Market Study on Construction and Demolition Waste Utilisation in Ahmedabad

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Resource Efficiency and Sustainable Management of Secondary Raw Materials

B-5/1, Safdarjung Enclave
New Delhi 110 029 India
T: +91 11 49495353
E: info@giz.de
I: www.giz.de

Responsible
Mr. Uwe Becker
E: uwe.becker@giz.de

Authors
DEVELOPMENT ALTERNATIVES
Achu R. Sekhar, Krishna Chandran, Vaibhav Rathi

Advisors
Dr. Soumen Maity, Dr. K. Vijayalakshmi

Reviewers
GIZ
Dr. Abhijit Banerjee, Dr. Rachna Arora, Uwe Becker

Research Partner

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Executive Summary

Cities are growing at a faster rate and so is the need for infrastructure and housing. As a result new construction, retrofitting and demolition of old buildings to construct new ones are commonly observed in cities. All of these activities generate Construction and Demolition (C&D) waste in significant quantities which in spite of its great potential to be reused in building materials is poorly managed in India. Ahmedabad is one of the first cities to successfully implement model for management and utilisation of C&D waste in to making new building products. Though the model is sustainable, it cannot cater to all of the C&D waste generated in the city due to various logistic challenges.

This report provides an analysis and evaluation of Construction and Demolition (C&D) waste management scenario in Ahmedabad and proposes suitable strategies to enhance the processing and utilisation of C&D waste. "Fostering Resource Efficiency and Sustainable Management of Secondary Raw Materials in India" is a project being implemented by GIZ in India and Development Alternatives, the knowledge and implementation partner of GIZ in this project conducted the study as part of this project.

C&D waste management in Ahmedabad is based on Public Private Participation (PPP) model. Ahmedabad Municipal Corporation (AMC) picks up and dumps C&D waste at 16 designated sites within City municipal limits. Amdavad Enviro Projects Pvt Ltd. (AEP), a private enterprise picks up waste from designated sites segregates and processes C&D waste in to various aggregates which are then used to make building products such as paver blocks, kerb stones etc. The survey revealed that out of the 16 only two dump sites are actively used and C&D waste dumped in rest of the sites is not utilised for processing. This is because of limited capacity of processing facility, challenges in waste transportation due to long distance of some dump site from processing facility and limited quantity of waste in inactive dump sites makes pick-up logistically unviable. However following a decentralised approach for waste processing can enhance use of C&D waste in Ahmedabad city. There are many paver block manufacturing clusters in Ahmedabad which can use aggregates processed from C&D waste. A survey of manufacturers in two such clusters revealed that there is acceptability of recycled aggregates if there is regular supply at rates lower than natural aggregates. It was also found that price of natural aggregates is directly proportional to distance of stone quarry from paver block manufacturers. Paver block manufacturers situated close to the stone quarry are paying less for per unit of aggregate than those situated far from them.

The opportunity thus lies for a C&D waste mobile processing unit or standalone processing unit of small capacity in dump sites near to the paver block manufacturers. The study identified two clusters of designated dump sites where such units can be set up. It is understood that the decentralised model will work if there is a viable business case. Thus a total of 6 business cases for standalone and mobile crushing units are developed based to prove the cost savings in decentralised recycled products business in Ahmedabad. Cost savings of 85%-90% was observed for recycled aggregates and about 10%-15% was observed for finished products (Paver blocks, Kerb Stones etc.). The survey findings show that there are challenges in the existing system. They can be addressed by either following a decentralised approach of C&D waste management or increasing capacities of existing unit and providing differential tipping fee (if necessary) to the waste processor based on distance of dumping sites from the processing facility.

Recommendations discussed on this report include effective utilisation of C&D waste collected from 16 dumping sites through decentralised approach, increasing the sanctioned capacity of the existing plant, providing logistics support to existing processing plant through differential

tipping fees, enhancing awareness among entrepreneurs in Ahmedabad towards the use of C&D waste to be a secondary raw material and its potential to generate income. Other recommendations on improving product quality made out of C&D waste such as introduction of preferential procurement, green labelling and other certification provided by National level organisations and the need for more research and development activities focused on use of fine particles (silt and clay) were also discussed.

Key findings

- Construction and Demolition waste is dumped in 2 sites out of the 16 designated sites.
- Cost of virgin aggregates is directly proportional to distance of stone quarries from the building material manufacturers.
- Opportunity exist for decentralised management of C&D waste if there is a viable business cases for mobile crushing units or standalone C&D waste processing facilities of small capacities.
- Acceptability of recycled aggregates was found amongst the paver blocks manufacturers only if uninterrupted supply is guaranteed at lower rates than that of virgin aggregates.
- Business case analysis suggests that cost savings up to 21% from processing of C&D waste can be observed as compared to natural aggregate.
- Cost savings up to 15% can be observed for finished products such as paving blocks made from recycled aggregates
- Lack of awareness about C&D waste aggregates and products amongst building material manufacturers

Abbreviations

C&D	–	Construction & Demolition
AMC	–	Ahmedabad Municipal Corporation
AEP	–	Amdavad Enviro Projects
TPD	–	Tons Per Day
C.P	–	Cost Price
S.P	–	Selling Price
ULB	–	Urban Local Body
PPP	–	Public Private Partnership

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Introduction

Ahmedabad, also known as the 'Manchester of India', is the largest city in Gujarat and seventh largest in India. It is one of the most important economic and industrial hubs in India. Ahmedabad Municipal Corporation (AMC) was formed during the 15th century. Growth in silk and cotton industry has spurred the development of the city. The AMC area is divided into 64 wards and 6 zones, namely Central, North, South, East, West and New West. Majority of the population was concentrated within the AMC limits upto 1981. Expansion of the peripheral areas began in the 1980s. 180.01 sq. km and 79.66 sq. km area had been added on the Western side and Eastern side of the city respectively (Amdavad Municipal Corporation, 2016).

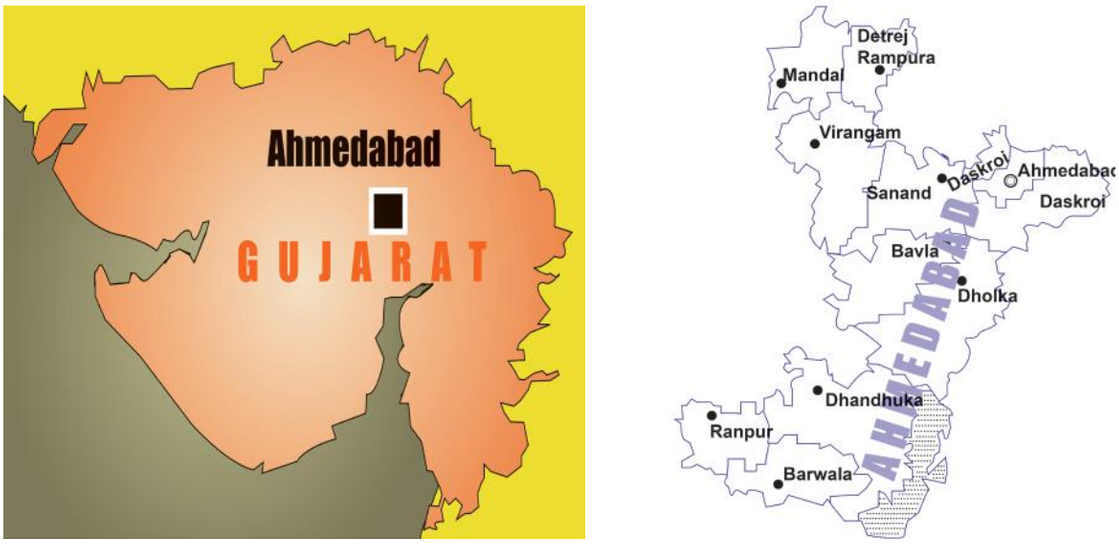

Figure 1: Map of Ahmedabad

Table 1: Demographics of AMC

Area	464 Sq. Km
Population	5.5 Million
No. of Wards/Zones	64/6

Objective of study

“Fostering Resource Efficiency and Sustainable Management of Secondary Raw Materials in India” is a project being implemented to achieve an improved understanding of resource challenges and resource efficiency with focus on Construction and Demolition (C&D) waste and its potential for reuse as a secondary material in the construction sector in India. As a part of the project, Development Alternatives (DA) along with GIZ conducted a market study in the city of Ahmedabad to understand the C&D waste ecosystem and evaluate various stakeholders’ interests towards the use of C&D waste processing for end products. Surveys and interviews were conducted involving the various actors in the C&D supply chain to collect data on the existing waste deposition sites, location of various stone quarries, building material manufacturers and C&D processing units.

