A study on C&D waste generation and recycling potential in Gujarat

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Abstract: In the context of urbanization and construction's unceasing expansion, management of Construction and Demolition (C&D) Waste is a major issue facing in the current era. About 30to 40% C&D waste is generate across globe. According to Center for Science and Environment estimates, India recycles only 1% of C&D waste. The emerging and visionary project to revolutionize the management of C&D waste is discussed worldwide. The present study deals with C&D waste generation in major cities of Gujarat. To understand the gap of advance technologies required to meet with effective waste processing for increasing the recycling potential of plant. The planning for future predication of next 30 years i.e. 2051 the waste generation and recycling plant required to tackle the waste is studied. The study of market survey showing about 5 to 25% cost saving in recycled materials and utilization of recycled material with traditional material in concrete showing good results.

Keywords: Construction, Demolition, Waste management, Major cities, Gujarat

I. INTRODUCTION

Construction & Demolition waste is "a waste generates from new construction, repair, renovation or explosion activities for a structure like building, bridges, dams etc." The study of C& D waste is a major concern to environment. The disposal of waste material leads to soil, water and air pollution. The volume of C&D waste generation and its recycling potential study is essential for effective waste management. It is necessary to carryout research and promotes solution for better efficiency and reduces environmental impact. As per CPCB 2020-21 report, the status of MSW generation in class – I cities is shown in chart. Considering major class-I cities, Gujarat generates 10373.79 TPD MSW waste, out of it approximately 30% C&D waste (i.e. 3112.137 TPD) is generated.

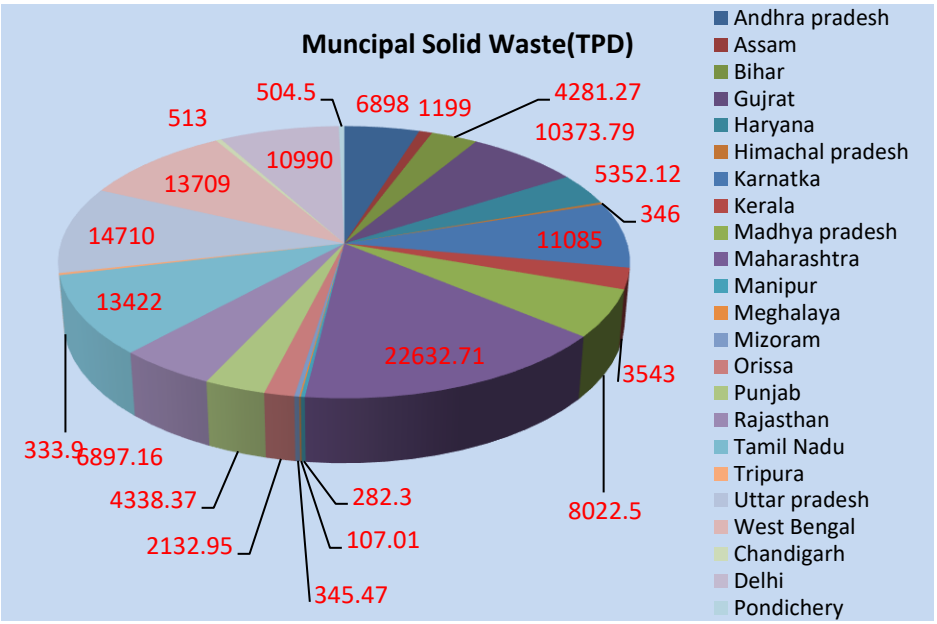

Fig. 1: MSW Waste generation as per CPCB 2020-21 report for class – I cities.

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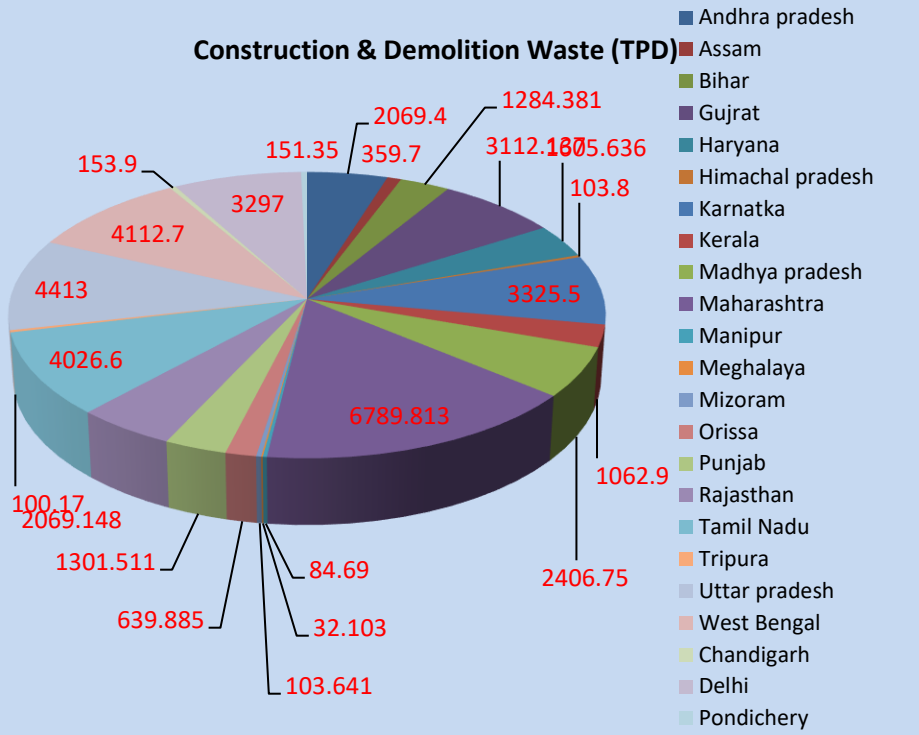

Fig. 2: C&D Waste generation for class – I cities.

