CHAPTER 52

Development of a Framework for Sustainable Development in the Domain of SWM using the Participatory Approach: Case of Pune

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ABSTRACT

Waste management has been a significant concern as cities expand, posing environmental risks. Using a participatory approach, the research attempts to present a framework for waste-to-energy (WTE) conversion within local communities using the participatory approach. Stakeholders provide insights through the survey conducted in the study area such that the solutions are socio-economically feasible and locally adapted. The study identified that the lack of proper integration of technological interventions, awareness, and community engagement desist the population from adapting the initiatives at community and individual levels. The proposed framework emphasized the need to educate the citizens to contribute towards waste collection, segregation, and WTE. This intervention highlights sustainable urban practices, less reliance on landfills, improved resource recovery, and an emphasis on using renewable energy in local communities. The framework highlights the action plan for Pune's municipal authorities, community members, garbage collection personnel, environmental NGOs, and commercial sector partners to develop WTE solutions, reflecting the participatory approach. The participatory method addresses common concerns by engaging residents early in decision-making. This framework promotes adopting contextually appropriate solutions that are efficient, sustainable, and aligned with the city's environmental goals and are most preferred by the respondents in the study area. In addition to technology selection, the participatory model emphasizes transparency and accountability through regular feedback mechanisms, allowing Pune's residents to contribute to its ongoing improvement. The framework is further validated using cost-benefit analysis (CBA) to demonstrate the environmental and economic benefits of the WTE project, ensuring that it remains responsive to evolving needs and environmental standards. Hence, this study frames the novel approach towards the sustainability pathway emphasizing the WTE with the participatory approach.

Keywords: Waste management; Circular Economy; Waste-to-energy; Participatory approach; Sustainability.

1.0 Introduction

The pressure on the municipalities is immense, to collect, to dump the collected waste

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involving working regressively throughout the year. According to the Central Pollution Control Board of India, the per capita waste generation has increased from 0.26kg/per to 0.89kg/day. Landfills remain the optimal choice for the municipalities for the disposal of waste but there remains a potential threat to them as they come up with lots of issues about environmental concerns and health hazards for the workers as well (Hui *et al.*, 2006). A few cities in India like Pune have shown a positive approach toward SWM, which this paper has highlighted. An observation was built based on data received from the departments and site visits, the main focus has been laid on the collection of waste, but a major lag has been observed over the further steps like segregation, treatment, disposal, and recycling.

Kumar & Agrawal (2020) Through this study, a focus is placed on reusing the SW and creating a framework for waste-to-energy through a participatory approach.(Tozlu *et al.*, 2016) The role of citizen participation and how it affects the cycle of WTE have been discussed in detail. Many attempts have been made in the past few years to resolve SWM-related problems, but they have not been effective as the generation of waste is much more than processed waste. Most of the issues have been seen during the collection of mixed types of waste, and implementation of the policies regarding the treatment system. (Kalyanasundaram *et al.*, 2023) After the introduction of the SDGs, the Government of India has laid mandates for the right treatment of the MSW and its disposals. While there are very few such technologies and methods introduced for doing it rightly. Now with the circular economy being in the focus, energy generation was also added to the agenda, and discussion was laid over conversion 'waste-to-energy'.(Dolla & Laishram, 2021)

The gap that was identified after ground-truthing and through the secondary data collected from the government officials was, that citizen participation was missing, and achieving the goal of WTE could play a major contributor to this aim. (Srivastava *et al.*, 2015)This study highlights the importance of citizen participation and forming a framework to achieve the WTE conversion which could be implemented in all the major cities throughout the country by doing a study on the selected site in PCMC. The research objectives of the study are:

- To identify literature in the field of SWM using a participatory approach.
- To interpret the parameters of SWM through the lens of a participatory approach.
- To analyze the parameters of SWM in the study area.
- To recommend the framework for SWM in the study area for sustainable development in the domain of SWM using a participatory approach.