The overall objective of the study is to primarily evaluate the Construction and Demolition (C&D) waste management scenario in Ahmedabad and recommend suitable strategies to enhance the processing and utilisation of C&D waste.

Construction trends in Ahmedabad

Ahmedabad is one of the fastest growing cities in India leading to huge infrastructure development including the metro rail project. Most of the construction occurs inside the main city. Construction is also increasing in the peripheries of the city in the anticipation of improved connectivity in the future due to development of roads and metro rail.

On an average all buildings in the commercial and residential area is G+5 storied high. Use of red bricks is common but fly ash and hollow bricks have also gained popularity in the last decade due to government restrictions, easy availability of raw material and ease of manufacture.
River sand mining is banned inside the city but is easily available from the outskirts of the city, aggregates are transported from neighbouring towns like Vadodara, Surat, Sevali and Moda. Hence an additional cost is paid for the transport. There is shortage of fine aggregates (river sand) during monsoon season and hence the construction industry is generally dull during this period[1].

Overview of C&D waste management in Ahmedabad

Although the demolition activities in Ahmedabad are not tracked, the construction permits throw some light onto the quantum of demolition activities. As per the data shared by AMC, about 2700 permits were issued for construction of buildings in 2014-15; approximately 50 percent of which were reconstructions projects with associated demolition activities. In addition 40-45 permits were issued for major renovation while minor renovations are done without even applying for permits. As per the new set of building by-laws proposed for the walled city, AMC proposes to convert unused government plots and old buildings into parking spaces. This will lead to demolition of buildings, generating large quantities of C&D waste. On an average AMC estimates that more than 700 tons of C&D waste is generated in Ahmedabad city per day. However the actual generation is likely to be higher as the data received by AEP does not cover generation from demolition carried out without permits.

The demolition is carried out through mechanical processes and the valuable materials are segregated onsite and sold off in the secondary market. The debris are later transported by private transport contractors and used for backfilling or dumped at sites designated by AMC.

C&D Waste management in Ahmedabad

The model of C&D waste management in Ahmedabad is based on Public Private Participation (PPP). Amdavad Enviro Projects Pvt. Ltd (AEP) is managing and processing all of C&D waste in the city. AEP charges AMC ₹ 160/ton tipping fee to pick up waste from any of the 16 designated dumping sites. AEP is responsible for transporting the C&D waste from the collection points to the processing facility, whereas the generator is supposed to dump the C&D waste at any of the 16 designated dumping locations. Collection and transportation of C&D waste from different unauthorised locations to the designated collection points is also carried out by AMC.

Currently the ground scenario is that C&D waste is actively dumped in only 2 designated dumping sites as large amount of C&D waste is generated in the vicinity of these sites as. However there are other designated sites where C&D waste is dumped but could not be picked up by AEP. This is due to the fact that financial viability to transport the waste over long distances is lost due to insufficient quantum

of waste dumped at these sites. Transport of waste is done by trucks owned by AEP and contracted tractors. To track the waste that is picked trucks are enabled with GPS tracking system and waste is weighed receiving station of AEP processing facility[2].

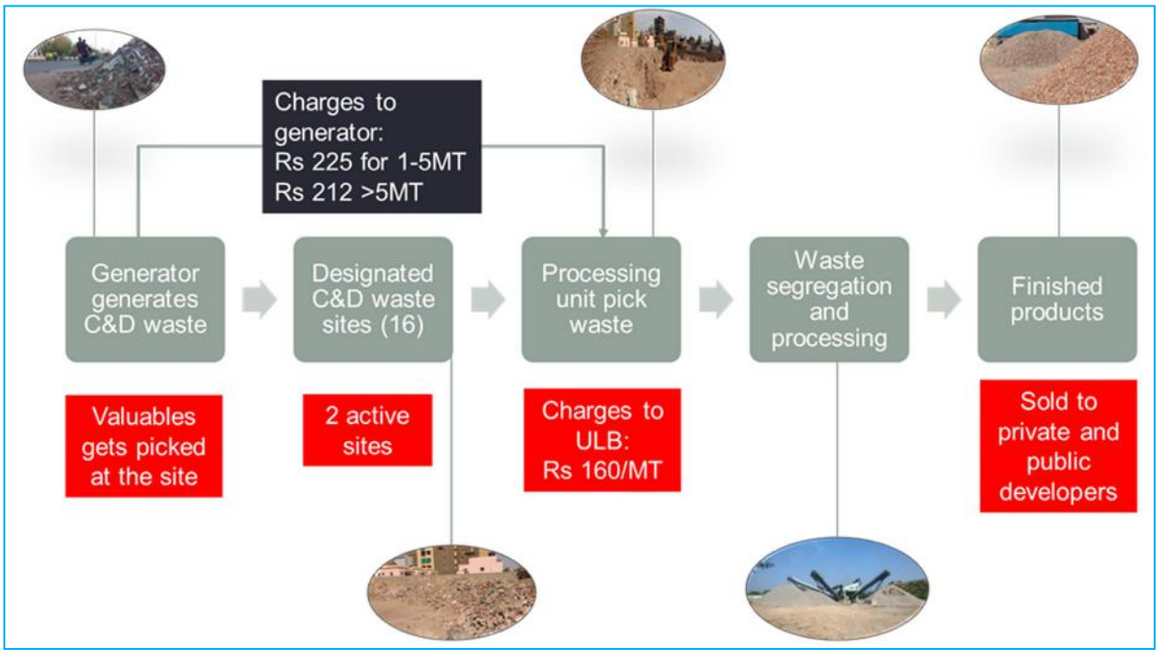

Figure 2: C&D waste management practices in Ahmedabad

C&D Waste recycling unit in Ahmedabad

Amdavad Enviro Projects Private Limited (AEP Pvt Ltd.) is a joint venture company formed by Ahmedabad Municipal Corporation and a private firm (DNP Infrastructure Pvt Ltd.) for management and processing of C&D waste in Ahmedabad. The company currently collects C&D waste from 2 designated points out of the 16 designated sites across the city and charges tipping fee of ₹ 160/Ton to AEP as mentioned earlier. The waste is also collected directly from generators at nominal charges as shown in

[1]Based on interaction with enterprises in Ahmedabad (enterprises listed in Annexure 3)

[2]Based on interaction with enterprises in Ahmedabad (enterprises listed in Annexure 3)

Table 2. Collected waste is processed at a centralised processing plant into coarse and fine aggregates. Processed waste is used for manufacture of secondary raw materials like Paver blocks, Kerb stones and other pre-cast structures which are sold under the brand name of Nu-Earth materials.

Table 2: Schedule of rates of AEP for collection of C&D waste directly from generator

Weight	Per metric ton rate	Per Trip (Minimum Rate)
Less than 1 MT Waste	-	₹ 200/-
For 1-5 MT waste (Minimum Quantity)	₹ 225/-	₹ 675/-
More than 5 MT waste (Large Quantity)	₹ 212/-	₹ 1700/-


29-5-2015

Methodology Adopted

The methodology was divided into design, data collection, analysis and interpolation.

Survey Design

Initially the stakeholders from whom the relevant information could be gathered were identified. Stakeholders were divided into the following categories:

- ULB representatives
- Builders/Building Contractors
- Demolition Contractors
- Entrepreneurs/Contractors involved in demolition waste handling / processing
- Construction raw material manufacturers
- Building Material manufacturers

A list of contact persons were identified under each category and people (maximum of 5 per category were shortlisted, based on initial conversations, stakeholder interest and geographical spread in city). A survey questionnaire was developed for data collection in the field for different stakeholders[3].

