are seen as a major challenge to CDW processing. This will enable smooth CDW disposal (by DTCs) as well as smooth collection (by CDW-processing plants).

- Provide a conducive market environment for CDW processing: Regulatory enforcement and oversight mechanisms need to be put in place by the BBMP, along with suitable incentives and publicity to encourage SCUs and PBMs to venture into CDW processing.

- Introduce standardisation and testing norms for CDW-derived products: This is essential to building confidence among the ultimate consumers of CDW-based products and dispel unscientific myths about the suitability of their use, especially in non-structural applications.

- Promote the use of CDW-derived products in public works: Public agencies like municipal corporations and state PWD will play a major role in the acceptance of CDW products which can potentially crowd-in the private sector developers, especially through recognition of CDW products as genuine substitutes to conventional products by inclusion in the Schedule of Rates.

- Incentivise private developers to utilise CDW on-site as well as derived products for specific applications: State and private associations such as CREDAI must devise strategies to improve awareness and generate demand for CDW-based building material via white-papers, workshops, targeted incentives for first-time users, etc.

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Appendix I: Sample Calculations for Financial Models

Greenfield Project

Capacity - 500 TPD SCU

Investment Cost - INR 45,000,000

Product Configuration - Aggregates: M-sand: Dust = 0.3: 0.4: 0.3 (II)

Capacity Utilisation - 70% (C)

CDW Handling Costs (Segregation, Transportation, Storage) = INR 150/T

Plant Life = 25 years

Maximum Operating Days = 300/year

$$Depreciation\ in\ Year\ n = 5\%\ X\ (Investment - \sum_{1}^{n-1} Depreciation)$$

$$Recurring\ Expenses = 3\ X\ Working\ Capital$$

$$Interest\ in\ Year\ n = 17\%\ X\ (Borrowed\ Capital - \sum_{1}^{n-1} Interest\ Paid)$$

$$Annual\ Revenue\ = Capacity\ X\ Utilisation\ X \sum_{Product=1}^{3} Product\ share\ X\ Price\ X\ 300$$

	Year 0	Year 1	Year 2	…	Year 24	Year 25
Depreciation on Building/ Civil Works (1)		382,500	363,375		117,564	111,686
Depreciation on Machinery & Equipment (2)		1,755,000	1,579,500		155,545	139,990
Depreciation on Office Furniture and Equipment (3)		360,000	288,000		2,125	1,700
Recurring Expenses (Operating Costs) (4)		40,500,000	40,500,000		40,500,000	40,500,000
Interest on Borrowed Capital (5)		7,650,000	6,349,500		105,307	87,405
CDW Handling Costs (6)		15,750,000	15,750,000		15,750,000	15,750,000

Annual Production Costs (7)= Sum (1-6)		66,397,500	64,830,375		56,630,541	56,590,781
Annual Revenues (8)		68,985,000	68,985,000		68,985,000	68,985,000
Annual Profit (Cash Flow)	-45,000,000	2,587,500	4,154,625		12,354,459	12,394,219
Cumulative Profit (Net Cash Flow)	-45,000,000	-42,412,500	-38,257,875		192,796,264	205,190,483

Discount Rate for NPV = 10%
NPV = INR 27,169,469
IRR = 15.98%
Payback Period = 7.26 years

