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State Space Model for Accounting Smart City Heating by Municipal Solid Waste Management

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1 ABSTRACT

As per the recent estimates, India produces about 100,000 MT urban solid wastes daily with typical characteristics. The municipal solid waste (MSW) generation in metro cities varies between 0.2 to 0.8 kg/capita/day and urban MSW generation is estimated to be approximately 0.5 kg per capita per day. This is estimated to be two or three times more than the waste generated by rural residents. The figures, however, vary from city to city. Over the next two decades, growing urbanization in India will result in a massive increase of waste. A study conducted by the Central Pollution Control Board, Government of India on management of MSW in the country estimates that waste generation from the present 48 million tons (MT) per year is expected to increase to 300 MT per year, by the year 2047 (490 g per capita to 945 g per capita). So, the estimated requirement of land for disposal would be 169.6 square kilometer (Sq. Km) in 2047 as against 20.2 Sq. Km in 1997.

More than 91% of MSW collected is still landfilled or dumped on open lands and dumps (Akolkar, 2009), impacting public health, deteriorating quality of life and causing environmental pollution. It is estimated that about 2% of the uncollected wastes are burnt openly on the streets; and about 10% of the collected MSW is openly burnt in landfills or is caught in landfill fires (Akolkar, 2009). Due to an increase in population and subsequently increase in waste generation, landfills could become a major source of atmospheric methane. Methane, at its current atmospheric concentration of 1.7 ppmv, accounts for about 15% of the anthropogenic greenhouse effect and concentration is on the increase. Generally, 50% of carbon emissions in the landfills are transformed into methane. It has been reported that 13% of landfill emission or 36.7 Tg/year of methane is emitted from municipal solid waste landfills in the World. Other reports said that the global projection of methane flux from landfill areas would be between 63 to 93 Tg/year by 2050, which will be due to population growth and subsequently increase in waste dumping in landfills. The total methane flux from Indian cities are 0.33 Tg/year. The power generation potential in India at present from municipal solid waste is 3276 MW/year against waste generation.

The quantity of MSW generated depends on a number of factors such as food habits, standard of living, degree of economic activities, seasons and location. Data on quantity variation and generation are useful in planning for collection and disposal systems. These are mainly depends on input state variables i.e. population, per capita generation, net inert material for disposal, Technological viability, air space limit and mangement approach. Difficulty in acquiring land for establishing waste management and disposal facilities are usual in urban areas. Total estimation of land requirement will be more over years. It is imperative that the existing dumpsites are redesigned to recover space for receive present and future wastes on the basis of minimization of practice.

State space model shows the temporal relationship of several factor or input state variables with output value. State Space model is a mathematical model of a physical system as a set of input, output. State-space modelling showed that temporal correlation in solid waste generation with input variables of population, per capita generation, technological viability for minimising the inert, air space of disposal and financial viability for indian cities. This correlation will help to predict the total estimated heat potentiality of smart city from waste generation over the period.

2 INTRODUCTION

The cities only encompass two percent of the world's land surface, yet they are responsible for consuming over 75% of the planet's resources and produce 75% of the world's waste (Siemens, 'Sustainable City'). The most pressing problem faced by any urban centre in India today is Municipal Solid Waste Management (MSW). Rapid urbanization and changing lifestyles have led to the generation of huge amounts of garbage and waste in the urban areas. Over the past few years, the handling this MSWM has become a major organizational, financial and environmental challenge. (Ramachandra T. V. & Bachmanda S. 2007). During the last century urban population of India increased ten folds from 27 million to 270 million. India produces 48.0 MT of MSW annually at present. Central Pollution Control Board, India (2009) said that by the year

2021, the urban population is expected to represent 41% of the overall population and subsequently MSW is expected to increase to 300 MT per year, by the year 2047 (490 g to 945 g per capita). A number of technologies are being proposed for management and disposal of garbage but so far no technology has been shortlisted as the one which would be viable not only from the environment angle but also in terms of the cost involved for unanimously in Indian context. (CPCB, 2000)

Waste dumping is the only favorable method to urban local body without any further action. Day by day increasing trend practice of dump to dump yard won't sustain the function. So there is a requirement of taking integrated policy and technology to use less land as land is precious.

Concentration of intense economic processes and high level of consumption in urban areas increase total waste generation and more space is required for waste disposal. Ever increasing population with end lasting waste production can be sustained with adopting an integrated approach for accounting solid waste management towards heat potentiality assessment from landfill waste in city planning. This requirement may vary on the basis of different state vector.