Data Collection

This phase forms the heart of the study, where all the data and information is collected. Data collection was based on secondary literature and field assessments. Secondary literature including information on size, population, geography, online articles on construction sector in Ahmedabad was used to have a general understanding of the city. Later the field visits were conducted to gather information from stakeholders based on the questionnaire prepared. The study focused on entrepreneurs in different geographies of Ahmedabad city who are already involved in manufacture of building materials using raw materials like aggregates and sand. Data collected during the market study enabled us to map various elements and stakeholders involved in the process such as C&D waste dumping sites, stone crushing units, building material manufacturers and C&D waste processing units and identify better management practices.

[3]Attached as Annexure 4

Survey Results and Analysis

As a part of the market analysis, GPS coordinates were utilised to visit and map the dumping sites in order to visualise the current management practice. Paver block manufactures were identified as potential users of C&D waste based aggregates and the paver blocks manufacturing units in two clusters namely Gota and Naroda-Dehgam region were mapped. Manufacturers were also interviewed for gathering knowledge about their willingness to buy recycled aggregates, understand selling prices of finished products and cost they pay for various raw materials including natural aggregates. A common response observed from all manufacturers was that if there is an uninterrupted supply of recycled aggregates at cost lower than natural aggregate then recycled aggregate can be used in manufacturing paver blocks. A sample of recycled aggregates was demanded by all manufacturers to test the quality internally. The selling price of paver blocks is almost stable in the surveyed paver block manufacturing unit clusters of Ahmedabad. Sand is brought from Sabarmati River and cost of delivery was found to be same in the surveyed clusters. A major difference however was found in delivery cost of stone aggregates (Figure 3). This is because large and varying distance (between 90 Km to 170 Km) of stone crushing units from city boundaries (Figure 5). Thus transportation makes significant difference in cost of natural aggregates. Manufacturers closer to stone quaries (Naroda Paver Cluster) pay less for natural aggregates while those far away (Gota Paver Cluster) pay more. Refer to Annexure 3 for detailed listing of costs.

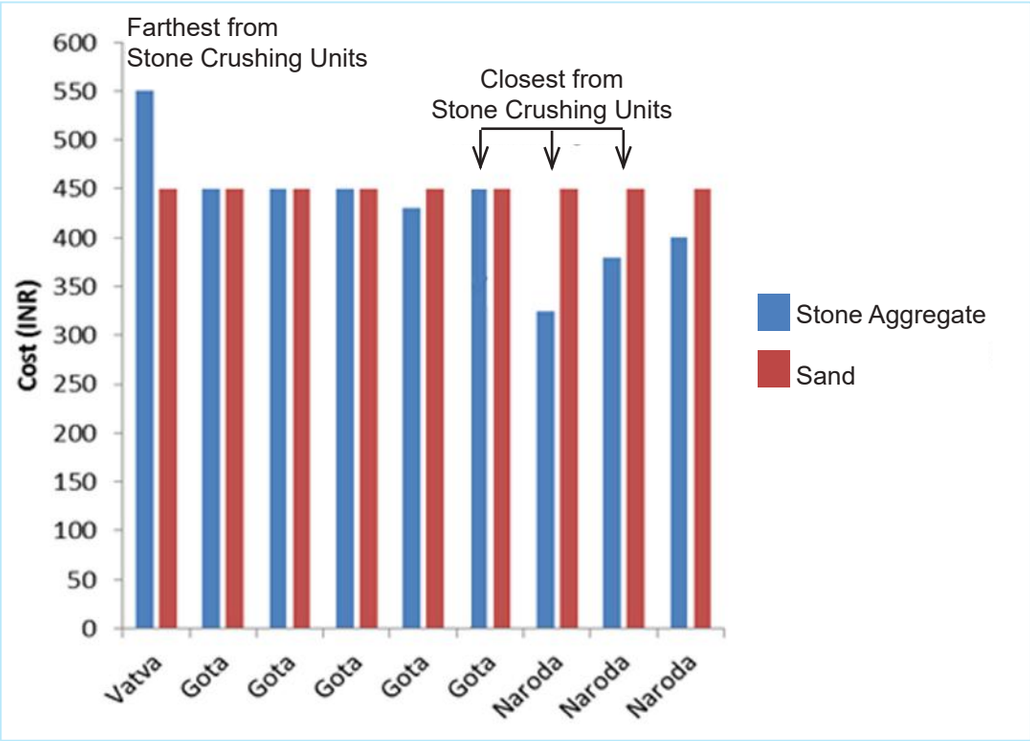

Figure 3: Market prices of raw materials and finished products

Distances of various dumping sites are illustrated in Figure 4 based on which dumping sites are selected where C&D waste can be processed into aggregates and sold to paver block clusters circled in Blue as in Figure 5. It is inferred from figure 4 that C1, C2 and C3 are suitable to process and supply C&D waste aggregates to Gota paver cluster. While C4, C5, C6, C7, C9 and C10 are suitable for supplying C&D waste aggregates to Naroda paver cluster. The road distances of above mentioned designated dumping sites are less than 10 km respective paver clusters. This will substantially reduce the onsite aggregate cost as compared to natural aggregates which are currently procured from average distances of 100-150 km.

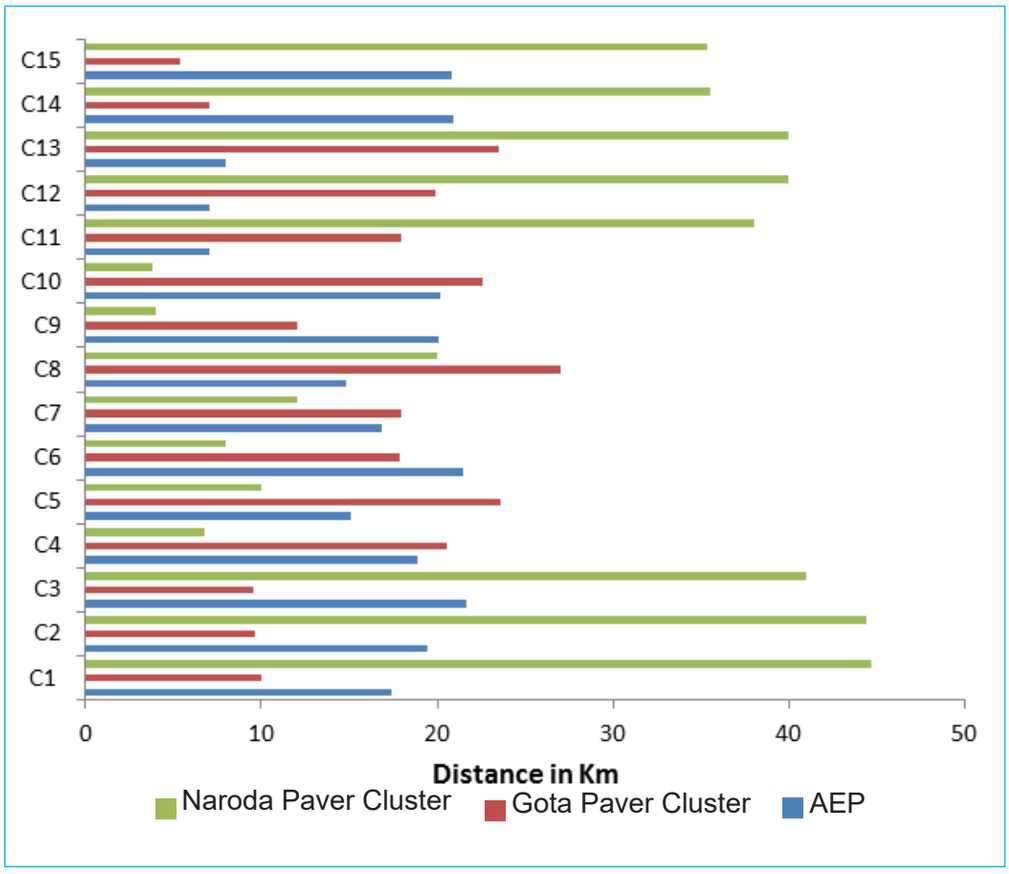

Figure 4: Distance Analysis

Thus opportunity lies in utilising the C&D waste from designated dumping sites and processing them to secondary raw materials including coarse and fine aggregates. Processing the waste and utilising it inside the city itself will drastically reduce the cost of transport of raw materials for paver block manufacturers.