2.0 Methodology

Using the mixed method with quantitative and qualitative approaches leads to this study in identifying the possible solutions and also give socially feasible and economically acceptable solutions. This combination will also strengthen the reliability of the conclusion concerning the objective. The image is a flowchart representing a structured research methodology. It outlines

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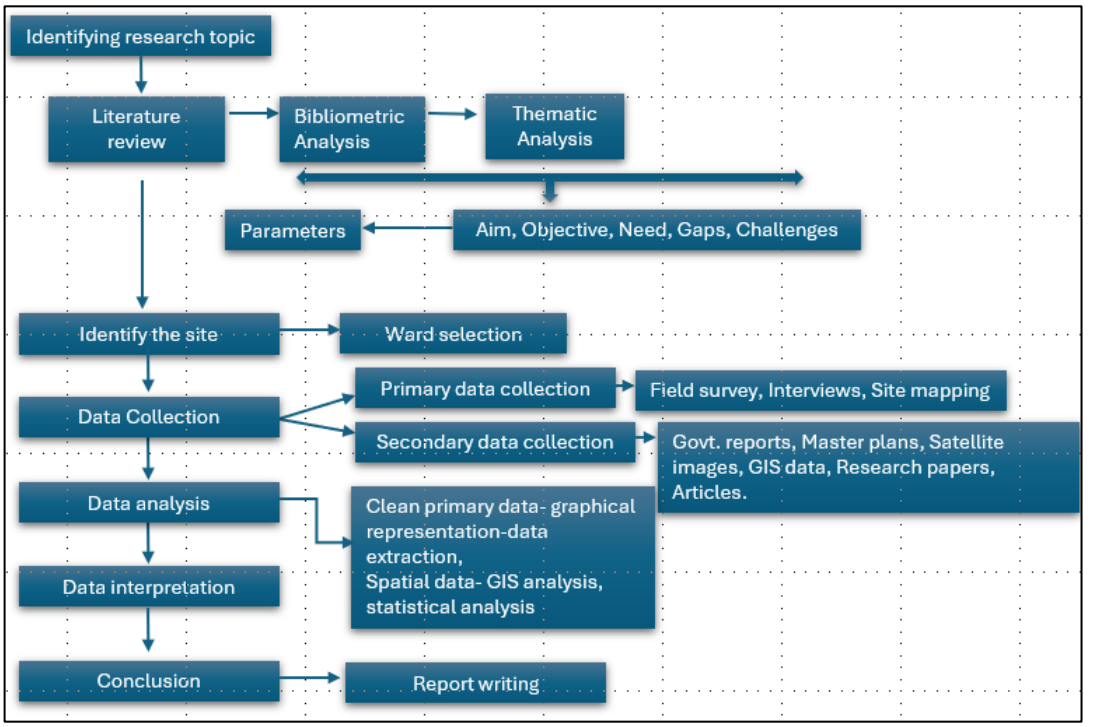
the steps involved in conducting a research study, particularly in fields like geography, urban planning, or environmental studies.

Figure 1: Methodology Used for Study



2.1 Data collection

Conducting field surveys, interviews, and site mapping. Gathering information from government reports, master plans, satellite images, GIS data, research papers, weather, and hydrological data. Processing and examining collected data using- GIS & Remote Sensing, Big Data Analysis, Spatiotemporal Analysis (data over space & time), Statistical Analysis, Data Interpretation

2.2 Conclusion and report writing

Summarizing findings, concluding, and documenting them in a research report. Purpose of the Flowchart- Provides a systematic approach for conducting research. Help researchers plan, collect, analyze, and interpret data efficiently. Ensures a logical flow of activities in research.

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2.3 Qualitative method

This method includes detailed interviews with stakeholders like municipal officials, activists, waste management workers, and local people living in the study zone, having a one-to-one conversation with the citizens living in the vicinity of the landfill zone. Going on-site and observing the management of the process and validating the information received from the above processes.

2.4 Quantitative method

Data collection from primary sources, i.e. the people living near the landfill sites to know about the importance of waste dumping and its harmful impact on the environment. Data collection from secondary sources of government departments like PCMC & PMC which will be the baseline for understanding and proposing solutions to the issue.