A. Need of the study

C&D waste in urban areas is a key issue due to the lack of attention, proper facilities and services. The waste generated during construction lifecycle and demolition activities is dumped in open areas, water bodies or road side creates adverse effects to pollution and health issues.

B. Objectives

To study existing scenario and practices for C&D waste management in major cities of Gujarat. Prediction of C&D waste generation and recycling plants required in next 30 years. i.e. 2050 To understand the recycled and natural material utilization in concrete. Also, products manufactured from C&D waste and its cost comparison in available market.

C. Scope and Limitations

Study emphasis on literature evaluation, prediction of future waste generation and required operational recycling plant. And effective utilization of C&D waste generated. Limitation associated with the research is due to lack of records and statistics on C&D waste and management, study does not carry more quantitative & qualitative research.

D. C&D Waste site and material

On the construction site, segregate waste at the source. Use clearly labeled containers for different types of materials like concrete, wood, metal, plastics, and insulation. Ensure that workers separate waste during the demolition process. Set up Material Recovery Facilities to process and sort C&D waste on a larger scale. These facilities use conveyor belts, screens, and manual labor to separate and recover recyclable materials. The materials recycled from the waste are as follows:

- **Concrete Recycling:** Crush concrete waste into aggregates to be used as base materials for new construction projects. Reinforced concrete can be processed to recover steel reinforcement.
- **Wood Recycling:** Salvage and process wood from C&D waste for reuse as building materials, landscaping, or biomass energy production.
- **Metal Recycling:** Recycle metals like steel, aluminum, and copper by melting and reusing them in new construction or manufacturing.
- **Asphalt Recycling:** Asphalt from road demolition can be recycled by milling and using it in new asphalt mixtures.
- **Drywall Recycling:** Process gypsum-based drywall to extract gypsum for use in new drywall manufacturing.
- **Plastic Recycling:** Recycle plastic materials, such as PVC pipes and plastic sheets, for use in non-structural applications or alternative construction products.
- **Brick and Masonry Recycling:** Clean and process bricks and masonry materials for reuse in new construction.
- **Insulation Recycling:** Some types of insulation materials can be recycled. For instance, fiberglass insulation can be melted down and reused.

- **Aggregate Recovery:** Crush and screen mixed C&D waste to extract clean aggregates for use in road base or concrete production.
- **Hazardous Material Management:** Safely dispose of or recycle hazardous materials like asbestos and lead based paints following regulations.

E. Methods of Estimating

Estimating the amount of construction and demolition (C&D) waste generated is essential for effective waste management planning and resource allocation. Several methods can be used to estimate C&D waste generation, depending on the level of detail required and the available data.

Fig. 3: Method of Estimation C&D Waste.

II. LITERATURE REVIEW

Swarna Swetha K, Tezeswi T.P, Siva Kumar M.V.N (2022), compared management plans, taxes and penalties, material recovery, etc. for India, China, Australia, and the United States. Policymakers, businesses, and academics can benefit from the study's positive approach and behavioral changes on the implementation of CWM.

Kamyar Kabirifar, Mohammad Mojtahedi, Cynthia Changxin Wang, Vivian W.Y.Tam (2020), conducted research on the framework used to evaluate the efficacy of C&D waste management. Three primary categories—contributing elements, hierarchy, and effective management—are part of the conceptual framework. A few contributing elements are the characteristics of stakeholders, project life cycle, instruments, and regulations pertaining to sustainable practices. Approaching, reusing, reducing, and recycling resources are all part of the hierarchy. favorable strategy, organizational circumstances, etc. are all part of effective management.

Gitanjali Bhatnagar, Devendra Pratap Singh (2020), assessment of the literature, major management and technology-related obstacles that cities confront while managing building and demolition waste were examined. Additionally, non-directive interviews with architects and construction managers were conducted. The study highlights the need for a developed framework and emphasizes the importance of institutional, technological, regulatory, and financial implementation constraints that have a detrimental impact on metro-city C&D waste management.

P N Ojha, Puneet Kaura, Brijesh Singh, B N Mohapatra (2023), experimental research, there are two distinct sources of recycled concrete aggregates: one batch comes from the Burari Plant in New Delhi, and another batch is produced in a

laboratory by crushing concrete cubes with a compressive strength of 20 to 30 MPa. Concrete based on RCA was found to have ten to forty percent lower compressive and flexural strengths than the control mix. The primary cause of this decrease in strength is the creation of a double interfacial transition zone (ITZ).

Sakshi Gupta, Malik RK (2018) talks about the environmental effects of C&D waste. In India, dust and noise are the main C&D waste disposal-related problems that have a negative impact on the environment. The current study examines the effects of building waste and its function in the industry, which is necessary to provide a proactive and hopeful system for environmental management and protection.

Soumen Maity, Pankaj Phulwari, Vaibhav Rathi, Krishna Chandran, Achu Sekhar, Avinash Kumar, Abhijit Banerje (2017), investigates Ahmedabad's use of the C&D waste management concept. Recognizing, characterizing, and assessing C&D waste to ensure appropriate product manufacture. The study indicates that recycling plants need to be improved. Waste can be decreased by utilizing cutting-edge technologies and ensuring that recycled goods are timely supplied and demanded.