Based on the survey and analysis, the following gaps were identified in Ahmedabad C&D waste management model:

Gaps:

- Limited sanctioned capacity of C&D waste processing unit restricts them from collecting more waste.
- Distance of designated dumping sites from C&D waste processing unit makes logistics difficult.
- Absence of C&D processing units near commercial clusters like Gota and Naroda where huge aggregate demand exists.
- Limited market for C&D waste based products, as there is no eco-labeling/green of finished products from reputed agencies.
- Unauthorized C&D waste dumping sites was observed during the field visits. There is a need to relocate or authorise more C&D waste dumping locations.

Results of survey show that there is huge scope for improvement for C&D waste management in Ahmedabad and this could be achieved through application of different business models and promotional initiatives and policy level interventions as mentioned in the recommendations section of the report.

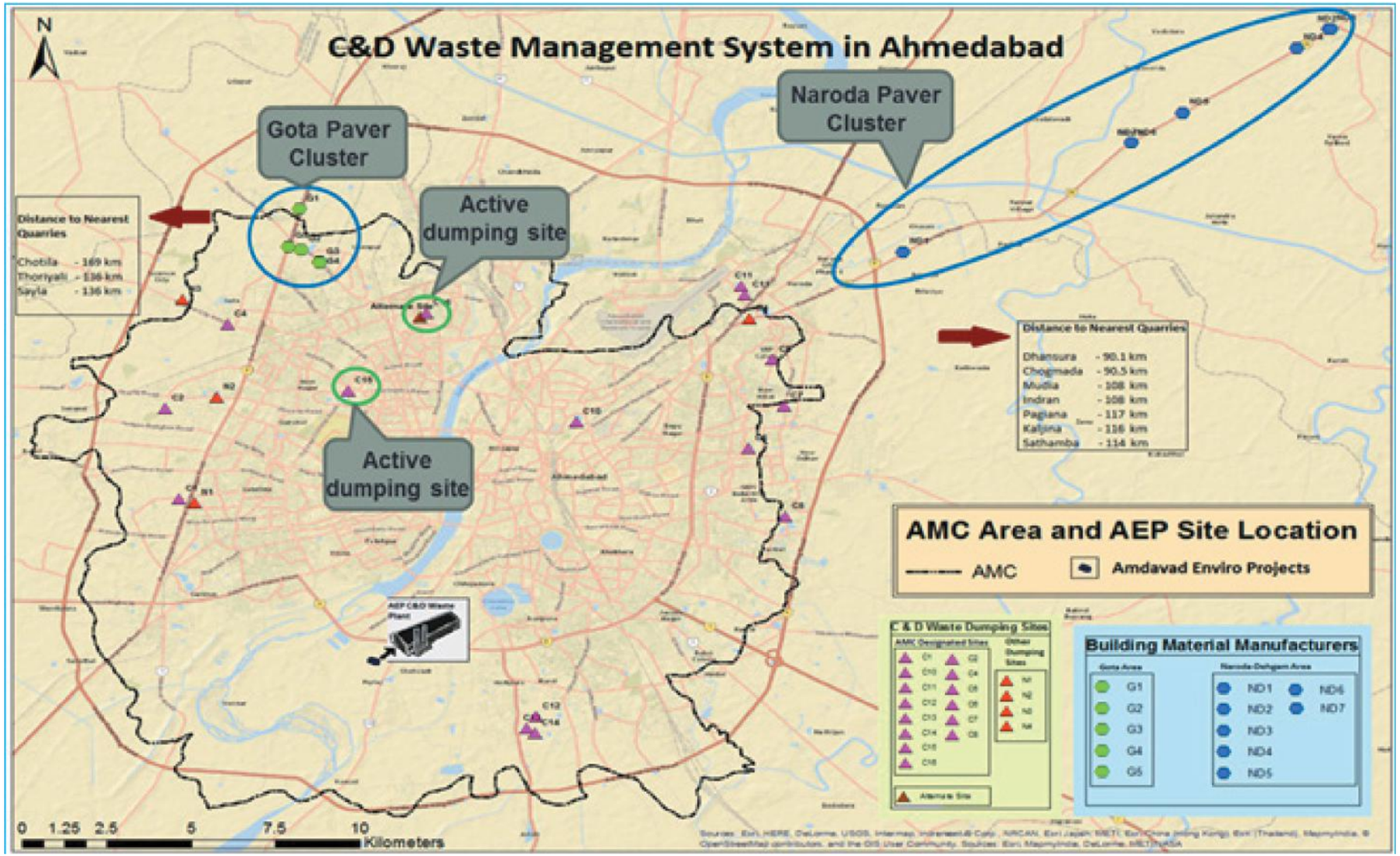

Figure 5. Hotspots of C&D waste management and reuse

Business Models

Business Opportunities

The market analysis of building materials and raw materials reveal that the distance of source of virgin raw materials from the city, increases the cost of materials inside the city. This in turn creates the market for C&D waste and C&D waste based building material products in Ahmedabad. Hence the financial and technical feasibility of different cases for better utilisation of C&D waste is assessed in the below mentioned business models.

Technical Specifications

1. Processing of C&D waste

The C&D waste mostly consists of broken bricks and concrete rubble in uneven sizes. The waste also consists of other materials including silt, stone rubble and ceramics. The C&D waste in order to be processed into aggregates of specific sieve size needs to be grinded (crushed) in crushing units similar to crushing of stones. Since the process of crushing remains the same, stone crushing machinery are used for the crushing of C&D waste. Hence the existing stone crushing machinery in the city (especially those facing shortage of access to raw materials) can be utilised for processing of C&D or a new units can be set up for the processing of waste. Existing stone crushing units may need minor modifications for utilising them for crushing C&D waste. The C&D waste crushing do not require the primary crushing which is used for crushing huge rock boulders into process able sizes and hence the feed entry need to be changed from the primary crusher to the secondary crusher. In addition to this, in many cases there is need for a fine material washing unit or a density air separator unit which might not be available in the already existing facility and may need additional expenditure. Business cases have been developed for medium size crushers, with a crushing capacity of 500 TPD and crushing on an average around 250-500 TPD. The size of the finished product is usually 20mm, 12mm, 10mm, 6mm and <4mm (dust), which can be retrieved according to the sieve arrangement at the outlet of the processing device that can be adjusted according to the need of the manufacturer. The business cases are developed for arrangements retrieving 10mm aggregates (passing through 12 mm sieve and retrieved in 10mm sieve) and fine aggregate particles (passing through 4.75 mm sieve) alone. Once the C&D waste is processed into aggregates, they can be used instead of coarse and fine natural aggregates in manufacture of building materials and also for road works. The paver block manufacturing industry utilising C&D waste is the case considered in this study and hence the technical specifications of a paver block manufacturing unit is detailed below.

Table 3: Specifications for manufacture unit

Product	I-shaped paver block, 60mm thickness
Manufacture technology	Vibrating table method
Manufacturing Capacity (bricks/day)	2500
Manufacture at 75% (bricks/day)	2000
Grade	M 30
Weight of Paver block (kg)	4.5

2. Concrete paver block manufacturing

Concrete paving block is a building material used for laying pavements, footpaths, and other kind of exterior pathways for pedestrians and also for vehicular movement. They are widely accepted for their aesthetic features and ease of laying. They are available in various sizes, shapes, colors and strength grades (concrete mix) depending on the utility and aesthetic requirements. Some specific designs like the I-shaped 60mm thick paver block and Zigzag shaped 80mm thick paver block are always in demand in the market due to their interlocking properties (does not need binder) and load bearing properties while other designs like grass pavers, square pavers, etc are made only according to order and as per client requirements. In Ahmedabad, it is observed that most of the paver block units are small or medium scale units which manufacture paver blocks in their own specific mix designs since the quality is rarely checked and more preference is given by clients to cost of the products. 10mm aggregates are used as coarse aggregates and river sand is used as fine aggregates, dust is sometimes used for colour mixing for the top surface and some time it is not. The change in raw materials includes use of 10mm processed aggregates for coarse materials and M-sand for fine aggregates. The business case is developed for a small scale enterprise with a manufacturing capacity of 2000 bricks per day using vibrating table technology inside the city and considered to be working at 75% efficiency. The business case also considers manufacturing of I shaped 60mm paver blocks (since from the market analysis it was observed that this is one of the most commonly manufactured kind of paver block which is made and stocked due to market demand). The standard mix ratio adopted in this business case is the mix design suggested as per IS standards for manufacture of M15 grade equivalent paver blocks with a mix ratio of 1:2:4 which consists of 1 part of cement 2 parts of sand and 4 parts of 10mm aggregates. Initially the colour and concrete is mixed in a colour pan mixer and poured to a thickness of an average 5mm for surface colouring and vibrated in rubber or fibre mould to remove air gaps. Later the concrete mix is prepared in a concrete pan mixer and poured into the mix and vibrated in a second vibrator. The pavers are cured inside the mould for one day and then taken out after which final curing happens over a period of 10 days.