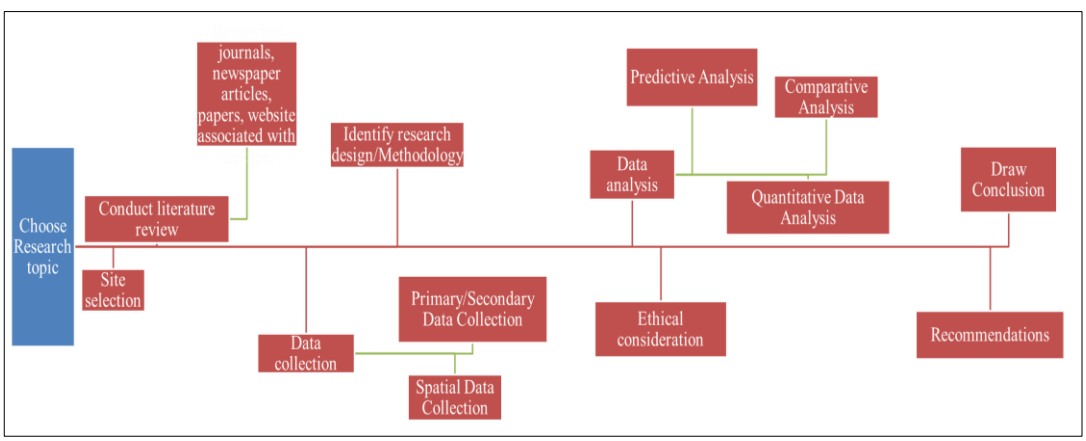
2.5 Participatory research method

With the help of the inputs received from the community, and data received from government officials and residents, areas with high volumes of waste generation could be identified and a specific proposal could be implemented for such areas. Government agencies could help arrange community workshops to educate participants about the benefits of WTE and encourage their participation in achieving its goal.

2.6 Analytical method

Analyzing the setting up of the WTE initiative in Pune through a SWOT analysis. GIS mapping can play a significant role in analyzing areas with high waste generation, collection, and potential WTE sites. Decision-making would become rational through GIS.

Figure 2: Flow of Study



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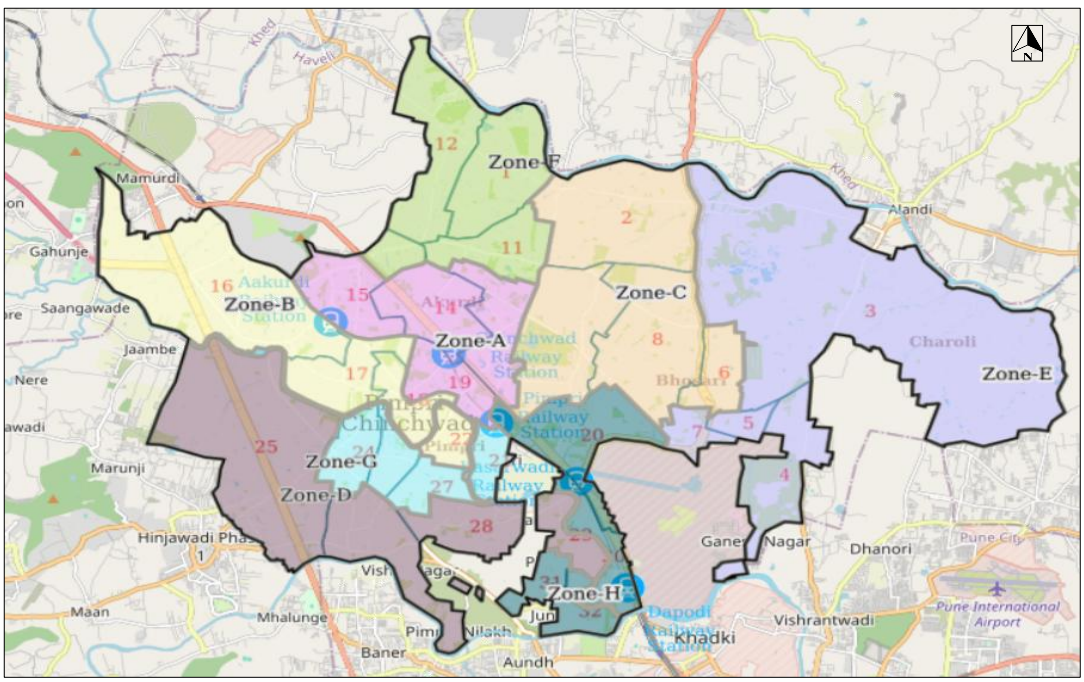
2.7 Site selection

Pune, one of India's rapidly growing cities, faces significant challenges in managing its increasing waste generation due to urbanization and population growth. With a diverse demographic and a thriving industrial sector, Pune generates substantial amounts of municipal solid waste daily. As the city strives to improve its waste management practices and address energy shortages, waste-to-energy (WTE) conversion emerges as a promising solution. This approach not only reduces the volume of waste sent to landfills but also generates renewable energy, contributing to a more sustainable future for Pune's PCMC. The image (Figure 3) represents the administrative boundary map of PCMC (*Pimpri-Chinchwad Municipal Corporation*). The map shows different ward boundaries and zoning divisions of the city. These boundaries help in municipal governance, planning, and infrastructure development.