Vatsal Patel, Srinivasarao Meka (2013), studies model the production of solid trash in medium-sized Gujarati towns. Population growth and solid waste generation are projected over a 25-year period using empirical models and a dynamic model that uses artificial neural networks.

Yunfu Gao, Zhiqi Gong, Na Yang (2018), study two types of methodologies for calculating the amount of C&D waste generated: basic approaches and comprehensive methods. Computer technology can help record the classified information of C&D trash for better waste management and benchmarking.

Anupam Rawat, A.K. Sachan, Ramashanker (2014), examined India's present waste management system and tested the obstacles to closing the usage loop and creating markets for recycled materials.

Marta BIAŁKO (2018), studied Methods of Estimating the Amount of C&D Waste. The GRC method has been identified by multiple researchers as the most common approach. The features of the estimating model (MPP) and the macroeconomic and microeconomic (ME) approaches are included in the characterization of the generation rate calculation method (GRC).

III. METHODOLOGY

The structure of methodology provides study of literature, existing data collection for major cities, future prediction analysis, market survey for recycled products and future scope as illustrate in below:

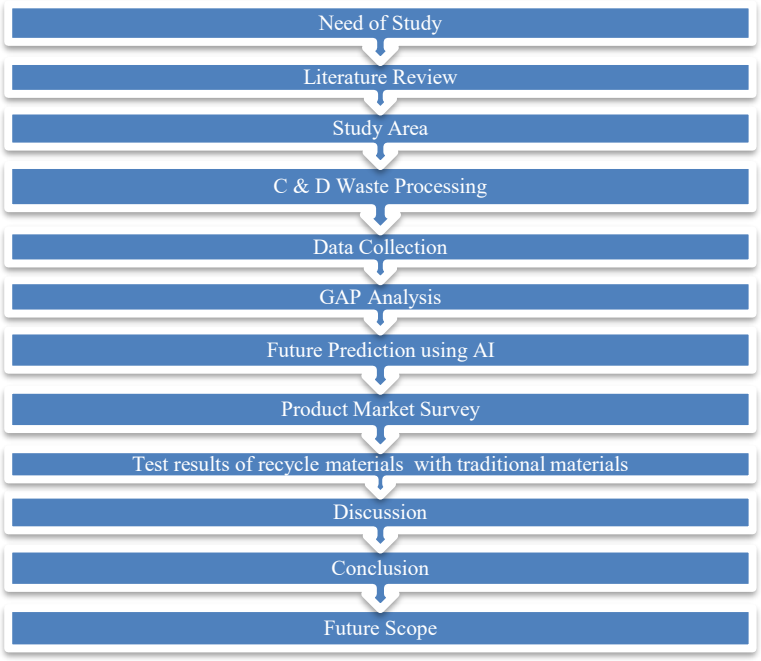

Fig. 4: Process of Work

IV. STUDY AREA

Gujarat is an Indian developing state of 6th largest in terms of area and 9th largest in terms of population. The major cities of Gujarat are Ahmedbad, Surat, Vadodara, Rajkot, Bhavnagar, Jamnagar, Gandhinagar and Junagadh. As per CPCB 2017, guidelines on environment management of C&D waste population more than 10 lakhs should setup a recycling plant mandatory. Also encourage the cities of population less than 10 lakhs to initiative recycling plant. More than one plant is implemented were waste generation is more than 2000TPD.

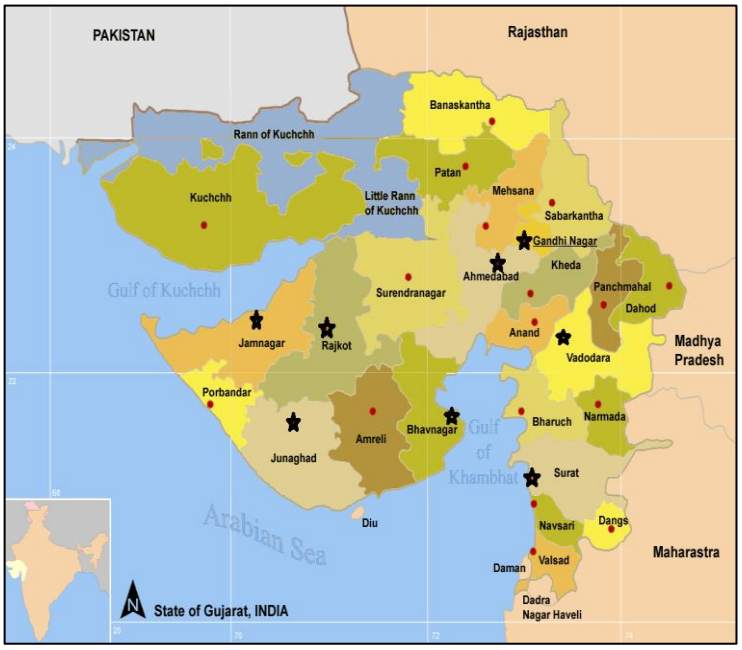

Fig. 5: Major Cities

According to TIFAC 2001 (Technology Information, Forecasting and Assessment Council, DST, GoI, 2001), C&D waste generation (40–60) kg per sq. m of new construction, (40–50) kg per sq. m of building repair and (300–500) kg per sq. m for demolition of buildings. The waste materials generated are Sand & Gravel (36 %), Bricks (31%), Concrete (23%), Metal (5%), Bitumin (2%), Wood (2%) and Other (1%). There is a demand of maufactured materials due less natural resources. The manufactured materials are made available less than 20% corresponding to natural resources.