Recommended Business Models

In this study multiple scenarios have been identified where different entrepreneurs can utilise C&D waste or waste based raw materials in their business with or without additional investment. The cases are developed based on several assumptions relating to ground reality. The assumptions are listed in Annexure 2 The business cases are also compared with business as usual scenario utilising natural aggregates to highlight the financial difference involved due to change of raw material from natural materials to C&D materials. The recommended business cases include:

Case 1	Existing stone crushing entrepreneur replaces natural raw material (completely/ partially) and process C&D waste into aggregates and an existing paver block manufacturer utilises the secondary aggregates into finished products

The case applies for any stone crushing enterprise to change their raw materials from natural stone to C&D waste and sell the material to existing paver block manufacturing entrepreneur who also changes his raw material from virgin aggregates to C&D processed aggregates. Scenarios are considered for complete replacement of aggregates (Case 1.A) as well as partial replacement of aggregates (Case 1.B). This case does not involve any major investments

Case 2	Existing stone crushing entrepreneur replaces natural raw material completely and process C&D waste into aggregates and invest on a new paver block manufacturing unit that utilises the secondary aggregates to make finished products

The case applies for any stone crushing enterprise to change their raw materials from natural stone to C&D waste and also is interested in investing to start a small scale paver block manufacturing unit to utilise the processed C&D waste. In this case the major investment is required to setup the paver block unit.

Case 3	Existing paver block manufacturing unit that utilises the C&D waste secondary aggregates with and without additional investment to make recycled aggregates.

The case takes an assumption of an existing paver block manufacturing unit to utiliseprocessed C&D waste aggregates, where the raw material is readily available in market or is processed in house using a mini crushing unit. In this case the major investment occurs for the paver block manufacturer for capital cost on the mini-crushing unit.

Case 4	New stone crushing entrepreneur process C&D waste into aggregates and a new paver block manufacturing enterprise utilises the secondary aggregates into finished products

The case applies for a new entrepreneur who is interested in investing in a C&D waste processing enterprise and the material is utilised by a new enterprise (in-house or market sale cases considered) manufacturing paver block manufacturing from virgin aggregates to C&D processed aggregates. The case involves major investment for establishing the C&D processing unit and paver block manufacture unit.

Case 5	Mobile type mini-C&D waste crushing & processing enterprise providing rental services

The case considers a scenario in which an entrepreneur (public or private) invests in a mini-mobile crusher suitable to be transported easily to different demolition sites where C&D waste is crushed according to the needs of the client. The business model considers that the mini-crusher is rented out to the clients in Ahmedabad where the C&D waste is crushed in-situ and used in-house by the client. In this case the income for investor is through renting out the machine.

Case 6	Mobile type mini-C&D waste crushing & processing and sales enterprise

In this case the entrepreneur (public or private) invests in a mini-mobile crusher suitable to be transported easily to different demolition sites where C&D waste is crushed transported back and stock piled by the entrepreneur in his stockyard. The processed material is later marketed by the entrepreneur. This is a mini-mobile version of the standalone crushing units.

Different business models are showcased in the study which is recommendable to be adopted by entrepreneurs in Ahmedabad.

Even though the C&D waste generation inside the city is assumed to be 700 TPD by AMC, field study reveals that there are huge number of unaccounted demolition debris being generated and disposed off in different pockets of the city hence even if the processing capacity of the existing plant is increased to maximum input, for waste from many parts of the city it would not be feasible to transferred to the centralised plant considering the logistic problems. Hence in addition to the existing model of C&D waste management, decentralised models would be more suitable for better waste to resource utilisation in the city and acceptability for implementation by the enterprises[4]. Moreover the decentralised approach would enable processing of waste at the commercial centers as discussed in survey results that would minimise transportation of waste and resources. Case 5 & Case 6 in the business models proposed focus on decentralised approaches and hence would be more feasible, enabling mainstreaming of C&D as a resource in Ahmedabad.

The detailed cost derivations and comparisons are attached as Annexure 1.

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The detailed cost derivations and comparisons are attached as Annexure 1.

[4]Considering the minimal investment requirement and business opportunities

Recommendations

The market analysis revealed that good initiatives are undertaken by the ULB in C&D waste management, which is supported by private enterprises (like DNP infrastructure Pvt Ltd who is the PPP partner of AMC in forming AEP Pvt Ltd). But according to the assessments made in the study, the waste management in Ahmedabad can further be enhanced through further activities, initiatives and gap filling which are given below as recommendations.

1. AEP Pvt Ltd. is presently performing at less than one third of their installed processing capacity of 1200 TPD (working at 300TPD). It is well established that more C&D waste is generated in the city every day and hence it is imperative to increase the sanctioned capacity of AEP for processing.

2. It is recommended that decentralised C&D processing units should facilitate the use of processed recycled aggregates in the two identified clusters of precast concrete manufacturers. As specified in the business models the processing units could be stationary or mobile type.

3. It should be ensured that C&D waste is collected from all 15 designated locations (or new designated locations) and waste is taken to the nearest processing facility (or the processing unit is taken to the collection point in case of the mobile crusher).

4. All mentioned business models require investment for crushing unit and the private enterprises might feel doubtful on investing on the new technologies, hence it is recommended that the public enterprises invest in for the business cases on a model pilot scale (similar to AEP Pvt. Ltd. initiative) on a PPP model which would encourage more enterprises to adopt the business models, resulting in better efficiency in C&D waste recycling in the city.

5. The use of C&D waste also need to be upscale through developing better awareness on the use of C&D waste as a secondary raw material and its potential to generate income. The awareness has to be spread among different stakeholders including the ULB, stone processing unit enterprises, construction material manufacturers, builders, architects and even waste generators in order to develop sense of ownership, develop capacities and initiate action from all the stakeholders.

6. Awareness activities in form of round table meetings, stakeholder awareness workshops, capacity development workshops, circulars (from ULB to contractors and public), and other mass community mobilisation programs can be organised by AMC and other government organisations.

7. The quality of secondary construction materials can be ensured through eco labelling and other certification provided by national level organisations and other certifying bodies (like GRIHA) which will give proper value for the C&D waste based products. The certified materials could also be preferentially procured by government constructions. This will provide support for creating initial market and hence mainstream the products in the construction sector. Preferential procurement could be implemented through adding special clauses in tender documents for public projects.

8. More research and development activities need to be initiated focused on use of fine particles (silt and clay) and other inert materials of C&D waste into recycle and reuse of construction and other allied sectors.

Conclusion

Ahmedabad Municipal Corporation is one of the pioneer ULBs in India to undertake the challenge of proper management of C&D waste, but there is a long way to go for the stakeholders to rest their shoulders. With a little support and added initiatives, AMC can become a prime example for not only other ULBs in India but also to other developing nations to follow. Coupled by the enthusiastic initiatives of AMC and mandatory requirements of the latest C&D waste management rules, 2016 the face of C&D waste management is sure to change forever in the very near future. The recommendations stated above in the market analysis, if implemented could help AMC upgrade its C&D waste management activities to a different level of performance. But more research, monitoring and pro-active measures need to be taken in a day-to-day manner to ensure maintenance of the quality of waste management in Ahmedabad and keep it upgraded to the needs of the fast changing society.