3 HEAT POTENTIALITY FROM WASTE

In developing countries like India with MSW which has a low calorific value (7.3 MJ/kg compared to values greater than 10 MJ/kg in Europe, Japan and US) and high percentage of inerts, processing of waste is necessary to make it suitable as a fuel. This makes RDF an important alternative to WTE combustion. One of the less expensive and well-established technologies to produce RDF from MSW is mechanical biological treatment (MBT). An MBT plant separates out metals and inert materials, screens out organic fractions (for stabilization using composting processes), and separates out high-calorific fractions for RDF. RDF can also result from a 'dry stabilization process' in which residual waste (after separating out metals and inert materials) is dried through a composting process leaving the residual mass with a higher calorific value (USEPA, 2010). The RDF thus produced is either used directly as floc/fluff or is compressed to make pellets. RDF fluff (as it is called in India) can be directly combusted in dedicated WTE plants whereas making RDF pellets increases the marketability of the product as they can be used for co-combustion in various solid fuel industries like cement kilns, coal fired power plants, etc.

RDF plants which make fluff are located near Hyderabad, Vijayawada, Jaipur and Chandigarh. RDF produced at Hyderabad and Vijayawada is taken to dedicated WTE plants for electricity generation, whereas RDF from Jaipur and Chandigarh plants is transported to cement plants to be used in place of coal. Hyderabad and Vijayawada had the first RDF facilities in India which served as demonstration projects. The administration of Nashik composting plant is testing the feasibility of using composting rejects as RDF in a cement plant; similar attempts are being made at Pimpri composting facility too.

High percentage of rejects from MBT facilities (60%), having a high calorific value (9.5 MJ/kg) opens a huge opportunity for RDF and WTE. Assuming 6% of all MSW generated in India is treated in MBT facilities, out of which, 60% is compost rejects which could be used as refuse derived fuel (RDF), India is currently generating 2.48 million TPY of RDF. Such a huge source of energy is being generated and landfilled every year. This is equivalent to landfilling nearly 4 million barrels of oil because there are no facilities which could use them. This RDF can be used in the already well established solid fuel industry in India. India would have landfilled 58 million barrels of oil in the form of RDF alone by 2041 if there were no RDF co-combustion or WTE facilities to generate energy out of it (NSWAI, 2010)

The overall power potential from MSW in India is estimated to be 3,650 MW by 2012 (NSWAI, 2010) Power potential from MSW from 59 cities was found out to be 1,292 MW. Generation of energy from MSW can displace 14.5 million TPY of low grade coal every year. Delhi has the highest potential for power generation from MSW (186.8 MW), followed by Mumbai (186.6 MW), Chennai (149 MW), and Hyderabad (91 MW). MSW generated in Chennai (6,118 TPD) is only about half of the waste generated in Kolkata (11,520 TPD) but it has a higher calorific value (10.9 MJ/kg), more than twice of that of MSW in Kolkata (5 MJ/kg). Chennai has the highest calorific value of MSW compared to other cities generating MSW > 1,000 TPD, followed by Ludhiana (10.7 MJ/kg), Pune (10.6 MJ/kg), and Bengaluru and Coimbatore (10 MJ/kg). WTE is a large scale technology. Most WTE plants are built with a capacity to handle 1,000 TPD of waste. The concept of regional landfills should be adopted to build regional WTE facilities to serve two or more cities, each of which landfill less than 1,000 TPD of MSW after recycling and composting (NSWAI, 2010).