Figure 3: PCMC Ward Map



3.0 About PCMC (Pimpri-Chinchwad Municipal Corporation)

Pimpri-Chinchwad is a major industrial and residential city in Maharashtra, India. It is located near Pune and forms a part of the Pune Metropolitan Region (PMR). The city is administered by the Pimpri-Chinchwad Municipal Corporation (PCMC). PCMC is divided into

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multiple zones and wards for governance and municipal management. Each ward has elected representatives (corporators) who work under the municipal administration. The Municipal Commissioner is the chief executive officer responsible for implementing policies and infrastructure projects.

3.1 Key features of the PCMC administration boundary map

The map shows the different numbered administrative wards. The Mumbai-Pune Highway (NH-48) and other major roads are visible. The map covers both industrial zones (like MIDC) and residential areas. The map includes neighboring regions like Pune, Alandi, and Talegaon. The Pavana River runs through the city, influencing land use and infrastructure.

3.2 Importance of PCMC

Home to major industries like automobiles (Tata Motors, Bajaj Auto), IT parks, and manufacturing units. Rapidly growing city with modern housing projects, malls, and metro connectivity. Includes BRTS (Bus Rapid Transit System), Pune Metro extension, and road expansion projects. Presence of reputed schools, colleges, and hospitals.

4.0 Governance and Planning

PCMC governs civic services like water supply, roads, waste management, and urban planning. The city follows a *Development Plan* (DP) to manage growth and infrastructure. Smart City Initiatives are also in place. PCMC is implementing technology-driven solutions for urban management. Image 4 is a PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) flow diagram, which is commonly used in systematic reviews and meta-analyses to track the selection process of studies.

4.1 Key features of the image

4.1.1 Stages of study selection

- *Identification:* The initial number of records identified from databases or other sources.
- *Screening:* The number of records after duplicates are removed, followed by the exclusion of irrelevant studies.
- *Flowchart structure:* Typically, PRISMA diagrams follow a top-to-bottom structure. Numbers at each stage indicate how many studies were retained or excluded. It helps researchers transparently report their selection process. Ensures reproducibility in systematic reviews.

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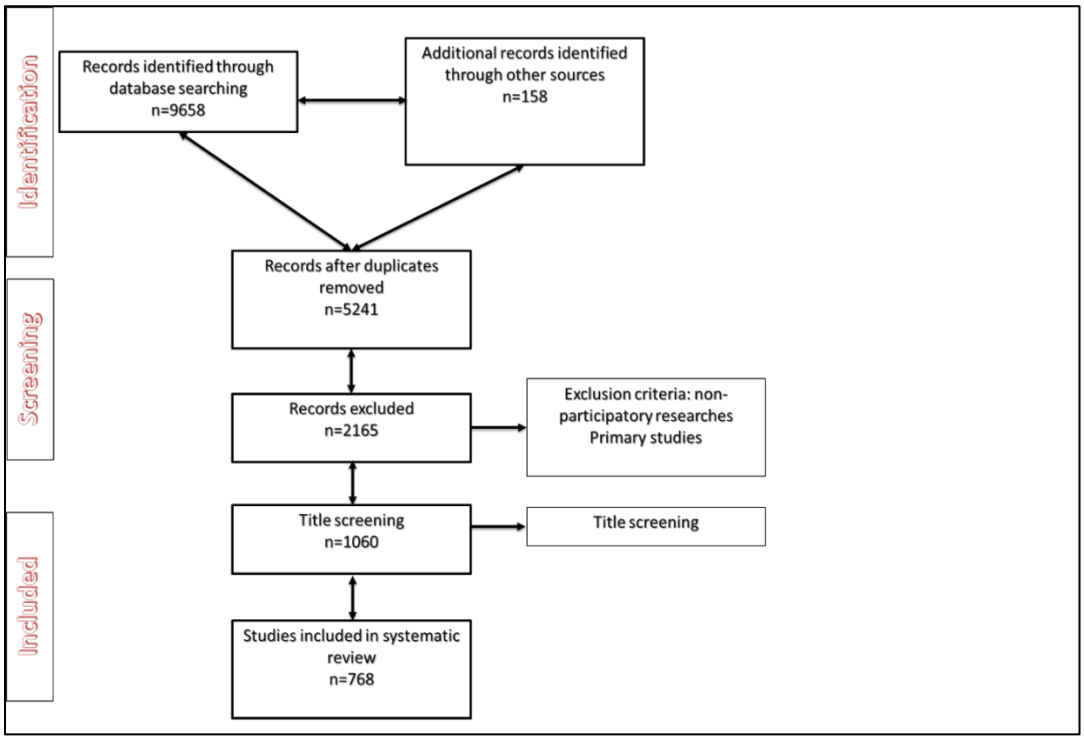
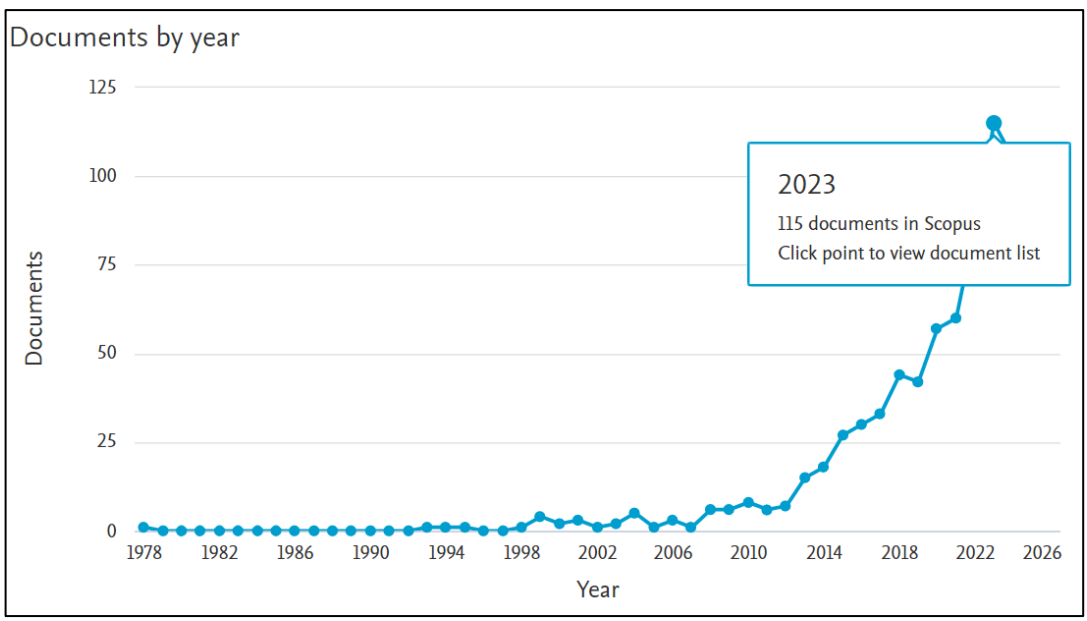
Figure 4: Literature Review Process