Existing SCUs

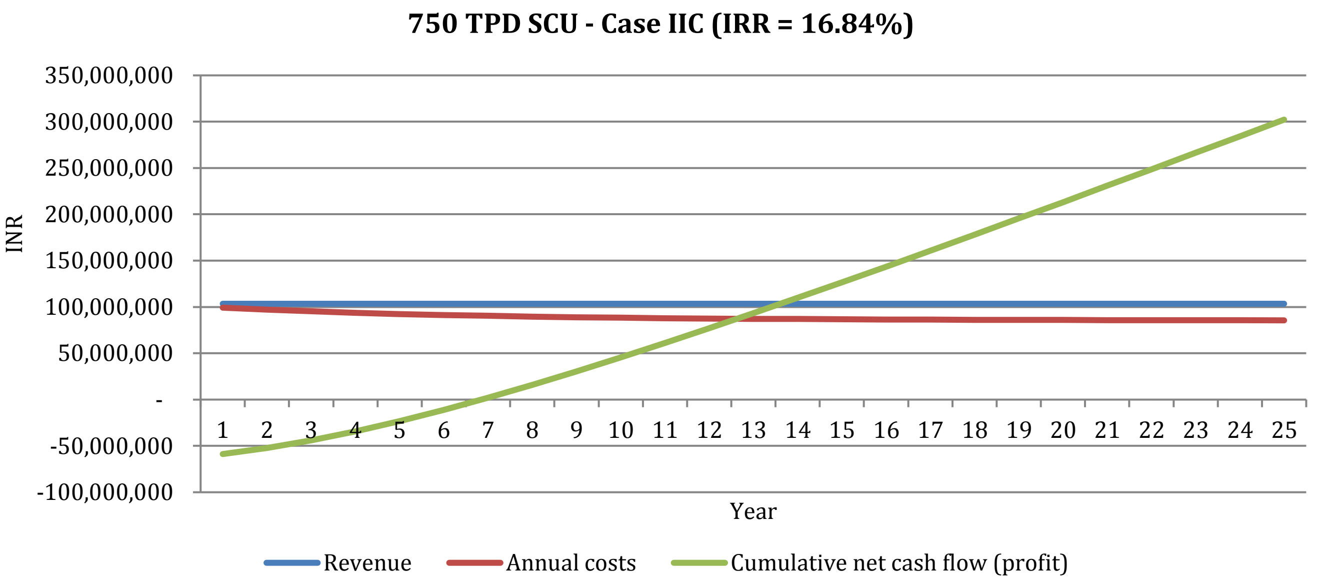
1. Investment Cost for CDW Processing = INR 6,400/TPD
2. Capacity Utilisation Factor (CUF) = 40%
3. Annual Operating Costs (CDW handling, etc.)

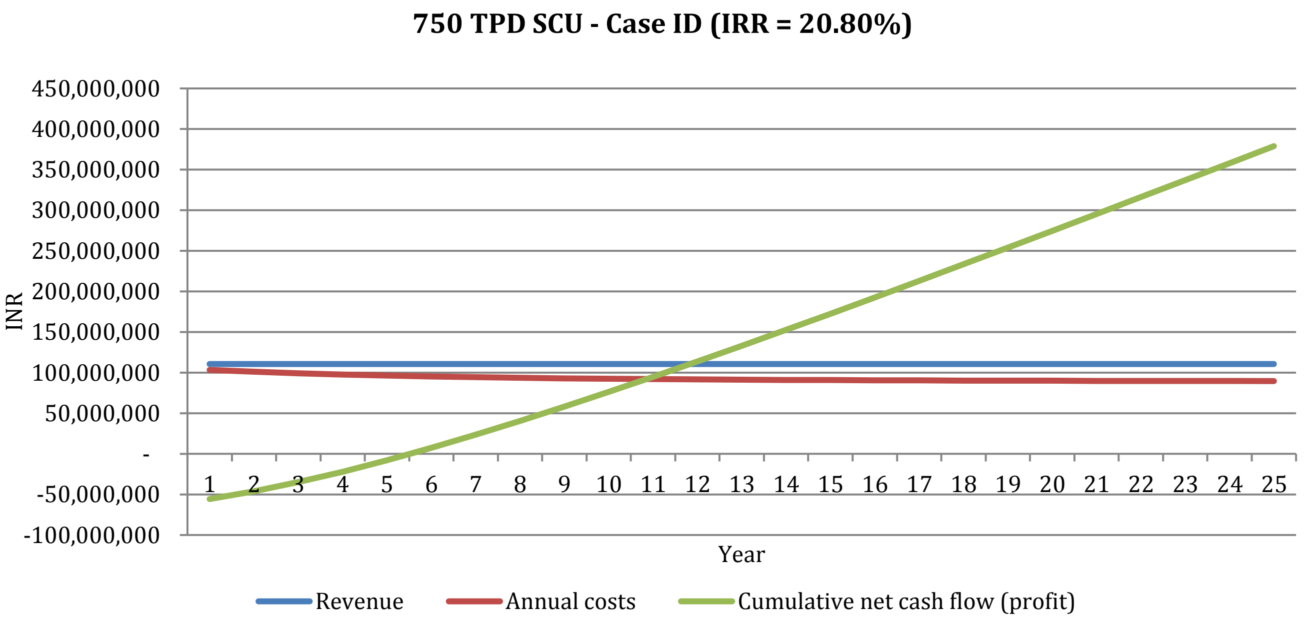
$$=CDWhandlingcosts\left(INR\,\frac{150}{T}\right)*MaxOperatingDays(300)*CUF = INR\,\frac{18{,}000}{T}/year$$