S.No.	City	MSW Generated (TPD)	Calorific Value (MJ/kg)	Power Production Potential (MW)	Coal substituted (TPY)
1	Kolkata	11,520	5.0	129.9	1,445,194
2	Mumbai	11,124	7.5	186.6	2,075,263
3	Delhi	11,040	7.5	186.8	2,078,043
4	Chennai	6,118	10.9	149.0	1,657,716
5	Hyderabad	4,923	8.2	91.0	1,012,526
6	Bengaluru	3,344	10.0	74.9	833,427
7	Pune	2,602	10.6	61.8	687,908
8	Ahmadabad	2,518	4.9	27.9	310,362
9	Kanpur	1,756	6.6	25.9	288,159
10	Surat	1,734	4.1	16.1	179,314
11	Kochi	1,366	2.5	7.6	84,327
12	Jaipur	1,362	3.5	10.7	118,652
13	Coimbatore	1,253	10.0	28.0	311,631
14	Greater Visakhapatnam	1,194	6.7	18.0	199,801
15	Ludhiana	1,115	10.7	26.8	298,041
16	Agra	1,021	2.2	5.0	55,457
17	Patna	945	3.4	7.3	80,844
18	Bhopal	877	5.9	11.7	130,174
19	Indore	867	6.0	11.7	130,139
20	Allahabad	815	4.9	9.0	100,455
21	Meerut	804	4.6	8.2	91,457
22	Nagpur	801	11.0	19.8	220,216
23	Lucknow	743	6.5	10.9	120,839
24	Srinagar	713	5.3	8.5	94,139
25	Asansol	706	4.8	7.7	85,250
26	Varanasi	706	3.4	5.3	59,291
27	Vijayawada	688	8.0	12.3	137,263
28	Amritsar	679	7.7	11.7	130,219
29	Faridabad	667	5.5	8.3	91,897
30	Dhanbad	625	2.5	3.5	38,583
31	Vadodara	606	7.5	10.1	112,737
32	Madurai	543	7.6	9.2	102,832
33	Jammu	534	7.5	8.9	99,398
34	Jamshedpur	515	4.2	4.9	54,279
35	Chandigarh	486	5.9	6.4	71,478
36	Pondicherry	449	7.7	7.8	86,578
37	Jabalpur	380	8.6	7.3	81,410
38	Bhubaneswar	356	3.1	2.5	27,592
39	Nashik	329	11.6	8.5	94,918
40	Ranchi	325	4.4	3.2	35,985
41	Rajkot	317	2.9	2.0	22,748
42	Raipur	316	5.3	3.8	42,019
43	Thiruvananthapuram	308	10.0	6.9	76,506
44	Dehradun	247	10.2	5.7	63,082
45	Guwahati	246	6.4	3.5	39,032
46	Shillong	137	11.5	3.5	39,153
47	Agartala	114	10.2	2.6	28,901
48	Port Blair	114	6.2	1.6	17,552
49	Aizwal	86	15.8	3.0	33,831
50	Panaji	81	9.3	1.7	18,707
51	Imphal	72	15.8	2.5	28,323
52	Gandhinagar	65	2.9	0.4	4,739
53	Shimla	59	10.8	1.4	15,851
54	Daman	23	10.8	0.6	6,218
55	Kohima	20	11.9	0.5	5,941
56	Gangtok	19	5.2	0.2	2,449
57	Itanagar	18	14.3	0.6	6,419
58	Silvassa	11	5.4	0.1	1,472
59	Kavarati	5	9.4	0.1	1,171
	TOTAL	81,407		1,292	14,367,909

Table 1: Potential for Waste to Energy (WTE) Generation. Source, NSWAI 2010

Small scale biogas is a decentralized technology and the most environmentally friendly technology to recover energy from organic wastes. It can be successfully deployed in South India where the temperatures favor the process yearlong. However looking at the public investment and integrated waste management perspective, it takes many such single units to address organic waste from a single community and the technology would be able to address only 50% of the waste stream in Thiruvananthapuram or Kochi.

12th Fuiive yaer plan (FYP: 2012-2017) has also emphasized the WTE for all SWM process. It has also emphasized that Solid Waste Management is an area that is funded through a separate central programme, namely the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). This subject, being of immense importance, should be monitored as a policy thrust area through the Prime Minister's Council; while the Habitat Mission under NAPCC should focus on critical areas like evolution, adoption and implementation of green building codes, urban habitat planning and development, so on. The state of solid waste management in Kanpur was no different from most other Indian cities until only a few years ago. Kanpur Nagar Nigam (KNN) had the responsibility for collecting, transporting and disposing of the solid waste generated in the city, estimated at about 1500 tonnes per day.In June 2008, KNN gave a BOOT (build, own, operate, transfer) contract for processing, disposing, collection and transportation of solid waste which was selected through a process of competitive bidding. Land (46 acres) was given free on a long lease of 30 years for the project. The plant to process 1500 tonnes per day capacity of solid waste was set up with a tipping platform, a pre-segregation unit, a composting unit, an RDF (Refuse Derived Fuel) unit, a plastic segregating unit, a briquette manufacturing unit, and a secured landfill in place. Garbage transport vehicle is equipped with Global Positioning System (GPS) and every incidence of the compactor halt to collect garbage is monitored and recorded. Rag-pickers have been given the opportunity of starting a new life. Some of the former rag-pickers (130, to be precise) now earn a regular salary as safaimitras, sport a bank ATM card, enjoy social security and health benefits, and their young kids have started going to schools.The garbage is taken to a central site where it is sorted, segregated, transformed into a number of products of value, for example, premium quality compost, refuse derived fuel (RDF), interlocking tiles from construction debris for use in footpath paving, and so on. Kanpur Waste Management Plant is the largest producer of compost from organic waste. The plant is not able to meet the growing demand for organic fertiliser. In the Twelfth Five Year Plan, every attempt will be made to replicate the similar model in maximum number of cities in the country. The main thrust is Sustainable Solid Waste Management Systems in Towns and Cities to reduce the carbon credit.