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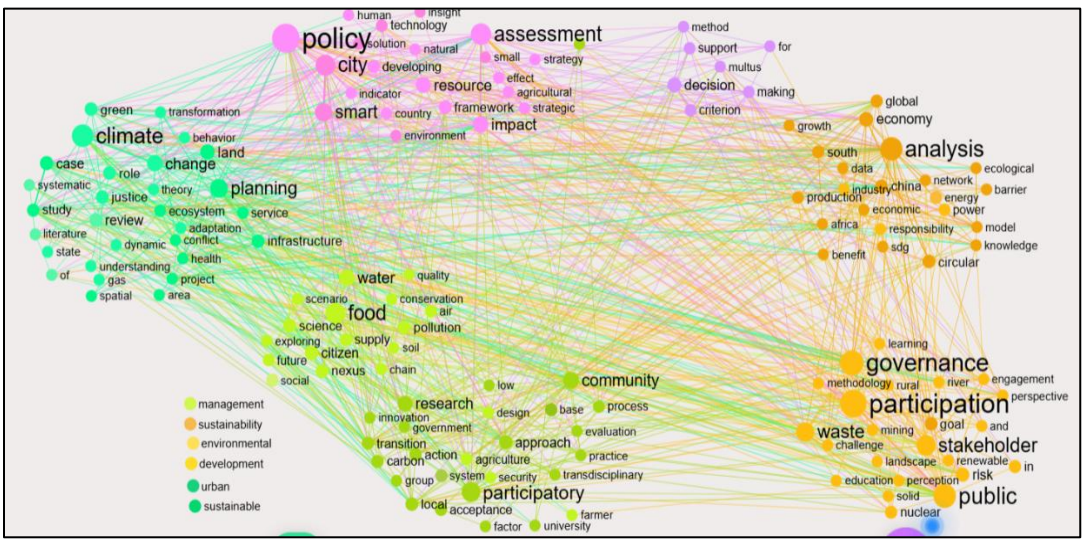
The image (Figure 5) is a network visualization of keywords and their relationships, likely from an academic or scientific domain. It consists of interconnected words in various colors, which appear to represent different thematic clusters. *InfraNodus* is the software used for getting results.