4. Adjustment Factor for Output = $\frac{\boldsymbol{CDWProcessingInvestment}}{\boldsymbol{SCUInvestment}\ (\boldsymbol{INR}\frac{\mathbf{25{,}600}}{\boldsymbol{T}})} XPriceAdjustment\ (1.25)$
5. Annual Revenue = INR 19,594/t/year
6. Annual Net Cash Flow = (5)-(3) = 1,594/t/year
7. Payback Period = (1)/(6) = 4.02 years

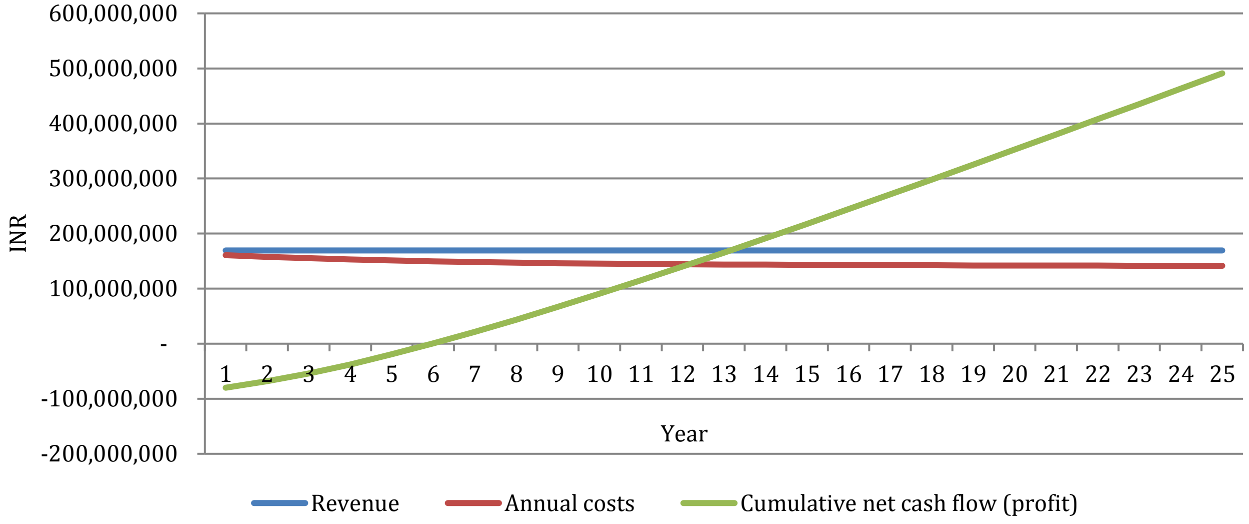
Appendix II: Sample Results for Individual Units