Being town and regional plan land is our subject. The precious land would become save from waste-ward site by using waste to enegy potential technique implementation in global earth. To account the space control and reduction of heat can be accounted by State space model.

4 STATE SPACE MODEL

In control engineering, a state space representation is a mathematical model of a physical system as a set of input, output and state variables related by first-order differential equations. To abstract from the number of inputs, outputs and states, the variables are expressed as vectors. Additionally, if the dynamical system is linear and time invariant, the differential and algebraic equations may be written in matrix form. The state space representation (also known as the "time-domain approach") provides a convenient and compact way to model and analyze systems with multiple inputs and outputs. With inputs and outputs, it would otherwise have to write down Laplace transforms to encode all the information about a system. Unlike the frequency domain approach, the use of the state space representation is not limited to systems with linear components and zero initial conditions. "State space" refers to the space whose axes are the state variables. The state of the system can be represented as a vector within that space. (http://en.wikipedia.org/wiki/State_space)

System type	**State-space model**
Continuous time-invariant	$\dot{\mathbf{x}}(t) = A\mathbf{x}(t) + B\mathbf{u}(t)$ $\mathbf{y}(t) = C\mathbf{x}(t) + D\mathbf{u}(t)$
Continuous time-variant	$\dot{\mathbf{x}}(t) = \mathbf{A}(t)\mathbf{x}(t) - \mathbf{B}(t)\mathbf{u}(t)$ $\mathbf{y}(t) = \mathbf{C}(t)\mathbf{x}(t) + \mathbf{D}(t)\mathbf{u}(t)$
Explicit discrete time-invariant	$\mathbf{x}(k+1) = A\mathbf{x}(k) + B\mathbf{u}(k)$ $\mathbf{y}(k) = C\mathbf{x}(k) + D\mathbf{u}(k)$
Explicit discrete time-variant	$\mathbf{x}(k+1) = \mathbf{A}(k)\mathbf{x}(k) + \mathbf{B}(k)\mathbf{u}(k)$ $\mathbf{y}(k) - \mathbf{C}(k)\mathbf{x}(k) + \mathbf{D}(k)\mathbf{u}(k)$

where:

$\mathbf{x}(\cdot)$is called the "state vector", $\mathbf{x}(t) \in \mathbb{R}^n$;

$\mathbf{y}(\cdot)$is called the "output vector", $\mathbf{y}(t) \in \mathbb{R}^q$;

$\mathbf{u}(\cdot)$is called the "input (or control) vector", $\mathbf{u}(t) \in \mathbb{R}^p$;

$A(\cdot)$is the "state (or system) matrix", $\dim[A(\cdot)] = n \times n$,

$B(\cdot)$is the "input matrix", $\dim[B(\cdot)] = n \times p$,

$C(\cdot)$is the "output matrix", $\dim[C(\cdot)] = q \times n$,

$D(\cdot)$is the "feedthrough (or feedforward) matrix" (in cases where the system model does not have a direct feedthrough,

$D(\cdot)$is the zero matrix), $\dim[D(\cdot)] - q \times p$,

$\dot{\mathbf{x}}(t) := \frac{\mathrm{d}}{\mathrm{d}t}\mathbf{x}(t)$.