Annexure 1 – Business Cases

Case 1: Existing stone crushing entrepreneur replace natural raw material completely or partially (10%, 25% & 50%) and process C&D waste into aggregates and an existing paver block manufacturer utilises the secondary aggregates into finished products

STONE CRUSHING UNIT					
Processing (T/D)	400				
Products	Aggregates (~10mm, <4mm)				
Financials	**Processing natural aggregates (₹/day)**	**Processing C&D aggregates by 10% replacement (₹/day)**	**Processing C&D aggregates by 25% replacement (₹/day)**	**Processing C&D aggregates by 50% replacement (₹/day)**	**Processing C&D aggregates by 100% replacement (₹/ day)**
Capex	-	486,850	981,850	1,806,850	4,116,850
Material stock load[a]		330,000	825,000	1,650,000	3,960,000
Machinery[b]		156,850	156,850	156,850	156,850
Opex (per day)	**102,369**	100,059	96,594	90,819	78,173
Material Cost	88,000	85,800	82,500	77,000	66,000
Other cost[c]	14,369	14,259	14,094	13,819	12,173
Cost of production[d]	**112,606**	110,690	107,514	102,220	91,273

Cost of production (per ton)[e f]					
Aggregates (~10mm)	169	166	161	153	137
Aggregate sand (< 4mm)	113	111	108	102	91
COST SAVINGS BY CHANGE OF RAW MATERIAL					
Specifications	**Processing natural aggregates (₹/day)**	**Processing C&D aggregates by 10% replacement (₹/day)**	**Processing C&D aggregates by 25% replacement (₹/day)**	**Processing C&D aggregates by 50% replacement (₹/day)**	**Processing C&D aggregates by 100% replacement (₹/ day)**
Cost saving per day (₹)		1,916	5,092	10,386	21,333
Cost savings per ton of aggregates (₹)		3	8	16	32
Cost savings per ton of sand (₹)		2	5	10	21
Cost reduction per day (%)		2%	5%	9%	19%
payback period (months)		10	8	7	8

PAVER BLOCK MANUFACTURING UNIT		
Processing capacity (Pavers/Day)	2000	
Products	Paver Blocks (M30 Grade, I-shaped)	
Financials	**Utilising natural raw materials (₹/day)**	**Utilising recycled raw materials (₹/day)**
Capex	0	0
Opex (per day)	15,560	15,101
Material Cost	12,398	11,961
Other cost	3,162	3,140
Cost of production per day	17,116	16,611
Cost of production per day per block	8.6	8.3
Cost of production per day per sq.ft	21.4	20.8
COST SAVINGS BY CHANGE OF RAW MATERIAL		
Cost saving per day (₹)	459	3%
Cost savings per block (₹)	0.25	Cost reduction per day
Cost savings per sq.ft (₹)	0.6	

Case 2: Existing stone crushing entrepreneur replace natural raw material completely and process C&D waste into aggregates and invest on a new paver block manufacturing unit that utilizes the secondary aggregates to make finished products

STONE CRUSHING UNIT		
Processing capacity (T/d)	400	
Products	Aggregates (~10mm, <4mm)	
Financials	**Processing natural aggregates (₹/day)**	**Processing C&D aggregates (₹/day)**
Capex[5]	-	4,116,850
Material stock load		3,960,000
Machinery		
Opex (per day)	102,369	78,173
Material Cost	88,000	66,000
Other cost	14,369	12,173
Cost of production	112,606	91,273
Cost of production (per ton)		
Aggregates (~10mm)	169	137
Aggregate sand (< 4mm)	113	91
Cost Savings by change of raw material		
Cost saving per day (₹)	21,333	19% Cost reduction per day
Cost savings per ton of aggregates (₹)	32	
Cost savings per ton of sand (₹)	21	

PAVER BLOCK MANUFACTURING UNIT		
Processing capacity (Pavers/Day)	2000	
Products	Paver Blocks (M30 Grade, I-shaped)	
Financials	Recycled aggregates based products (Standalone unit with outsourced materials) (₹/day)	Recycled aggregates based products (Integrated unit with inhouse materials) (₹/day)
Capex	1,034,550	1,001,550[g]
Opex (per day)	15,101	12,726
Material Cost	11,961	9,939[h]
Other cost	3,140	2,787
Cost of production per day	17,939	15,284
Cost of production per day per block	9	8
Cost of production per day per sq.ft	22	19

[5] Refer end note 'a' and 'b's

COST COMPARISON OF INHOUSE PAVER UNIT TO STANDALONE UNIT		
Cost saving per day (₹)	2,655	15%
Cost savings per block (₹)	1.33	
Cost savings per sq.ft (₹)	3	cost reduction per day

ADDITIONAL PROFIT PER DAY BY ESTABLISHING THE PAVER BLOCK ENTERPRISE		
Specifications	**Along with crusher**	**Standalone unit**
Number of Blocks per day	2,000	2,000
Paver block (per sq.ft)		
Cost Price (₹)	19	22
Selling price (₹)	25	27
Profit (₹)	6	5
Total profit per day (₹)	12,308	10,000
Payback period (Months)	3	4

[a]Raw material stock load cost for a period of 50 days

[b]Cost of implementing a magnetic separator system from removing the metallic waste from the input C&D waste and also implementing the support structures for changing the input feed of the materials.

[c]Other cost include Machinery cost, Manpower cost, miscellaneous cost, depreciation cost & additional unexpected cost (which is a factor of total cost including material cost)

[d]Cost of production includes Operating cost (Opex) as well as regular payback amount of loan

[e]Cost of production at factory excluding transport cost

[f]60% output is aggregate stone and 40% is sand (Annexure 2)

[g]Costs lesser than standalone unit since infrastructure including office building, water supply etc. is already available in the existing stone crushing unit

[h]Lesser cost than a standalone unit since recycled aggregates are sourced from within the factory at original cost price of material

Case 3: Existing paver block manufacturing unit that utilizes the C&D waste secondary aggregates with and without additional investment to make recycled aggregates

PAVER BLOCK MANUFACTURING UNIT			
Processing capacity (Pavers/Day)	2000		
Products	Paver Blocks (M30 Grade, I-shaped)		
Financials	**Utilising natural raw materials (₹/day)**	**Utilising recycled raw materials (₹/day)** *outsourced*	**Utilising recycled raw materials (₹/day)** *inhouse*
Capex	0	0	200,000[i]
Opex (per day)	15,560	14,206	13,140
Material Cost	12,398	11,109	9,778
Other cost	3,162	3,097	3,363
Cost of production per day	17,116	15,627	15,477
Cost of production per day per block	8.6	7.8	7.7
Cost of production per day per sq.ft	21.4	19.5	19.3

COST SAVINGS BY CHANGE OF RAW MATERIAL (INHOUSE MANUFACTURING)	
Per block (₹)	0.8
Per Sq.ft (₹)	2
Per day (₹)	1639
Cost savings per day	12%
Payback period (months)	5

COST SAVINGS BY CHANGE OF RAW MATERIAL (OUTSOURCED MATERIAL)	
Per block (₹)	1
Per Sq.ft (₹)	2
Per day (₹)	1489
Cost savings per day	10%

Case 4: New stone crushing entrepreneur process C&D waste into aggregates and a new paver block manufacturing enterprise utilizes the secondary aggregates into finished products

C&D WASTE CRUSHING UNIT	
Processing (T/D)	400
Products	Aggregates (~10mm, <4mm)
Financials	Processing C&D aggregates (₹/day)
Capex	10,876,300
Material stock load	3,960,000
Machinery and other investment	6,916,300
Opex (per day)	78,173
Cost of production (per day)	99,948
Cost of production (per ton)	
Aggregates (6mm-12mm)	150
Aggregate sand (< 4mm)	100
Selling price (per ton)	
Aggregates (6mm -12mm)	290
Aggregate sand (< 4mm)	235
Profit (per ton)	
Aggregates (6mm- 12mm)	140
Aggregate sand (< 4mm)	135
Profit (per day)	
Aggregates (6mm-12mm)	33,598
Aggregate sand (< 4mm)	21,599
Net Profit (per day)	55,197