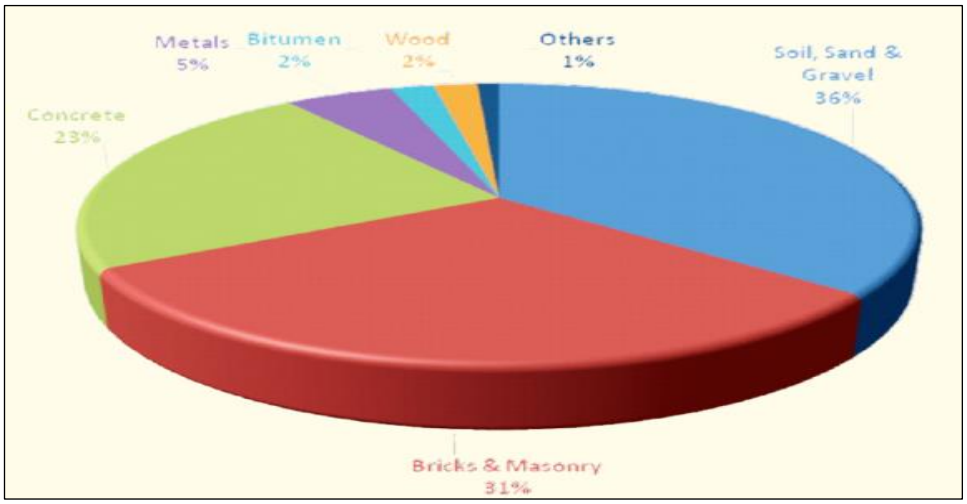

Fig. 6: Composition of Waste

V. C&D WASTE PROCESSING

Recycling construction and demolition (C&D) waste involves the use of various machines and technologies to sort, process, and repurpose materials. Here are some of the key machinery and technologies commonly used for recycling C&D waste:

A. *Collection and Transportation:*

Wheel loader and power shovel are used to collect the material and trucks and wagon are used to transport the materials.

B. Crushing:

Jaw crushers and impact crushers are used to crush materials like concrete, bricks, and asphalt reducing them to manageable sizes for reuse.

- **Concrete Pulverizes**: These machines are designed to crush and separate concrete from steel reinforcement, allowing for the recycling of both materials.

- **Crane Systems**: These are used to handle heavy materials and large debris, facilitating the efficient movement and sorting of C&D waste.

Screening: Vibrating screens are used to separate materials by size. This is essential for sorting materials into different categories, such as aggregates and fines.

- **Magnetic Separators**: Magnetic separators, like overhead magnets or drum magnets, are used to remove ferrous metals (iron and steel) from the waste stream. This allows for the recovery of valuable metals.
- **Air Classifiers**: Air classifiers use air streams to separate lighter materials (e.g., plastics) from heavier materials (e.g., concrete). They can also sort materials based on size.
- **Density Separators**: Density separators use gravity and air flow to separate materials based on their density. This is useful for separating aggregates from lighter materials like wood and plastics.

C. Material Recovery Facilities (MRFs):

MRFs use a combination of conveyor belts, screens, and manual labor to sort, separate, and process C&D waste. They are highly automated facilities that can handle a wide range of materials.

- **Dust Control Systems**: Dust control equipment is essential in C&D recycling facilities to reduce airborne particles and protect workers' health.

D. Recycling Product Plant

- **RMC:** Replacement with traditional material mix, used in all construction activities.
- **Casted Products:** Hollow bricks used in compound walls, Blocks used in pedestrian and parking area, Tiles used in buildings, Granular sub-base used as pavement base layer, Sand & Aggregates used in construction of different infrastructures,