5 STATE-SPACE VARIABLES IN SWM

For Solid Waste Management the input state variables are:

(1) Per Capita generation

(2) Waste Composition

(3) Technological viability/options

(4) Management Approach

(5) Costs

These variables are positively correlated of following factors:

Factors influence variables

(1) Per Capita Waste Generation

(I) Population

(1) Sector wise/ward wise present population (Initial Year)

(2) Population projection in different years (block year)

(II) Socio-Economic Condition

Social

- Family size
- Education
- Life style
- Practice

Economic

- Gross Income of family
- No person employed
- Type of job

(2) Waste Composition

(III) Types of Waste

Biodegradable

- compostable
- non compostable

Non Bio Degradable

- recyclable
- debris

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(IV) Quantity of each typology waste

- Source
- Segregation
- Waste Reduction

(V) Quality of waste

- Physical Characteristics
- Chemical Characteristics

(3) Technological Option

(VI) Composting

(VII) Sanitary landfill

(VIII) Bio Methanation

(IX) Incineration

(X) RDF

(XI) Pyrolysis

(4) Management Approach

(XII) Collection

(A) Source Segregation

(B) Methods

- Residential Collection
- Open Residential Collection
- Municipal Residential Collection
- Municipal Contracted Residential Collection
- Zoned Residential Collection
- Commercial Collection
- Recyclables Collection
- Residential Curbside Collection
- Commercial On-Site Collection

(XIII) Transportation

- Direct Haul
- Transfer Station

(XIV) Drop-off Recycling Centers

- Recyclables Commodities / Material Processing (MRF: Material recycling facility) :
- Newspaper/papers (Office Paper , Phone Books, Magazines, Mixed Paper)
- Corrugated Cardboard
- Aluminum Cans /Misc. Aluminum
- Bi-Metal (Tin) Cans
- Ferrous
- Non-Ferrous
- Glass Containers
- Plastic Film /Plastic Containers

- Yard Waste
- Food Waste
- Wood
- Textiles
- Rubber

XV. Yard Waste Composting

(5) Costs

XVI. Capital Cost

- Collection Costs
- Transportation Costs
- Operating Costs
- Total Facility Costs (Equipment Cost)
- Debt Service
- Gross Costs
- Net Costs

XVII. Revenue cost

- Tipping Fees
- RDF Sales
- Electricity Sales
- MSW Compost Sales /Yard Waste Compost Sales
- Recyclables/Commodities Sales
- Other Fees if any

Per Capita Waste Generation: City size and per capita waste generation is positively correlated. Subsequently bigger city occupies big landfill area so > population > waste generation > landfill area. 366 towns' data has collected and tabulated as under.

Original Classification	**Classification for this Study**	**Population Range (2001 and 2011 Census)**		**No. of Cities Studied**	**Total No. of Cities**	**Per Capita kg/day average**	**Landfill Area to City area %**
Class I	Metropolitan	5,000,000	Above	6	6	0.605	Upto 5
	Class A	1,000,000	4,999,999	32	462	0.518	Upto 3
	Class B	700,000	999,999	20		0.487	Upto 2
	Class C	500,000	699,999	19		0.464	
	Class D	400,000	499,999	19		0.459	
	Class E	300,000	399,999	31		0.448	Upto 1
	Class F	200,000	299,999	58		0.445	
	Class G	150,000	199,999	59		0.436	
	Class H	100,000	149,999	111		0.434	
Class II		50,000	99,999	6	345	0.427	Upto 0.5
Class III		20,000	49,999	4	947	0.425	Crude Dumping
Class IV		10,000	19,999	1	1,167	0.342	
	TOTAL			366			

Table 2: Per Capita Waste Generation in Different Class of Town in India. Source: Census of India, CPCB Report, Municipal Document

Waste Composition: Materials in MSW can be broadly categorized into three groups,

Compostables: Compostables or organic fraction comprises of food waste, vegetable market wastes and yard waste.

Recyclables: Recyclables are comprised of paper, plastic, metal and glass

Inerts : The fraction of MSW which can neither be composted nor recycled into secondary raw materials is called Inerts. Inerts comprise stones, ash and silt which enter the collection system due to littering on streets and at public places.

366 towns data has analyzed to assess the waste composition in different region of country as under.