PAVER BLOCK MANUFACTURING UNIT	
Processing capacity (Pavers/Day)	2000
Products	Paver Blocks (M30 Grade, I-shaped)
Financials	**Utilising natural raw materials (₹/day)**
Cost Price	
Capex	1,001,550
Opex (per day)	12,819
Cost of production (per day)	15,387
(per paver block)	8
(per sq.ft)	19.2
Selling price	
(per paver block)	10
(per sq.ft)	26
Profit	
(per paver block)	3
(per sq.ft)	7
Net profit (per day)	5,413
Gross profit per day	60,611
Payback period (months)	8

Case 5: Mobile type mini-C&D waste crushing & processing enterprise providing rental services

C&D WASTE CRUSHING UNIT (50 TONS PER DAY)	
No: of working days per annum	200
Output Materials	~10mm aggregates
	< 6mm aggregates (M-sand)
Rated Capacity (Tons/day)	65
Production (Tons /day)	50
Working Hours per day	8
Capex	
Machinery	1,203,000
Opex (per day)	
Depreciation on machinery (10% / annum)	602
Electricity & Fuel	3,448
Manpower	480
Transport	3,000
Additional cost	196
Total	7,725
Cost of production per day (Capex + Interest + Opex)	9,129
Total Cost	10,042
Equivalent aggregate cost (6mm-12mm) per ton	157
Equivalent sand cost (.75 - 6mm) per ton	104
Rent of Machine (₹/hr)	1,632
Rent of Machine (₹/day)	13,054
Profit per day from machinery (₹/day)	3,013
Payback period (months)	25

[i]Paver block manufacturing enterprise just purchase a Jaw crusher and manual sieve to crush and use C&D waste as raw material for his product

[j]All machinery costs are based on original quotations received by Author from enterprises providing similar machinery (Details in Annexure 2)

Case 6: Mobile type mini-C&D waste crushing & processing and sales enterprise

C&D WASTE CRUSHING UNIT (50 TONS PER DAY)	
No: of working days per annum	200
Output Materials	~10mm aggregates
	< 6mm aggregates (M-sand)
Rated Capacity (Tons/day)	65
Production (Tons /day)	50
Working Hours per day	8
Capex	
Machinery	1,203,000
Opex (per day)	
Depreciation on machinery (10% / annum)	602
Electricity & Fuel	3,448
Manpower	480
Transport	6,000
Additional cost	196
Total	10,725
Cost of production per day (Capex + Interest + Opex)	12,129
Total Cost	13,342
Equivalent aggregate cost (6mm-12mm) per ton	160
Equivalent sand cost (.75 - 6mm) per ton	107
Selling price of aggregates (6mm-12mm) per ton	192
Selling price of sand (.75 - 6mm) per ton	128
Profit per day (₹)	2,668
Profit per annum (₹)	533,675
Payback period (months)	28

Annexure 2: Assumptions considered for developing business cases

Since the practical situation scenario varies between every enterprise, few assumptions have been made in the business models, as listed below:

- The cost of collection and transport of C&D waste to the crusher enterprise is considered ₹150/ton[6].
- Cost of 50kg cement bag considered as ₹ 350/-
- 60% of output from crusher unit is course aggregates and 40% of output is fine aggregates[7]
- The enterprise establishment capital expenditure cost is considered to be made on a bank loan of 15% for a period of 5 years
- The cost of labour is referred from costing of Labour commission and MSME documents (MSME, 2010)(MSME, 2010)
- The cost of machinery is referred based on secondary data collected from entrepreneurs in Ahmedabad and invoices received for new machinery[8] (Red Rhino Crushers, 2016) (Shanghai Zenith Mining and Construction Machinery Co., 2016)(Henan HongXing Mining Machinery Co., 2016)(Star Trace, 2016)(TARA Machines Pvt Ltd, 2016)
- The efficiency of the processing machinery is considered as 80%[9]
- Depreciation cost of building considered to be 5% per annum
- It is assumed that the entrepreneurs owns their own land (or land is available) to start the enterprise and no additional cost for land is considered
- Depreciation cost of machinery considered to be 10% per annum
- Electricity cost calculated using latest Industrial rate slabs(UGVCL)
- 10% additional charges are provided for cost price (C.P) considering manufacturing losses
- Selling price of paver block(I shaped,60mm thick, M30 grade) in market is ₹ 25 per Sq.ft[10]
- One way Transport cost of materials from or to outside the city region is considered ₹ 250 per Ton (Considering a 16 Toner truck with carrying capacity of 12 Tons and transporting at ₹ 3000 per truck load for an average distance of 100 Kms)
- One way Transport cost of materials within the city region is considered ₹ 125 per Ton (Considering a 16 Toner truck with carrying capacity of 12 Tons and transporting at ₹ 1500 per truck load for an average distance of 30 Kms)
- The paver block manufacturers use 10mm aggregates as coarse aggregates[11]
- Cost of river sand is ₹ 450 per Ton The Enterprises under business as usual scenario are working at a profit margin of 10%[12]
- Total number of working days is considered as 200 days per annum for crushing industry and 250 days for paver block manufacture industry
- Average weight of I-shaped 60mm paver considered as 4.5kg per block
- Stock pile of new raw materials is considered for 50 days in advance, which is considered as a capex cost for new business
- All derived values in the developed business cases (Annexure 1) is rounded off to the nearest unit for ease of calculation and understanding

[6] Based on rate of collection by AEP.Pvt Ltd in Ahmedabad

[7] Based on interaction with enterprises in Ahmedabad (enterprises listed in Annexure 3)

[8] Based on interaction with enterprises in Ahmedabad (enterprises listed in Annexure 3)

[9] Based on interaction with enterprises in Ahmedabad (enterprises listed in Annexure 3)

[10] As per market rate on May 2016

[11] Based on interaction with enterprises in Ahmedabad (enterprises listed in Annexure 3)

[12] As per market rate on May 2016

Annexure 3: List of Enterprises Consulted

S.No.	Details of enterprise	Product manufactured	Cost of Aggregates ₹/Ton	Cost of Sand ₹/Ton	Selling price of Products ₹/Sqft
1	Hindustan Machines Pvt Ltd, Vatva.	Paver blocks, Kerb stones, checker tiles	550	450	22
2	Super tiles, S.G highway, Gota.	Paver blocks, Kerb stones, checker tiles	450	450	23
3.	Shree Balaji tiles, Gota cross road, Gota.	Paver blocks, Kerb stones, checker tiles	450	450	23
4.	Arhint Industries, Oganaj road, Gota.	Paver blocks, Kerb stones, checker tiles	450	450	25
5.	Laxmi tiles, opp. Khodiyar Mandir, Gota.	Paver blocks, Kerb stones, checker tiles	430	450	22
6.	Ravi tiles, GIDC, Dehagam.	Paver blocks, Kerb stones, checker tiles	290-360	450	22
7.	Darsh paver tech. Dehgam road, Enasam.	Paver blocks, Kerb stones, checker tiles	380	450	23
8.	Punit Corporation, Naroda.	Paver blocks, Kerb stones, checker tiles	400	450	23
9.	Sabar Tiles, Railway crossing, Gota.	Paver blocks, Kerb stones, checker tiles	450	450	22
10	Umiya Cement Product	Concrete fencing blocks	550	450	120
11	Chandubhai Patel, Dehgam	Concrete fencing blocks	550	450	120

Annexure 4
Questionnaire for Stakeholders

Urban Local Bodies& Contractors

1. What is the quantum of C&D waste that is collected per day inside governance area (Tons/Day)?
2. What is quantum of construction and demolition in the region (sq.m per year)?
3. Does the quantity of waste depend on seasonal variations, if Yes then please elaborate? How did the quantum of C&D waste changed during the past years / Do you have statistics on monthly/ yearly gathered C&D waste?
4. How/When is the C&D waste collected? Who is the responsible contact person?
5. What is the minimum quantity of waste which is collected? Process Flow?
6. How is the cost of managing C&D waste recovered (eg – tariff, tax etc)?
7. Have the C&D waste been characterised? If Yes what is the detailed breakup of components in percentage? If not, rough estimations of composition – element wise?