4.2 Clusters of words

- *Green (sustainable & environmental):* Words like climate, planning, food, water, research.
- *Yellow/Orange (governance & participation):* Words like analysis, economy, governance, and participation.
- *Pink/Purple (policy & decision making):* Words like policy, city, resource, assessment, and decision.
- *Connections (edges):* Lines connecting words indicate relationships or co-occurrence. Denser connections suggest frequent associations.
- *Font size & node size:* Larger words indicate higher relevance or frequency in the dataset.
- *Possible purpose:* This could be a bibliometric analysis, topic modeling, or keyword co-occurrence map, visualizing research trends or themes in sustainability, governance, and urban planning.

Figure 5: Network Visualization



4.3 Data collection

The following data set Table 1 has been received from the official Department of Solid Waste Management, PCMC. The image is a ward map of Pimpri-Chinchwad Municipal Corporation (PCMC), which is part of Pune's metropolitan area in India.

4.3.1 Key features of the map

- *Zonal divisions:* The map is divided into multiple zones (e.g., *Zone-A, Zone-B, Zone-C, etc*.), with boundaries for each zone marked. The zones contain numbered wards (e.g., 16, 19, 7), which likely correspond to electoral or administrative units within the PCMC.
- *Key areas:* The map labels prominent locations such as railway stations (e.g., Chinchwad Railway Station, Pimpri Railway Station). Areas like Akurdi, Charholi, and Hinjewadi are shown within their respective zones.
- *Color coding:* Different zones are represented by various colors, aiding in distinguishing between them.
- *Surrounding landmarks:* Areas outside the PCMC boundaries like Pune International Airport and neighborhoods such as Dhanori and Baner are also visible on the map.

This kind of map is typically used for Municipal Administration, managing urban planning, civic issues, and governance aiding understanding ward boundaries for local elections. The Table 2 represents garbage collection data across different zones of PCMC (*Pimpri-Chinchwad Municipal Corporation*). It provides details on the number of households and commercial establishments covered, the type of vehicles used for collection, and the average amount of garbage collected daily (*in metric tons per day, MTs/day*).

4.4 Key data components in the table

- *Zones & Wards:* The table categorizes garbage collection based on different zones (A, B, C, D, E, F, G, H) in PCMC. Each zone consists of multiple wards, which are identified by numbers.
- *Households & Commercial Coverage:* The table lists the approximate number of households and commercial establishments covered in each ward. The number varies significantly across wards, indicating differences in population density and commercial activity.
- *Type of Vehicles & Capacity:* The table mentions Mini Tippers as the vehicle type in Zone A, while for other zones, vehicle type and capacity details are missing. These vehicles are responsible for collecting garbage from the specified areas.
- *Insights from the Data:* High Household & Commercial Coverage: Some wards (e.g., ward 14 in Zone A, Ward 2, 4, 9, 8, 5 in Zone F) have a large number of commercial establishments, indicating areas with high business activity. Residential areas also vary, with some wards having more than 20,000 households covered. Some wards (e.g., Ward 2, 4, 5 in Zone B) have very few commercial establishments, while others have over 3,000 businesses, showing major commercial hubs.

The type of vehicle and carrying capacity is only mentioned for Zone A but is missing for other zones. The garbage collection data (MTs/day) is not filled in, which is crucial for waste management planning.

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5.0 Proposed Framework

This framework comes from digging into the Pune waste management study and thinking about how to make waste-to-energy (WTE) work with people at the heart of it. It's about getting Pune—Pimpri-Chinchwad area to cut down on landfills, turn trash into power, and build something that lasts. Through this study, we're aiming for a bigger picture which include turning Pune into a city that handles waste smartly—less dumping, more energy, and folks pitching in. Goal is to get people sorting trash better, pick WTE tech that fits Pune, keep things open and honest, and tie it all to India's sustainability targets. Through this framework, we aim to break down the process into five key components that work together: getting people involved, selecting the right technology, collaborating with the city, disseminating information, and monitoring progress.

Based on the study and literature review we went through, one of the outcomes that we came to is that people aren't engaged enough. An effort has been made to involve them more through various methods, including neighborhood meetups to determine where waste accumulates and what people want to do about it, and setting up small groups in each ward—called waste squads—to monitor sorting and pickup. One-on-one or through quick surveys to hear what they think about WTE ideas could be yet another method to keep them involved. People trust the plan more when they help shape it.