Region/City	**MSW (TPD)**	**Compostables (%)**	**Recyclables (%)**	**Inerts (%)**	**Moisture (%)**	**Cal. Value MJ/kg**	**Cal. Value kcal/kg**
Metros	51,402	50.89	16.28	32.82	46	6.4	1,523
Other Cities	2,723	51.91	19.23	28.86	49	8.7	2,084
East India	380	50.41	21.44	28.15	46	9.8	2,341
North India	6,835	52.38	16.78	30.85	49	6.8	1,623
South India	2,343	53.41	17.02	29.57	51	7.6	1,827
West India	380	50.41	21.44	28.15	46	9.8	2,341
Overall Urban India	130,000	51.3	17.48	31.21	47	7.3	1,751

Table 3: Composition of MSW in India and Regional Variation.

A major fraction of urban MSW in India is organic matter (51%). Recyclables are 17.5 % of the MSW and the rest 31% is inert waste as shown in above table. The average calorific value of urban MSW is 7.3 MJ/kg (1,751 Kcal/kg) and the average moisture content is 47%. It has to be understood that this composition is at the dump and not the composition of the waste generated. The actual percentage of recyclables discarded as waste in India is unknown due to informal picking of waste which is generally not accounted.

Technological Viability: Waste composition categories include organic material (biodegradable) and inorganic material (non-biodegradable). Inorganic portion is mostly occupied by inert material but also include paper, plastics, glass, paper, rubber, etc. Despite the best efforts to reduce, reuse and recycle, there will always be residual waste requiring disposal. The alternative treatment and disposal technologies are:

- Recycle/Reuse/Material Recovery
- Energy recovery
  - Aerobic digestion
  - Anaerobic digestion / Biomethanation
  - Pelletisation / Refuse Derived Fuel (RDF)
  - Pyrolysis and Gasification
  - Incineration
- Composting
- Landfills - Sanitary Landfill / Bioreactor landfill / Secured landfill (for inert waste)`

Recycling and composting efficiency are greatly reduced due to the general absence of source separation in India. Absence of source separation also strikes centralized aerobic or anaerobic digestion processes off the list. Anaerobic digestion is highly sensitive to feed quality and any impurity can upset the entire plant. Aerobic digestion leads to heavy metals leaching into the final compost due to presence of impurities and makes it unfit for use on agricultural soils. In such a situation the role of waste to energy technologies and sanitary landfilling increases significantly in India. This is due to the flexibility of waste-to-energy technologies in handling mixed wastes. Cost and space requirement for different time the comparative assessment of different process are as under:

Item	**Composting/ aerobic Digestion**	**Sanitary/Bioreactor Landfill**	**Bio-Methanation /Anerobic Digestion**	**Incineration**	**Pelletisation**	**Pyrolysis**
Retention Period	*5 Year*	*25-30 Years*	*6days*	*30 minutes*	*20-30 minutes*	*1 hour*
Space Requirement	High : (50-70% reduction of waste to manure)	Moderate : 10-20% reduction of waste Quantum	Low to Moderate 70 % reduction and produce electricity	Low 90% reduction	Low 7-10% waste inert	Moderate 30%
Area Calculation (based on usual practice)	*1 MT for 20 sq mt area*	*1 MT for 10 sq mt*	*1 Mt for 15 sq mt area*	*1 Mt 5 sq mt*	*1 Mt for 5 sq mt area*	*1 MT for 15 sq mt*
Concern for Atmospheric Pollution	Moderate	Low	Low	High	Moderate	Moderate
Capital Investment	*High (INR 200,000 per tom)*	*High*	*High (INR 350,000) per ton*	*High (INR 1000,000 per ton)*	*Moderate (INR 5310 per*	*High ((INR 1000,000*

Item	Composting/ aerobic Digestion	Sanitary/Bioreactor Landfill	Bio-Methanation /Anerobic Digestion	Incineration	Pelletisation	Pyrolysis
					ton)	*per ton)*

Table 4: Technological Viability with Space and Time in India.

Management Approach;

In India, in most of the cities, residents collect waste in plastic buckets and deposit it regularly in community bins located near the house. In some areas, the waste is collected from individual houses by corporate staff. Street sweepings are also collected in community bins. There are no separate bins exclusively for collec¬tion of waste paper, plastic, etc.(S. Kumar et al. in Waste Management 29 (2009) 883-895). Several types of waste receptacles are used in the urban area. These are (i) large masonry bins, locally called "Dhalao" , a community storage of solid waste (ii) metallic bins of covered and open types (iii) 4-wheeled plastics and FRP (Fibreglass Reinforced Plastics) bins with large covers (iv) dumping in open area low lying or road side. For effective solid waste management in a city, the desired strength of workers is 2-3 workers per thousand, which has been indicated as adequate and can be considered to be 200-250 kg/worker/8 h shifts. But very few cities is following the MSW Rule, 2000. The following table gives the idea of management status of municipality and state capital of India.