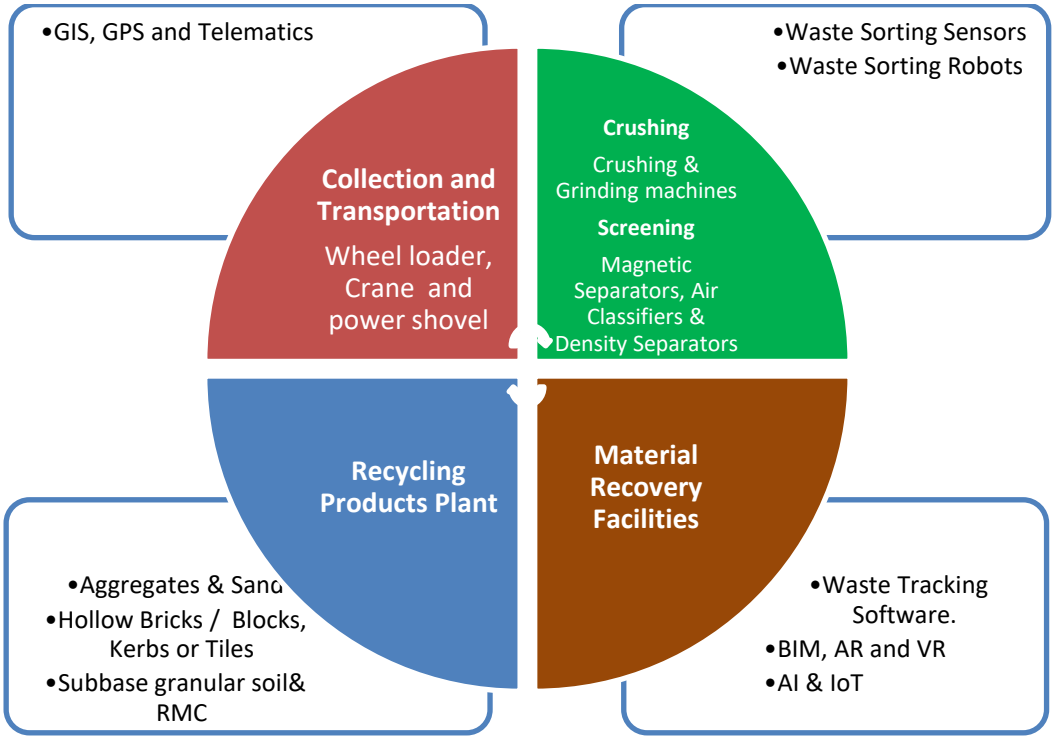

Fig.: 7: Recycling Process

VI. DATA COLLECTION

As per BMTPC Guidelines 2016, cities with more than 10 lakhs population should have recycling plant. Also population less than 10 lakhs cities initiate and encourage for reuse and recycle c & d waste. Approximately 5 to 7 acre land is required for 1000TPD recycling plant. According to CPCB guidelines for solid waste management the average rate of C&D waste generation per person per day is estimated to be 0.2 to 0.5 kg. The current status of recycling plant in major cities of Gujarat is discussed below:

Table: 1
C&D WASTE MANAGEMENT IN MAJOR CITIES OF GUJARAT

No	Major Cities in Gujarat	Area (sq. km)	Population 2011 (Lakhs)	Ward	C & D Waste Generation (Ton Per Day)	C & D Waste Collection Location (No.)	C & D Treatment / Recycling Unit	Recycled Products
1	Ahmedabad	530.0	72.14	63	700	17	01 1000 TPD DNP Infrastructure Pvt. Ltd 2013 Amdavad Enviro Project Pvt Ltd (https://amdavadenviro.in/)	Products Paver Block Kerb Masonary Block Aggregate M sand
2	Surat	461.6	60.81	107	550	10	01 300 TPD Surat Precast Green Pvt. Ltd (https://sgppl.co.in/)	Products sand, block, Paver block M sand Aggregate Stone dust Interlocking tiles
3	Vadodara	454.33	41.65	28	750	10	01 1000 TPD Picson Construction Equipments Pvt. Ltd. (https://www.picsinternational.com/c&d-waste-recycling-plant-in-vadodara)	Product M sand Aggregate Stone dust
4	Rajkot	170	38.04	29	75	3	Proposed 50TPD Capacity Plant (Village: Nakarawadi - 1.5 acres)	--
5	Jamnagar	125.67	27.43	21	45	39	Proposed 50TPD Capacity Plant	--
6	Bhavnagar	108.27	28.80	19	45	13	Proposed 50TPD Capacity Plant (Parsi Bhisto - 5 acres)	--
7	Gandhinagar	326	13.91	58	10	3	Treated at Ahmedabad Plant	--
8	Junagadh	160	27.43	18	18	9	Proposed 25TPD Capacity Plant	--

Source: Census of India 2011 & Municipal Cooperation

VII. GAP ANALYSIS

C&D waste generation in major cities of Gujarat is increasing due to growing population and human activities. The demand of recycling plant to reduce the waste is projected as per CPCB guidelines. There is a demand of recycling plant were population is more than 10 lakhs.

There is a demand of advanced technologies in the plant for effective waste management. The some of the technologies should be adopted as follows:

- **GIS, GPS and Telematics**: These technologies are used to monitor the movement of C&D waste materials, equipment, and transportation vehicles, improving logistics and tracking
- **Waste Sorting Robots**: Some advanced facilities use robotic arms / optical sorting equipped with sensors and cameras to automate the sorting process and improve efficiency.
- **Waste Tracking Software**: Digital platforms and software systems are used to track, monitor, and report on the types and quantities of materials processed, making data management more efficient.
- **BIM, Augmented Reality (AR) and Virtual Reality (VR):** BIM, AR and VR technologies can be used for training and guiding workers in sorting and processing tasks.

VIII. FUTURE PREDICTION USING AI

The future prediction of C&D waste generation and population is estimated using AI. Using historical Population growth trends and assuming future growth rate the projection of next 30 years data is prepared. The method used to predict the population for 2051 is Average Annual Growth Rate. In year 2051, the average percentage increase in population estimated from 2021 to 2051 across all cities is approximately 91.82%.

TABLE: 2
PROJECTED POPULATION FOR YEAR 2051

Year		**2001**	**2011**	**2021**	**2031**	**2041**	**2051**
Sr No	**Major Cities**	**Population (Lakhs) using** Growth Rate to Future Years					
1	Ahmedabad	58.93	72.14	88.31	108.11	132.34	162.01
2	Surat	42.75	60.81	86.50	123.04	175.02	248.96
3	Vadodara	36.41	41.65	47.64	54.50	62.34	71.32
4	Rajkot	31.69	38.04	45.66	54.81	65.80	78.98
5	Jamnagar	19.04	27.43	39.52	56.93	82.02	118.16
6	Bhavnagar	24.69	28.8	33.59	39.19	45.71	53.32
7	Gandhinagar	12.37	13.91	15.64	17.59	19.78	22.24
8	Junagadh	24.48	27.43	30.74	34.44	38.59	43.24

Source: Census of India (2001-11)

The average percentage increase in C&D waste generation estimated from 2021 to 2051 across all cities is approximately **98.07%**. These projections provide rough estimates using AI.