   As options for recycling mainly depend on the strength of the components, it would be helpful for our future work to gather the different components classified by strength

Component	Estimated share (%)
Natural stones and gravel	
Fragments of concrete	
Hard burned bricks, ceramics	
Soft burned bricks (if there are in India?)	
Sand-lime stones	
Aerated/gaseous/lightweight concrete	
Mortar, plasters, etc.	
Adobe	
Other, please specify (e.g. metals, glass, wood, plastics, bituminous fractions, …)	

8. Is there any check or analysis for detecting other materials in C&D waste and quality of C&D waste (if it is to be processed)?
9. What is the C&D waste management policy of the ULB? Is there any program or scheme to support C&D waste management?

   a. Is there is a C&D landfill in operation. If yes what is the capacity of the landfill? How much of it is fill and for how many years it will remain operational? Is there plan for a new C&D landfill or new units to existing landfill? If Yes then details?

   b. Is the C&D waste processed or recycled, if Yes what is the process? Are the fractions of C&D waste separated, if yes: how? What percentage? Are the recycled/reused products marketed? If Yes details? If not, is there a potential? And for what kind of materials in which form?

c. Are valuables from C&D waste collected by rag pickers during the process of collection and transportation, if yes which components? What percentage?

10. Who performs collection and transfer of C&D waste, is a private entity involved? If it is a private (contractor / consultant), who is/are the private entity? For how long has the private contractor been involved and how long is the contract? What are the payment terms with the private entity?

11. Who operates the processing facility?

    a. If it is a private (contractor / consultant), who is/are the private entity? For how long has the private contractor been involved and how long is the contract? What are the payment terms with the private entity?

    b. If there is a processing facility then was it built on any special fund?

12. How and where is the C&D waste disposed? What is the technology used? Is the C&D waste separated and is some of the fractions further processed/recycled? If Yes: what kind of products/ recycled materials do they produce and who uses/where are the products/recycled materials used? Who operates and maintains the disposal facility? If it is a private (contractor / consultant), who is/ are the private entity? For how long has the private contractor been involved and how long is the contract? What is the payment and operational terms with the private entity?

13. Is there illegal dumping of C&D waste? Is there a penalty or punishment for illegal dumping of C&D waste? Illegally dumped C&D waste if found, is it collected?

14. How is the competition in this field?

15. What are the constraints faced with C&D waste? Do you wish for a change in the present C&D waste management practices? If Yes please brief the points?

16. Are you interested in implementing better C&D reuse and management programs?

    a. Are enough IEC activities been performed among the public to avoid open dumping of C&D waste and for proper disposal of waste with the ULB?

    b. Is there any fund or scheme from state government in the new budget which could be utilized for development of C&D waste management services?

    c. Is there any support provided by bank or is it available on request? If Yes then details?

C&D Waste Managers / Processing Enterprises

1. What is the total C&D waste generated in the city and what is the quantum collected?

2. What is the total quantum of waste managed/ processed by the particular unit?

3. What is the reusable quantum / percentage of waste?

4. What is the characterisation of waste?

5. What is the flow materials of C&D waste from source to product/landfill?

6. How the management charges retrieved? What the contract clauses?

7. What is the major processing done? What is the end product and what is the use of end products?
8. What are the capex and opex charges?
9. Is the business financially profitable?
10. What is the kind of technical and marketing support that is required to help the business?
11. What are the policy changes that you suggest to help the recycling of C&D waste?
12. What are the factors the C&D waste characteristics and quantum depend on?
13. If there is a material change/ technology change option available, then what is minimal additional profit margin for which it will be adopted?
14. Is the quality of product according to national standards? If Yes, then has it been tested? If No, Why not? Will the test results be shared or samples be provided for testing?
15. Would a centralized or decentralized approach be more suitable for the city for C&D waste management? (briefly explain)

Developers

1. What is the demolition technique used? Technique used for each kind of building? How much waste generated per unit area / per unit time? Do you have a calculation on construction / demolition waste per unit area been made? (Even a rough calculation would be appreciated)
2. What is the component percentage breakup (or the major components) in each category of building? What percentage of each component waste gets reused? What is the usual percentage cost saving involved of each component?
3. Is the C&D waste load quantified before clearance?
4. Is the demolition process outsourced or in-house resources are used? If outsourced then what is process of outsourcing?
5. Have the C&D waste been characterised? If Yes what is the detailed breakup according to the type of building? If Not what is rough estimate& which are main components?
6. What is the C&D waste management practice in the site (what is done with it)? What do you do with your C&D waste? What do you do with your renovation waste? What is the common C&D waste management technique used by rest of the developers?
    a. Do you know that open dumping is bad for the environment?
    b. Do you engage professionals or Contractors for demolition / construction/ renovation purposes?
    c. Is any part of C&D waste reused on site itself, if Yes then how and what percentage? Is the reusing of C&D waste profitable? If Yes what is the percentage? Do reused/ recycled materials affect quality of construction? If yes then how?
    d. Is any part of C&D waste sold to scrap, if Yes then how and what percentage?

e. If the municipal authorities / contractors collect the waste, is it done on time? What are the payment terms for waste collection (what, how, who and where)?

7. Is any waste reduction practice followed during construction or demolition process? If Yes please provide a brief information on it. If Yes then are the laymen trained to do so?

8. Do you wish for a change in the present C&D waste management practices? If Yes please brief a few points?

9. What is the growth potential of the city (with reference to land availability, land cost, resources and activities) in terms of construction?

10. Which construction materials have resource shortage in the region? What is the cost of major raw materials used for construction? (sand, soil, aggregates, bricks, steel, concrete)

11. Do you wish to use building materials made out of C&D waste? If Yes: what kind of advantages do you see (e.g. much less costlier), if No: what kind of disadvantages do you see (e.g. no harmonised product standards)? What kind of recycled materials would you use, what kind of recycled materials do you reject to use and why?

Stone Crushing Units

1. What is the capacity of the crushing unit?
2. What is the operating efficiency?
3. What is the different size of products manufactured? Which materials have maximum demand in market?
4. What are the rough capex and opex charges for manufacture?
5. If there is a material change/ technology change option available, then what is minimal additional profit margin for which it will be adopted?
6. What is the technical and policy support required for better business?
7. What are the environmental or mining legal constraints faced that hinder the business?
8. Is the entrepreneur ready to make additional investments if profit margin can be increased?

Material Manufacturers

1. What are the Plain Cement Concrete construction materials that have a strong market in the city?
2. What are the materials processed in your company? What is the capacity of your processing plant? Operation efficiency?
3. What are the capex and opex charges?
4. What is the kind of technical and marketing support that is required to help the business?
5. If there is a material change/ technology change option available, then what is minimal additional profit margin for which it will be adopted?

6. What is the source of raw materials and technology used (brief)?
7. What is the transport cost of finished products and raw materials?
8. What is expected to be the acceptance of the materials if there is a change in raw materials from virgin to recycled materials (if it has been technically and financially proven compatible)?
9. Has any innovative technology or raw-material been tried for the manufacture of the product?
10. Is the quality of product according to national standards? If Yes, then has it been tested? If No, Why not? Will the test results be shared or samples be provided for testing?

Technical Experts

1. What are the commonly used reuse or recycle technologies and products used in the region regarding construction materials? What kind of advantages and disadvantages of the reused/ recycled technologies / products do you see? Do you see option for improving the existing technologies/ products?
2. Is there an applicable reuse / recycle technique or technology that could be used which is currently not being practiced? If Yes is it being practiced somewhere and the reference?
3. Is there any innovative technology being used for raw material resource efficiency in the region which could be given more attention? If Yes then the reference?
4. What kind of technology / product should be further developed in order to improve reuse/recycling construction materials?
5. What is the kind of technical and policy support given to different stakeholders to increase use of recycled materials in construction?

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The Chennai Silks

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices: Bonn and Eschborn, Germany

B-5/1, Safdarjung Enclave
New Delhi 110 029 India
T: +91 11 49495353
E: info@giz.de
I: www.giz.de

Development Alternatives
B-32, TARA Crescent, Qutub Institutional Area
New Delhi - 110016
Ph: +91-11-2654-4100, 2654-4200, Fax: +91-11-2685-1158
Contact person: Krishna Chandran, Mob. +91-07042439455