WTE's is the ultimate solution to the increasing pollution crises inclined with participation of the citizen. Look at the waste breakdown from the study—wet stuff like food scraps, dry stuff like plastic, green waste from markets. Composting for the organic waste, burning or gasifying the dry junk for power. Using later technologies like maps (like those GIS ones mentioned) to find location for WTE setups. Starting small with a test run in a factory-heavy area where businesses toss out a lot. Coordinating with green groups (NGO) and businesses to pool in money or know-how for WTE projects. Push sorting rules hard—maybe a fine for slacking or a perk for doing it right. Waste moves smoother, and WTE fits into the *Smart City Plans*.

The study says people's participation is less. Run some ads or talks—hit schools, homes, markets; about why sorting matters and what WTE can do. Show waste workers the ropes on handling stuff safely and splitting it up. Hand out flyers or tips in Marathi and Hindi to make even the locals to come up and participate. Observation is the key, keeping track of the process can boost the results as we can monitor positives and negatives of the aspects. Integrating a technological aspect maybe through an app or a spot on PCMC's site.

Check in every few months with a quick pros-and-cons rundown, like that SWOT analysis of the situation. Crunch some numbers yearly—how much does it cost versus what we save or earn? The plan stays sharp and bends with what people need. The first six months are crucial in analyzing the outcome. Based on the analyzed outcome, the way forward can be plotted.

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Working on STRENGTHS; OPPORTUNITIES based on received output provided by the citizens and the THREATS and WEAKNESS highlighted during the observation stage can help building up a robust framework.

6.0 Conclusion

The data highlights the scale of waste collection efforts in PCMC across different zones and wards. It can be used to analyze the efficiency of garbage collection and resource allocation, such as increasing the number of vehicles in high-density areas. Completing missing data (vehicle types, MTs/day collection details) would improve waste management planning.

Table 1: Waste Received in Different Months

Total quality received	Sep-23			Oct-23			Nov-23			Dec-23			Jan-24		
	PP	Com	WC	PP	Com	WC	PP	Com	WC	PP	Com	WC	PP	Com	WC
Wet waste	13984.3	13984.3	13984.3	14642.03	14642.03	14642.03	12907.61	12907.61	12907.61	13645.09	13645.09	13645.09	14267.32	14267.32	14267.32
Wet waste processed	13984.3	13984.3	0	14642.03	14642.03	0	12907.61	12907.61	0	13645.09	13645.09	0	14267.32	14267.32	0
Compost produced	447.50	447.50	0	468.55	468.55	0	413.05	413.05	0	477.58	477.58	0	499.36	499.36	0
Compost sold/used	447.50	447.50	0	468.54	468.54	0	413.05	413.05	0	477.58	477.58	0	499.36	499.36	0
Dry waste	25970.84	0	25970.84	27192.34	0	27192.34	23971.27	0	23971.27	25340.88	0	25340.88	26496.45	0	26496.45
Dry waste processed	25970.84	0	0	27192.34	0	0	23971.27	0	0	25340.88	0	0	26496.45	0	0
Plastic	7271.84	0	7271.84	7613.86	0	7613.86	6711.96	0	6711.96	7095.45	0	7095.45	7419.01	0	7419.01
Non recyclable	1298.54	0	0	1359.62	0	0	1198.56	0	0	1267.04	0	0	1324.82	0	0
Cloth	1558.25	0	0	1631.54	0	0	1438.28	0	0	1520.45	0	0	1589.79	0	0
Glass	519.42	0	0	543.85	0	0	479.43	0	0	506.82	0	0	529.93	0	0
Paper	1038.83	0	0	1087.69	0	0	958.85	0	0	1013.64	0	0	1059.86	0	0
Carboard	233.74	0	0	244.73	0	0	215.74	0	0	228.07	0	0	238.47	0	0
Packing material	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal	285.68	0	0	299.12	0	0	263.68	0	0	278.75	0	0	291.46	0	0
RDF	13504.84	0	0	14140.02	0	0	12465.06	0	0	13177.26	0	0	13778.15	0	0
Rubber	259.71	0	0	271.92	0	0	239.71	0	0	253.41	0	0	264.96	0	0
Hazardous waste	7.99	0	7.99	8.37	0	8.37	7.38	0	7.38	7.8	0	7.8	8.15	0	8.15
Revenue generated		46707			469			31537			62335			62335	

Table 3 represents waste collection data from all wards of Pimpri-Chinchwad Municipal Corporation (PCMC) over 14 months (*Feb-23 to Mar-24*). It categorizes waste into different types and tracks their collection month by month. Monthly Data (*Feb-23 to Mar-24*): The columns represent monthly tracking of waste collection for each category. However, the actual numerical values are missing, meaning the table might be used for recording or analyzing trends over time.