Table: 3
PROJECTED C&D WASTE GENERATION IN TPD FOR YEAR 2051

Year		**2021**		**2031**		**2041**		**2051**	
Sr No	**Major Cities**	**Population (Lakhs)**	**C&D Waste**	**Population (Lakhs)**	**C&D Waste**	**Population (Lakhs)**	**C&D Waste**	**Population (Lakhs)**	**C&D Waste**
1	Ahmedabad	88.31	700	108.11	857	132.34	1049	162.01	1284
2	Surat	86.50	550	123.04	783	175.02	1113	248.96	1584
3	Vadodara	47.64	750	54.50	858	62.34	981	71.32	1122
4	Rajkot	45.66	75	54.81	90	65.80	108	78.98	129
5	Jamnagar	39.52	45	56.93	65	82.02	93	118.16	135
6	Bhavnagar	33.59	45	39.19	52	45.71	61	53.32	71
7	Gandhinagar	15.64	10	17.59	11	19.78	13	22.24	14
8	Junagadh	30.74	18	34.44	20	38.59	23	43.24	26

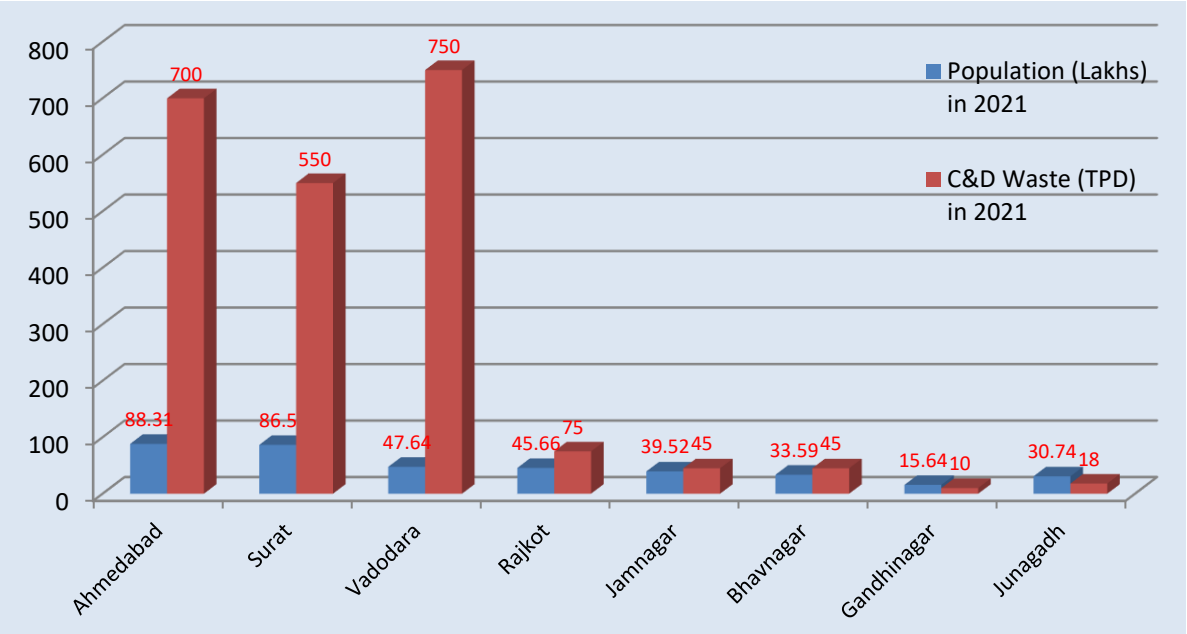

Fig. 8: Graphical representations Population v/s C&D waste generation in major cities (as per 2021)