Greenfield Projects

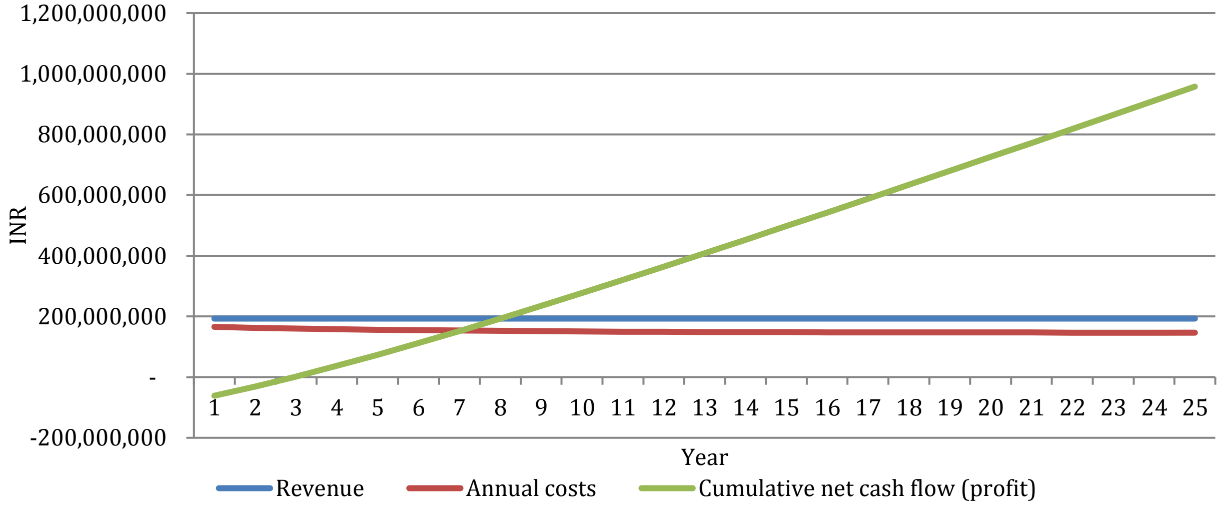




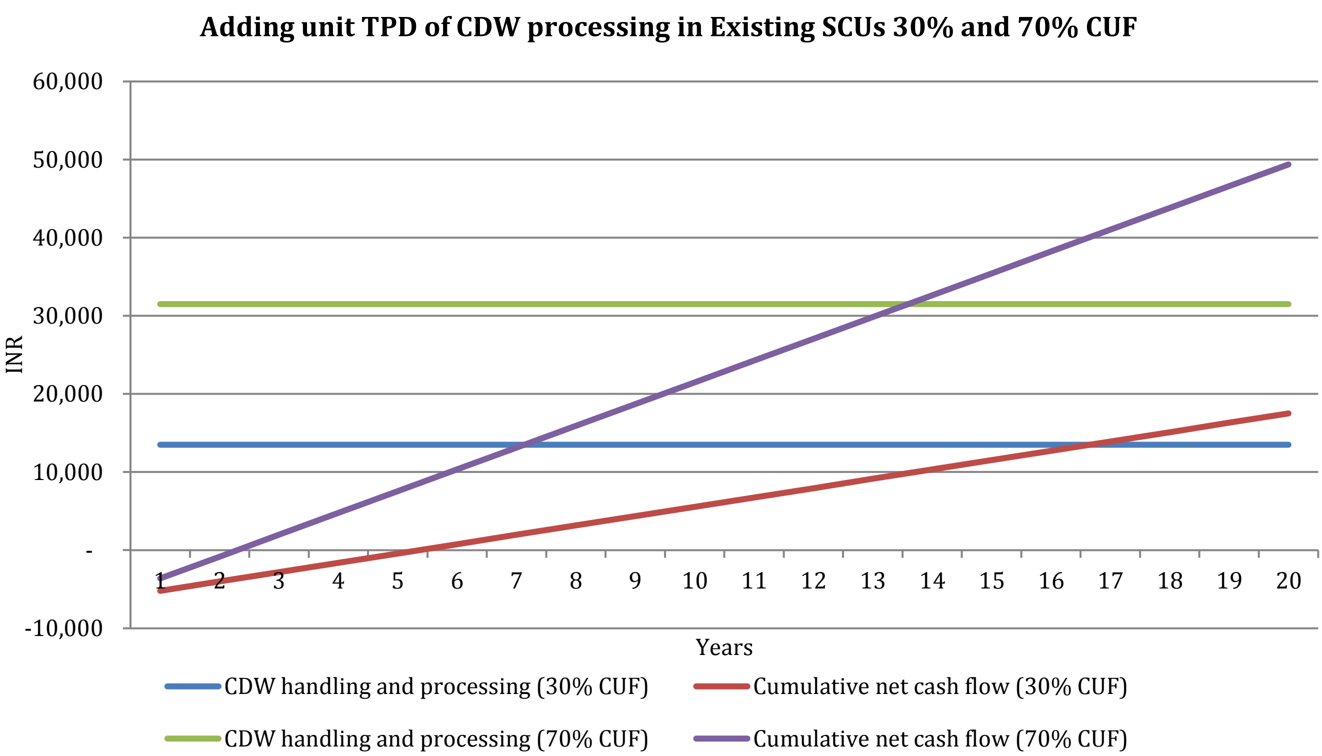
750 TPD IPBM Case IIC (IRR = 19.21%)



750 TPD IPBM Case ID (IRR = 37.29%)



Existing SCUs



Appendix III: Estimation of CDW from Construction Projects in Bengaluru

The quantity of CDW generated can be estimated from the total built-up area of the construction projects in a city/region under examination. Databases were created that could estimate an approximate quantity of debris generated by each project upon input of its total built-up area. Details of all newly built or approved large residential construction projects in Bengaluru City were obtained, and the amount of C&D generated by each project was calculated from the Guidelines for Construction and Demolition Waste Management of BBMP (as shown in Table 1).

Along with this data collection, the nearest CDW disposal sites were identified for each construction project. The study has been conducted for 25 construction projects in Bangalore Urban district and has found about 200,000 tonnes of CDW generation during the construction period. This study has been extended to locate CDW disposal sites near each construction project. It is also to be noted that there are about seven landfill sites approved by BBMP as CDW disposal sites, whose areas range from 1 acre to about 49 acres. These data can also be used by builders and local bodies to dispose the CDW generated during construction. Details of CDW disposal sites for large construction projects in Bangalore are provided below.