S N.	Name of City	Waste Qty. (TPD)	MSW Management Scenario			Collection of MSW			Transportation of MSW			
			Organization in charge	Penalty clause	Manual handling	Community bin system	House to house collection	Segregation by rag pickers at community	Municipal vehicles	Private vehicles	Provision of tarpaulin/ good quality cover	Transfer station facility
	Meerut	490	HO	X	✓	✓	No	✓	✓	X	X	X
	Nashik	200	HO	X	✓	X	Fully	✓	✓	✓	✓	X
	Jabalpur	216	HO	X	✓	✓	Partially	X	✓	✓	X	X
	Jamshedpur	338	PP	X	✓	✓	No	X	X	✓	X	X
	Asansol	207	ME	X	✓	✓	Partially	X	X	✓	X	X
	Dhanbad	77	SO	X	✓	✓	No	X	✓	X	X	X
	Faridabad	448	HO	X	✓	✓	Partially	X	✓	X	X	X
	Allahabad	509	AHO	X	✓	✓	No	X	✓	X	✓	X
	Amritsar	438	MHO	X	✓	✓	Partially	X	✓	X	✓	X
	Vijaywada	374	MC	X	✓	✓	Partially	X	✓	X	X	X
	Rajkot	207	DMC	X	✓	✓	No	✓	✓	X	✓	✓
	Port Blair	76	SO	X	✓	✓	No	X	✓	X	X	X
	Guwahati	166	MC	✓	X	✓	No	X	X	✓	✓	X
	Chandigarh	326	MOH	X	✓	X	Fully	X	✓	X	✓	X
	Raipur	184	HO	X	✓	✓	Partially	X	✓	X	X	X
	Panjim	32	AO/TO	X	X	X	Fully	X	✓	X	✓	X
	Gandhinagar	44	DC	X	✓	✓	No	✓	✓	X	✓	X
	Simla	39	HO	X	✓	✓	Partially	✓	✓	X	X	X
	Srinagar	428	HO	X	✓	✓	Partially	X	✓	X	X	X
	Ranchi	208	HO	X	✓	✓	Partially	X	✓	X	X	X
	Thiruvanamthapuram	171	HO	X	✓	✓	Partially	X	✓	X	✓	X
	Imphal	43	HO	X	✓	✓	Partially	X	✓	X	X	X
	Shillong	45	CEO	X	✓	✓	Partially	X	✓	X	✓	X
	Aizawal	57	SO	X	✓	✓	No	X	✓	X	X	X
	Kohima	13	AO	X	✓	✓	No	X	✓	X	X	X
	Bhuveneshwar	234	HO	X	✓	✓	Partially	X	✓	✓	X	X
	Agartala	77	CEO	X	✓	✓	Partially	X	✓	X	X	X
	Dehradun	131	SHO	X	✓	✓	Partially	✓	✓	X	X	X
	Pondicherry	130	HO	X	✓	✓	Partially	✓	✓	X	✓	X
	Itanagar	12	DC	X	✓	✓	No	X	✓	X	X	X
	Gangtok	13	JS	✓	X	X	Fully	X	✓	X	✓	X
	Kavaratti	3	CP	X	✓	✓	Partially	X	X	✓	X	X
	Daman	15	ME	X	✓	✓	No	X	✓	X	X	X
	Jammu	215	HO	X	✓	✓	Partially	X	✓	X	X	X

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S N.	Name of City	Waste Qty. (TPD)	MSW Management Scenario			Collection of MSW			Transportation of MSW			
			Organization in charge	Penalty clause	Manual handling	Community bin system	House to house collection	Segregation by rag pickers at community	Municipal vehicles	Private vehicles	Provision of tarpaulin/ good quality cover	Transfer station facility
	Silvassa	16	CMO	X	✓	✓	No	X	✓	X	X	X

Table 5: Status of State Capital Cities in implementation of MSW (Management and Handling) Rules, 2000. Source: CPCB 2006-07

Note: Note; CEO: Chief Executive Officer, DC: District Collector, MOH: Municipal Officer (Health), AO/TO: Accounts Officer/Tax Officer, DC: Dy. Commissioner, JS: Joint Secretary, CP: Chairperson (Village Panchayat), CMO: Chief Medical Officer, SHO: Senior Health Officer PP: Private Party, ME: Municipal Engineer, SO: Special Officer, AHO: Asst. Health Officer, MHO: Municipal Health Officer, MC: Municipal Commissioner

Cost:

To account the cost of solid waste management process in city the following cost to be accounted:

For accounting Transportation cost

(1) from individual node to transfer stations or processing unit or disposal sites.