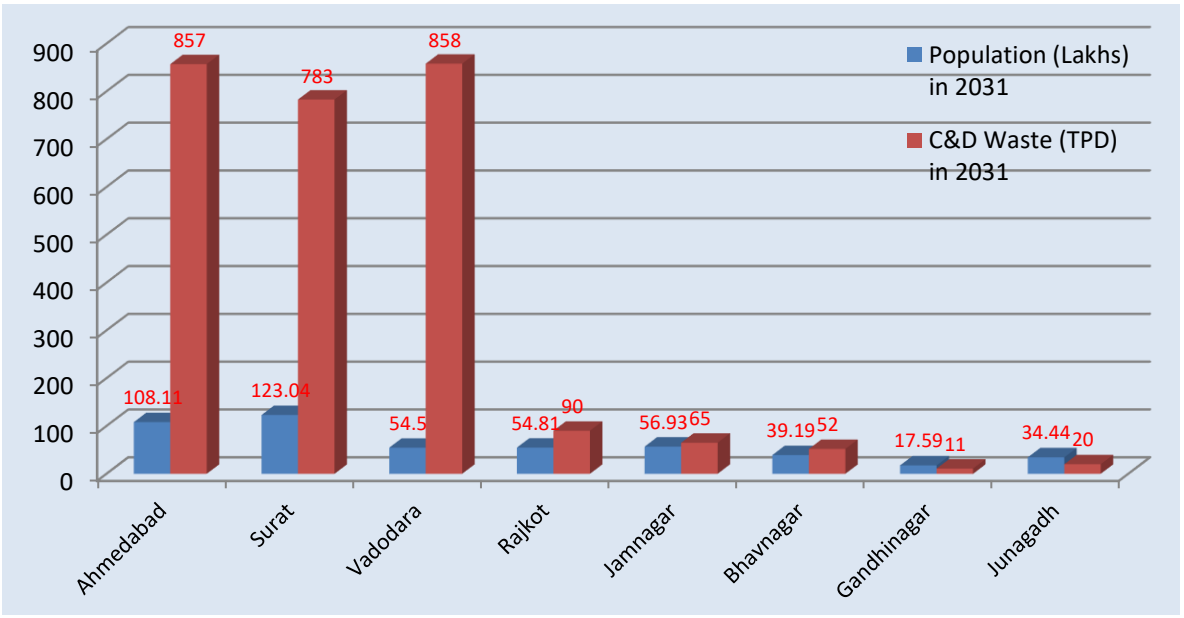

Fig. 9: Graphical representations Population v/s C&D waste generation in major cities (as per 2031)

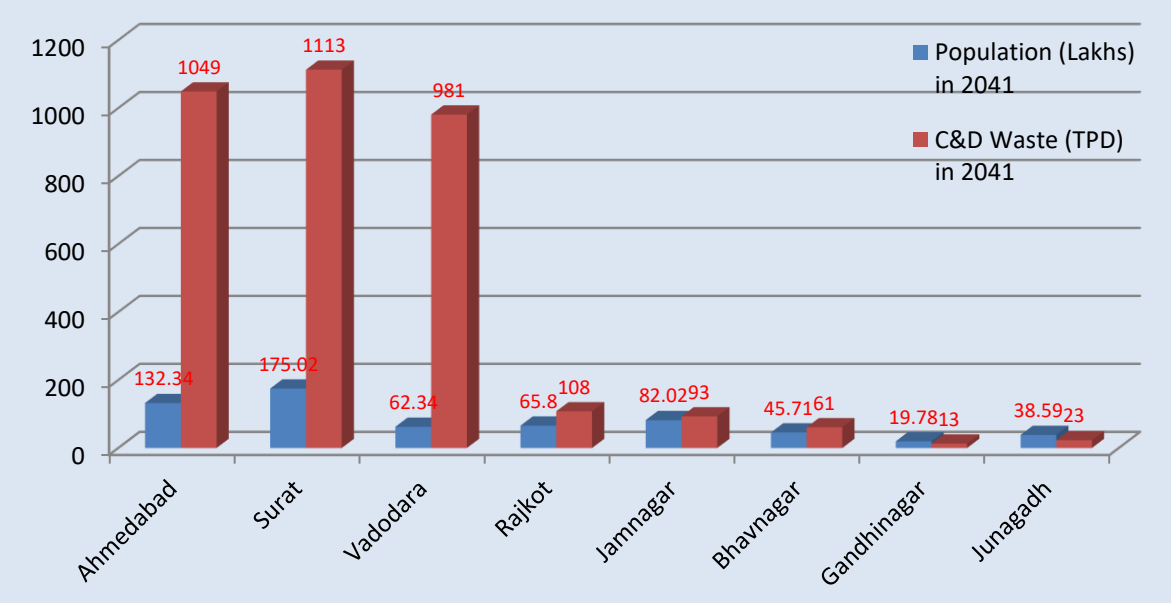

Fig. 10: Graphical representations Population v/s C&D waste generation in major cities (as per 2041)

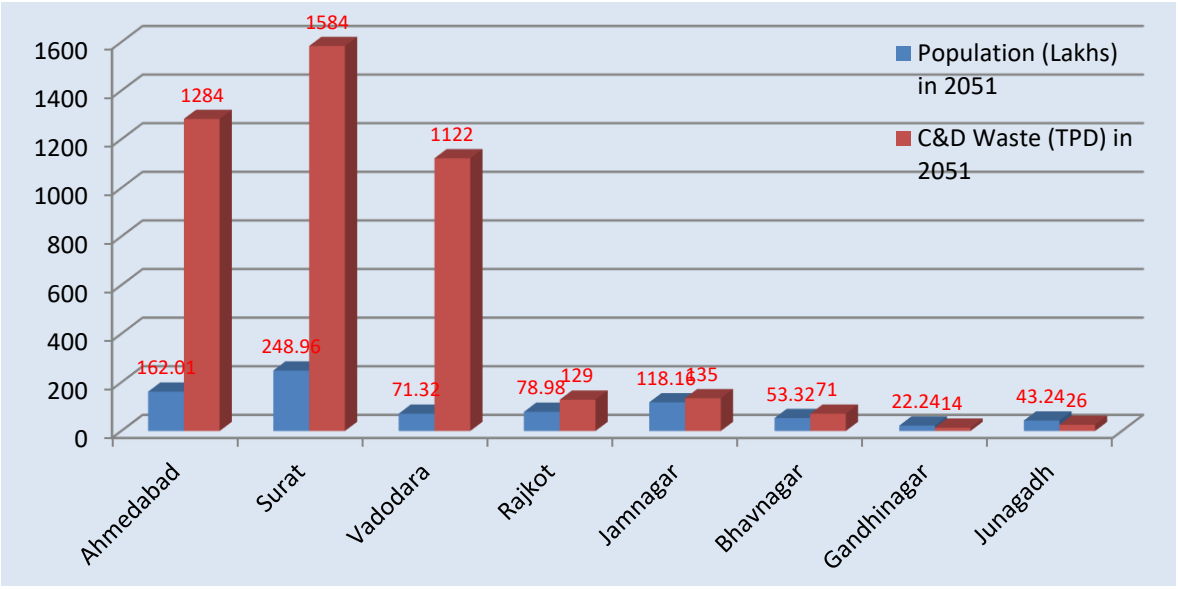

Fig. 11: Graphical representations Population v/s C&D waste generation in major cities (as per 2051)