Sl. No.	Property Name	Location	Acreage	CDW (t)	Nearest CDW Disposal Site
1	Pursuit of a Radical Rhapsody	Whitefield	35	16,900	Kadu Agrahara
2	Presidential Tower	Yeswanthapura	13	6,313	Mallasandra
3	Malhar Terraces	Kengeri	2	1,107	Anjanapura
4	Bharatiya City	Thanisandra Main Road	126	61,188	Kannur
5	White Waters	Gunjur	3	1,214	Kadu Agrahara
6	Mahendra Aarna	Electronic City	1	583	Kadu Agrahara
7	Song of the South	Begur off Bannerghatta Road	33	16,026	Kadu Agrahara
8	Prestige Misty Waters	Hebbal near Nagavara Lake	6	2,768	Mittaganahalli
9	Arvind Sporcia	Near Rachenahalli Lake	5	2,428	Kannur
10	Mantri Lithos	Near Manyata Embassy	6	2,914	Kannur
11	Godrej Platinum	Ayyappa Layout	2	971	Mittaganahalli
12	Embassy Lake Terraces	Near Columbia Asia hospital	15	7,042	Mittaganahalli
13	Shriram Hebbal One	Near Bethel AG Church, Hebbal	1	631	Mittaganahalli
14	Hiranandani Glen Classic	Devi Nagar, Bhadrappa Layout	10	4,856	Srinivasapura & Kogilu

15	Sobha City	Near Thanisandra Main Road, Hebbal	36	17,482	Srinivasapura & Kogilu
16	Valmark Orchard Square	8th Phase, JP Nagar	3	1,578	Anjanapura
17	Prestige Falcon City	Kanakpura Road	49	23,601	Anjanapura
18	Salarpuria Sattva Greenage	Hosur Road	21	10,198	Anjanapura
19	Casa Irene	Bannerghatta Road	11	5,342	Anjanapura
20	MJ Lifestyle Astro	Electronic City, Phase 2	3	1,457	Anjanapura
21	Mantri Blossom	Lalbagh Road	3	1,214	Anjanapura
22	Saibya Sterling	HSR Layout	1	486	Anjanapura
23	SV Spring Woods	Kanakpura Road	2	728	Anjanapura
24	Salarpuria Sattva Cadenza	Kudlu Gate	6	2,817	Anjanapura
25	Purva Skydale	Sarjapur Road	5	2,258	Kadu Agrahara

Appendix IV: List of SCUs and PBMs

List of Stone Crushing Units (Source: KSPCB)

Sl. No.	Name	Address	Latitude	Longitude
1	Preetham Stone Crusher	Bettalsur Village, Bengaluru North Taluk	13.1611	77.6196
2	Venkata Stone Crusher	Sy. No.88, Chagalatti Village, Bengaluru North Taluk	13.1198	77.6589
3	Sree Manjunatha Stone Crusher	Sy. No. 92, Chagalatti Village, Bengaluru North Taluk	13.1099	77.6830
4	Vijayalaxmi Stone Crusher	Sy. No. 96/4, Bettahalasur Post, Bengaluru North Taluk	13.1611	77.6196
5	Pooja Stone Jelly Crusher	Sy. No.19 and 20, Mittaganahalli, Bidarahalli Hobli, Bengaluru	13.1088	77.6535
6	Venkarama Reddy Crusher	Sy. No.24/1, Kadagrahara Village, Bidarahalli Hobli, Bengaluru East Taluk	13.0859	77.6958
7	GMS Stone Crusher	Sy. No. 77, Dodderi Village, Tavarekere Hobli, Bengaluru	12.8723	77.3689
8	Sri Byraveshwara Stone Crusher	Sy. No. 20/P-10, Madapatna Village, Tavarekere Hobli, Bengaluru	12.9302	77.3495
9	Bengaluru Super Alloy Castings	Plot No. 113, Phase-II, Jigani Ind. Area, Anekal Taluk, Bengaluru	12.7167	77.6668
10	Chitrashree Stone Crusher Unit-2	Sy. No.60, Kolur Village, Tavarekere Hobli, Bengaluru	12.9389	77.3237
11	Kashyap Construction Pvt. Ltd.	Sy. No.77, Dodderi Village, Tavarekere Hobli, Bengaluru	12.8723	77.3689
12	S.L.N. Stone Crusher	Sy. No. 61/P12, Kolur Village, Tavarekere Hobli, Bengaluru South Taluk	12.9389	77.3237
13	M/s. S.L.N. Stone Crusher	Sy. No. 26/P23, Donnenahalli Village, Tavarekere Hobli, Bengaluru South Taluk	12.8771	77.3932
14	Sri Lakshmi Venkateshwara Stone Crusher	Sy. No. 16/1B3, Kanayakana Agrahara, Jigani Hobli, Bengaluru	12.8414	77.5603
15	R.S.R. Stone Works	Sy. No. 263, Thammanayakana halli, Bengaluru	12.6884	77.6471
16	Jai Bharathi Granites	Sy. No. 48, Mahanthalingapura Village, Anekal Taluk, Bengaluru	12.7167	77.6668
17	Sri Lakshmi Venkateshwara Crusher	Sy. No. 47, Mahanthalingapura Village, Anekal Taluk, Bengaluru	12.7167	77.6668
18	Chowdeshwari Crusher	Sy. No. 35A, Anekal Taluk, Bengaluru	12.7167	77.6668