6.1 Purpose and use of this data

Monitoring Waste Trends: Helps PCMC track the quantity and type of waste generated in different wards. Planning Waste Management Strategies: Identifies seasonal trends (e.g., more green waste in monsoon, more hotel waste during festivals). Optimizing Waste Collection & Recycling: Helps in resource allocation, such as deploying more vehicles for dry/plastic waste recycling. Assessing Environmental Impact: Helps in understanding the proportion of biodegradable vs. non-biodegradable waste.

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Table 2: Zone-wise Waste Collected by Vehicles

Zones	Wards	Approx. household covered	Approx. number of commercial covered	Type of vehicle	Carrying capacity of vehicle	Avg. amount of garbage collected (MTs/day)
A	**10**	18521	1020	Mini Tipper		3.250
	14	18910	4145			2.500
	15	20567	1430			3.000
	19	22331	2571	Compactor	0.65	9.000
B	16	18757	2690	Compactor		16.000
	17	23990	500			9.000
	18	17560	970			16.000
	22	24550	43		8000	
C	2	25985	3018	Mini Tipper		1.800
	6	15077	393			2.600
	8	19850	3000			2.600
	9	16838	405		0.65	2.600
D	25	23451	1485	Compactor		16.000
	26	23397	1600			16.000
	28	24136	1534			16.000
	29	23100	1395		8000	9.000
E	3	18491	355	Mini Tipper	3.900	2.600
	4	23590	1016			3.900
	5	14700	816			2.600
	7	19015	436			1.800
F	1	24725	1002	Mini Tipper		2.700
	11	28890	2400			2.250
	12	24985	3850			1.800
	13	19211	297		0.65	2.600
G	21	20049	2824	Mini Tipper		3.000
	23	17989	2200			
	24	17839	3200		0.65'	
	27	17964	1850	Compacto	8	16
H	20	20980	1200	mini Tippe	0.600	3
	30	22455	729	Compactor		16
	32	22912	930			12
	40	18785	940		12000	12

Table 3: Categorization of Waste Received over a Year

INBOUND WB (all wards)	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24
CHICKEN WASTE	392530	450405	439265	421010	414965	412135	347725	323610	414920	411685	443465	449460	403765	464785
DRY WASTE	18995275	22222620	22512085	22247515	23759905	25299945	25327230	26183625	24794175	20961155	21871670	24007765	21783755	24594170
GHATAK WASTES	175	340	130	130	155	1220	345	345	345	345	1175	1175	995	995
GREEN WASTE	600795	667660	654585	668365	837990	857520	808795	746720	890925	797010	833450	878225	975850	927480
HOTEL WASTE	1474225	1614105	1652560	1765065	1796655	1843435	1775840	1737130	2078005	1704715	1913995	1825730	1701830	1739050
JALPARNI	2280385	3581685	3673445	3087335	2492120	832730	832730	832730	36420	25345	1305	1305	1615	1615
MANDAI	103540	104480	109155	103205	179785	666265	594080	600295	579180	536535	647890	602710	582425	638605
MATTI SOIL	44925	44925	44925	44925	44925	44925	44925	44925	44925	44925	44925	6150	1223665	1296010
MIX WASTE	1403940	507570	449225	623720	992330	1493985	1282800	1382395	3813915	4848630	4327130	3830300	3190395	3926630
NALA WASTE	9335	7550	8610	439595	737225	228685	16190	16600	7710	7710	1705	53490	40990	34310
PLASTIC WASTE	10440	645	595	1120	655	870	755	1090	6965	685	1860	80	225	1095
SLS	3279710	3301110	3904155	3781410	3726355	4217715	4023865	4009750	4265535	4476250	4508410	4567985	4452225	4460610
WET WASTE	9855580	11000455	10153830	10163540	10195060	9898810	9438480	9199225	9779285	8030110	9243620	9725795	9148200	10241640

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7.0 Observations

On the basis of the primary and secondary data collected, the framework has been designed based on the participatory angle this study's pushing feels right. Without locals on board, any fancy tech will flop. I noticed during site visits that mixed waste is a huge issue. Everything's tossed together, which messes up recycling or WTE plans. If we could get neighborhoods to sort at home, maybe through small incentives or school campaigns, it'd lighten the load on PCMC's end. The GIS maps mentioned could help pinpoint where to start wards with tons of shops or homes, like Zone F, seem like good spots for a trial run.

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