As per the future prediction of c&d waste generation i.e. 2051 using AI the demand of recycling plant is calculated to setup the plant. The typical size range of c&d recycling plant available in India classified based on small scale (20 to 50 TPD), medium scale (50 to 200TPD) and large scale (200 to 1000TPD)

Table: 4
C&D WASTE TO BE HANDLING FOR NEXT 30 YEARS IN 2051

Sr. No	**Major Cities**	**C&D Waste Generation in 2051 (TPD)**	**Recycling Plant Operational in 2021**	**Additional Setup Recycling Plant (as per CPCB 2017)**
1	Ahmedabad	1284	1 (1000TPD)	1 (300 TPD Capacity)
2	Surat	1584	1 (300TPD)	1 (1000 + 300TPD Capacity)
3	Vadodara	1122	1 (1000TPD)	1 (200 TPD Capacity)
4	Rajkot	129	0 (Proposed 50 TPD)	1 (200 TPD Capacity)
5	Jamnagar	135	0 (Proposed 50 TPD)	1 (200 TPD Capacity)
6	Bhavnagar	71	0 (Proposed 50 TPD)	1 (200 TPD Capacity)
7	Gandhinagar	14	--	1 (50 TPD Capacity)
8.	Junagadh	26	0 (Proposed 25 TPD)	1 (50 TPD Capacity)

IX. RECYCLED PRODUCT MARKET SURVEY

The product available within the market rate is compared with recycled manufactured product from C&D waste results to 5 to 25% cost saving is achieved.

Table: 5
MARKET RATES OF RECYCLE PRODUCTS

Item	Unit	Rate (Rs.)	Price of equivalent item made using C&D (Rs.)	% saving
Sand	m^3	700	665	5.2
Dust	m^3	1100	950	13.6
Brick aggregate	m^3	600	465	22.5
Aggregate (20 or 10 mm)	m^3	1175	900	23.4
Surkhi	m^3	700	635	9.2
Kerb stone	m^2	4100	3950	3.65
Paver block	m^2	360	340	5.5

Source: IRC: 121-2017

X. TEST RESULTS OF RECYCLE MATERIAL WITH TRADITIONAL MATERIAL

Some of the C&D waste recycled fine and course aggregate with traditional materials are used in concrete. The test result for different grade of concrete is listed below

Table: 6
COMPRESSIVE STRENGTH COMPARISON FOR FINE AGGREGATES

Natural Fine Aggregates				Recycled Fine Aggregates			Reference
Sr No	Replacement	7 Day	28 Day	Replacement	7 Day	28 Day	
1.	0%	25.93	38.98	75%	30.55	39.87	[27]
2.	0%	13.50	20	10%	13.02	19.65	[28]
3.	0%	44.44	33.14	20%	46.66	31.11	.[31]
4.	0%	38.51	48.88	20%	31.25	45.03	[32]
5.	0%	23.63	28.56	40%	22.59	28.1	[35]
6.	0%	35.6	49.8	60%	42.4	54.7	[36]

Table: 7
COMPRESSIVE STRENGTH COMPARISON FOR COURSE AGGREGATES

Natural Course Aggregates				Recycled Course Aggregates			Reference
Sr No	Replacement	7 Day	28 Day	Replacement	7 Day	28 Day	
1.	0%	25.93	38.98	25%	26.28	44.48	[27]
2.	0%	13.50	20	10%	13.12	19.72	[28]
3.	0%	21.32	24.86	20%	21.79	24.75	[29]
4.	0%	22.8	30.52	10%	21.49	29.89	[30]
5	0%	--	32.05	25%	--	31.03	[33]
6	0%	33.13	47.53	20%	31.93	43.92	[34]

XI. DISCUSSIONS

- The average percentage increase in population estimated from 2021 to 2051 across all major cities is approximately 91.82%.
- The average percentage increase in C&D waste generation estimated from 2021 to 2051 across all major cities is approximately 98.07%. .
- The product available within the market rate is compared with recycled manufactured product from C&D waste results to 5 to 25% cost saving is achieved.
- An optimum recycled material used in concrete is 25% for course aggregates and 45% for fine aggregates.
- The partial replacement of fine and course aggregates shows good results in concrete and is recommended for manufacturing of blocks, tiles, concrete furniture etc.

XII. CONCLUSION

- Set up of processing / recycling plant should meet the future growth of population, waste generation and human activities for all major cities of Gujarat.
- Recycled materials help to reduce the cost and use of natural resources. i.e About 30% replacement of ingredient shows better results in concrete.

XIII. FUTURE SCOPE

- Automation in recycling plant to increase the efficiency of waste recycling.
- BIM modeling for ongoing project.
- Study on smart technologies for on-site sorting of C&D waste.
- Manufacturing & selling Regulation for recycled materials in terms of policies and taxes.

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