19	RNS Infrastructure Limited	Sy. No. 47/Ps, Mahanthalingapura Village, Anekal Taluk, Bengaluru Urban	12.7167	77.6668
20	SLN Stone Crusher	Sy. No. 88, Chagalatti Village, Bengaluru	13.1201	77.6587
21	Sri Manjunatha Stone Crusher	Sy. No. 88, Chagalatti Village, Bengaluru	13.1176	77.6563
22	Muneshwara Stone Crushers	Sy. No. 425, Bagalur Village, Bengaluru North Taluk	13.1541	77.6678
23	Sri Manjunatha Diggers & Stone Crusher	Sy. No. 376, Chagalatti Village, Bengaluru North Taluk	13.1125	77.6539
24	Channakeshava Stone Crusher	Sy. No. 425, Bagalur Village, Bengaluru North Taluk	13.1541	77.6678
25	Sri Lakshmi Narasimha Stone Crusher, (SLN Stone Crusher)	Sy. No. 2/P 17, Mittaganahalli, Bidarahalli Hobli, Bengaluru	13.1088	77.6535
26	Sri Siddeshwara Stone Crusher	Sy. No. 271/P2, Bagalur Village, Bengaluru	13.1541	77.6602
27	Sri Manjunatha Crusher	Sy. No. 271, Bagalur Village, Bengaluru	13.1541	77.6602
28	N.K. Stone Crusher	Sy. No. 271/P1, Bagalur Village, Bengaluru	13.1541	77.6602
29	Nandini Stone Crusher	Sy. No. 271/P1, Bagalur Village, Bengaluru	13.1541	77.6602
30	Lakshmi Kiran Stone Crusher	Sy. No. 86, Chagalatti Village, Bengaluru	13.1252	77.6602
31	Sri Venkateshwara Stone Crusher	Sy. No. 271/P1, Bagalur Village, Bengaluru	13.1541	77.6602
32	SLV Stone Crusher	Sy. No. 271/P1, Bagalur Village, Bengaluru	13.1541	77.6602
33	Sri Lakshmi Stone Crusher	Sy. No. 16/1B3, Kannayakana Agrahara, Anekal Taluk, Bengaluru	12.8414	77.5603
34	S.M. Crusher Works Unit-IV	Sy. No. 9, Bellahalli Village, Yelahanka, Bengaluru	13.1041	77.6474
35	Manjunatha Stone Crusher	Sy. No. 93/5, Bettahalasur Village and Post, Bengaluru	13.1611	77.6195
36	S.L.N. Stone Crusher	Sy. No. 271/P1, Bagalur Village and Post, Bengaluru	13.1541	77.6602
37	Sri Mahakala Byraweshwara Swamy Stone Crusher	Sy. No. 96/2, Bettahalasur Village, Bengaluru	13.1611	77.6195
38	Sri Vinayaka Stone Crusher	Sy. No. 10/2 and 7/1, Mittaganahalli Village, Bengaluru	13.1088	77.6535
39	Sree Manjunatha Stone Crusher	Sy. No. 92, Chagalatti Village, Bengaluru	13.1234	77.6563
40	Manjunatha Stone Crusher	Sy. No. 93/5, Bettahalasur Village, Bengaluru	13.1611	77.6195

41	Sri Muneshwara Stone Crusher	Sy. No. 425, Bagalur Village, Bengaluru	13.1541	77.6602
42	Balaji Granites (Stone Crusher)	Sy.7/2.7/3.7/4, Mittaganahalli Village, Bidarahalli Hobli, Kannur Post, Bengaluru	13.1088	77.6535
43	Nandini Stone Crusher	Sy. No.:271/p1, Bagalur Village, Bengaluru	13.1541	77.6602

List of Paving Block Manufacturing Units (Source: KSPCB)

Sl. No.	Block Manufacturers	Address	Contact details
1	Sri Balaji Flooring	No. 128/2 - A, Kempegowda Nagar, Magadi Main Road, Behind Shell Petrol Bunk, Near College Stop	7829218971
2	Style Earth	55, 4th Cross, Somappa Layout, Sampige Halli, Jakkur Post, Yelahanka, Bengaluru	080-48113116
3	Sri Someshwara Concrete Blocks	No.57, VeeraSagara Main Road, Dodda Petta Halli, Vidyaranyapura, Bengaluru - 560097, Near Government School	9945201545
4	Wellcon	No.4. Dr.Raj & Ramu H S Residency, No.593, 11th `B` Main, 13th Cross, Yelahanka New Town, Bengaluru	9845107475 8088997475
5	Shree Banashankari Construction	No.5/1, Hosakere Grama, Hobli, Kengeri, Bengaluru - 560060, Near Sulikere Grama	080-39557180
6	Sri Venkateshwara Parking Tiles And Pavings	No 48/3, Thirumala Dhaba Road, Thirumalappa Nagar, Attur layout, Yelahanka, Bengaluru - 560064	080-33722842
7	Indian Pavings and Tiles	No.48/10, Hosur Bande, Kannur Post, Bengaluru East, Kothanur, Bagalur, Bengaluru - 562149, Near Bagalur Road	080-33538131
8	Udaya Paving Blocks	No. 42, Ramohalli, Mukti Naga Temple Road, Doddaladamara Road Bengaluru	7053136277
9	RV Tiles Co.	No.14,100 feet Inner Airport Ring Road, near Ejipura signal, Koramangala, Vivek Nagar post	7053136110
10	S. V. Enterprises	No.59/3d2, Avalahalli, Virgonagar, Bengaluru - 560049, Near Glass Factory	080-33674277
11	Futura Blocks Pvt. Ltd.	Tavarekare, Magadi road	080-33056722
12	Sree Manjunatha Floorings	No.5, Pantharapalya, Nayandanahalli, Bengaluru – 56, near Nayandanahalli lake and Railway Station	080-33536695
13	Divya Tiles	Kada Agrahara Village, Hobli Hoskate Village, Kothanur, Bengaluru	080-39627670
14	Aadhya Concrete Blocks	No. 529, 1st A Main, 2nd Stage, 3rd Block, Nagarabhavi, Bengaluru plant in Magadi road near water tank	080-48429712

15	Icon Pavings India Pvt. Ltd.	Survey No 27, Vaderahalli, Mathahalli Post, Dasanapura Hobli, Nelamangala, Bengaluru - 562123	080-33618679
16	Decora Designer Tiles Private Limited	No. 21, G-1, Madhuban, Kaggadaspura Main Road, New Thippasandra, Bengaluru	9916063999
17	GCB & Company	near Rajarajeshwari Medical College, Mysore road	9448014870
18	Conmat India Pvt. Ltd.	Survey No. 31, Suggatta Village., Bengaluru North Bengaluru	9880488765
19	Unitech Tiles And Pavings	Budigere near Chowdappanahalli lake	080-33619490
20	Supreme Tiles & Pavings Factory	No.39/5, Budigere Post, Jala Hobli, Budigere To Devanahalli Road, Budigere, Bengaluru - 562129, Manchappanahalli	080-33536155
21	P. V. Enterprises	No.95/96, Gottigere Gate, Venkatappa Layout, Pillaganahalli, Bannerghatta-Gottigere, Bengaluru– 560083	080-33792155
22	Basant Betons	plants in Harohalli and Jigani	080-33052105
23	Sri Tulsi Concrete Precast	#140, 23km, Mysore road, Kumbalgodu, Bengaluru– 560074	9945026489
24	RMN Enterprises	No.23,Renukamba Nilya, Valaba Nagar, Vasanthapura Main Road, Konanakunte, Bengaluru - 560062	9066595922
25	Svt Concrete Blocks	Thyvakanahalli Village, Sarjapur, Hobli, Attibele, Bengaluru - 562107, Near Exide Gate near confident aeries layout	080-27823595
26	Sobha Concrete Products	No.329, Kiadb, Bommasandra-Jigani Link Road, Ind. Area, Jigani, near Bio Con	9980070106
27	Masa Concrete Plants India Pvt. Ltd.	No.5, Bommasandra Industrial Area, Bengaluru - 560099, Kiadb, Attibele Hobli, Anekal Taluk near Shetron	080-26283848
28	Shree Durga Concrete Block And Constuctions	No.85, Nayandahalli, Mysore Road near Bhel	9632973289
29	Excel Precast	No. 63, 1st Floor, Ayodhya, Ravishankar Residency, Sanjeevini Nagar, Kodigehalli, Bengaluru near United Bank of India	9886590394

Appendix V: Market Survey Questionnaire

BBMP

1. Current policy/guidelines on CDW management
2. Is there enough enforcement from the government?
3. Awareness about products from CDW and readiness to use
4. Challenges faced and future plans in handling CDW
5. Data on locations of projects, waste being generated, log sheets of construction projects, contacts of demolition contractors, etc.

Suppliers of Construction Material

Stone Crushing Units (SCU)

This plant-level survey seeks inputs on the operational parameters of stone crushing units. The purpose of this survey is also to analyse the stone crushing unit and check the possibility of Construction and Demolition Waste processing at this unit.

- Plant Name: ___________
- Address/Contact Details:____
- Unit Capacity:___________ tonnes/day
- Number of crushing/grinding units:_________
- Capital cost by unit _______________ INR Crore

1. What are the major products of the unit and provide the details of crushers/technologies adopted in the plant?
2. Stages of crushing and product size at each stage- primary, secondary and tertiary
3. Is there any scope to process CDW at the plant?
4. What are the challenges (logistical, financial, technical, etc.) in processing CDW compared with regular stone crushing process?
5. What is the nature of support required from the state government/BBMP?

Plant Parameters

Year/Parameter	2013-14	2014-15
Capacity		
Main products: gravel , sand, etc.		
Coarse vs. fine ratio		
Number of crushing units		
Number of grinding units		
Annual energy consumption		
Specific energy consumption		

CDW Contractors

1. How many tonnes of CDW do you carry per day?
2. How much do you charge for each tonne or for each trip to carry CDW?
3. Is there any traffic problem in carrying CDW?
4. How much do the suppliers need to pay for land filling?
5. Are there any C&D recyclers available to carry the waste?
6. Do you segregate the waste?
7. Have you received any training on CDW management?

Other Industries (PBMs, landscaping contractors, sub-contractors, etc.)

1. Location of manufacturing plant
2. Distance from storage area
3. Transportation costs
4. Types of products
5. Recycled products, if any?
6. Awareness of recycled CDW products
7. Price list of products
8. Applications of these products
9. Best-selling product
10. End users
11. In what kind of construction are your products used the most (such as residential buildings, parks, schools, etc.)?

Contractors and Consultants

1. Procurement of raw materials
2. Current prices of raw materials
3. Operating costs
4. Area of construction project
5. Products being used in construction (quantity and price)
6. Waste management policy on site
7. Estimation of waste being generated
8. Any use of recycled products
9. Sustainable methods/techniques being applied
10. What would be the effect of using recycled products in construction?

Research Institutions

1. What are the ways/methods to increase the recovery rate (reuse and recycle) of CDW?
2. What are the differences between the properties of recycled products and natural products?
3. Feasibility of using recycled products?
4. What technologies are available to process CDW and how energy-intensive are these processes?
5. Do you organise any training programmes on CDW management?
6. Is there any CDW collection mechanism provided by the government or by private business holders?

CREDAI

1. What are the primary efficiency measures in development/ construction activity that is promoted by your organisation?
    a. What are the best examples of resource-efficient construction projects in Bengaluru
2. Is there an organisation-wide policy/ template of good practices for construction waste disposal/reuse?
3. How much real estate development typically happens in a year in Bengaluru? (in square foot terms)
4. How do you expect the size of residential and commercial real estate to grow in Bengaluru?
    a. Magnitude
    b. Geography
5. What is the annual demand for paving block/ concrete/ aggregates (fine and coarse) in Bengaluru?
6. What is the nature of interaction with policy/ regulatory bodies in the government?
    a. Is there any engagement on the topic of green building construction, especially with regard to the use of CDW?
7. How does the use of recycled/waste materials affect your business proposition overall?
    a. Are there any special incentives or goodwill (LEED rating, etc.) linked with the use of such materials?
8. What part of structural/non-structural applications would CDW be most suitable for? What are the associated risks/concerns?

9. Would you be ready to pick up CDW products on a larger scale? What are the conditions [(cost, technical, financial, logistical etc. - qualifying (necessary) and incentivising (optional, but good to have)]?
10. Is there any amount of CDW already in circulation in your knowledge? If so, how do you think it is performing versus the regular materials used?

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