(2) from transfer station to R.D.F. plant , compost plant, recycling plant and landfill

(3) from transfer station to incinerator, vermicular compost plant and landfill

For accounting revenue cost

(4) revenue respectively per unit of waste from RDF plant mechanical compost plant, recycling plant, incinerator, vermicular compost plant, bio-medical treatment plant .

(5) cost of buying dumpers and special vehicle for bio medical waste.

(6) total amount of waste at transfer from different stations

(7) fixed cost incurred in opening a RDF plant, mechanical compost plant, recycling plant , an incinerator , vermicular compost plant , bio-medical treatment plant and landfills

(8) respectively variable cost incurred in handling of plants and landfill site

6 STATE SPACE MODEL IN SWM

For Accounting Per Capita Waste Generation in State-Space Linear modeling is as followed:

Based on Linear Equation

Equation:

$Z1= \sum Y1/\sum X1$

$Z2= \sum Y2/\sum X2$

Where:

$\sum X1$ = Total Population of wards

i-n

where I to n are wards

$\sum X2$ = Total Projected ward Population

i-n

where i to n are wards

$\sum Y1$= Collected total waste

i to n

$\sum Y2$ = Estimated total waste

i to n

For accounting Waste Composition

Based on Linear Equation

Equation

$\sum a_{i-n} + \sum b_{i-n} + \sum c_{i-n} + \ldots\ldots \sum Z_{i-n} = \sum Y2$

where:

$\sum a_{i-n}$= Composting Waste

$\sum b_{i-n}$= Recycle Waste

$\sum c_{i-n}$= Construction Debris Waste

$\sum d_{i-n}$= WTE Waste

$\sum Y2$= Estimated total waste

For accounting Technological Option

Based on Linear Equation

Equation:

$\sum Y2 - (\sum a_{i-n} + \sum b_{i-n} + \sum c_{i-n} + \ldots\ldots \sum Z_{i-n})$ = Sanitary Landfill

Where:

$\sum a_{i-n}$= Composting Waste= compost plant

$\sum b_{i-n}$= Recycle Waste= Pyrolysis

$\sum c_{i-n}$= Construction Debris Waste= incineration

$\sum d_{i-n}$= WTE Waste (RDF)

For accounting Management Approaches

Based on Linear Equation

equation

$\sum aX\ it1 + \sum a\ Xyt2 \geq T1 + T2$

Where:

Total waste moved from each waste collection points i=1,…5

and j=1,…4 should at least be equal to the total amount of waste at that point or net density waste.

t1, t2 : transfer station

If only direct Haul exist then Transfer station is equal to zero

For accounting the Cost

Based on Linear Equation

Net cost ≤ Revenue Cost

Net Cost= $\sum F1Xi\text{-}z + \sum F2Ti\text{-}z + \sum F3Oi\text{-}z + \sum F4Ei\text{-}z + \sum F5Si\text{-}z$

where

$\sum F1Xi\text{-}z$= Sum of Every HH/Nodes collection cost

$\sum F2Ti\text{-}z$-= Sum of Every node to transfer station cost

$\sum F3Oi\text{-}z$= sum of Operating cost of different processing plant per unit

$\sum F4Ei\text{-}z$= Sum of equipment cost

$\sum F5Si\text{-}z$= Sum of salary cost

Net revenue= $\sum f1X1 + \sum f2R + \sum f3\ E + \sum f4A + \sum f5B$

Where

$\sum f1X1$=Sum of revenue collection from HHs

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∑f2R= Sum of RDF sales cost (yearly)

∑f3 E=Sum of electricity sale

∑f4A= Sum of Compost plant sale

∑f5B= sum of recyclable waste

7 CONCLUSION

The proposed model is a good starting point upon which future variation can be built. So for net Cost determine the selection of processing technology for town and on that account net inert to be account. After calculating net inert area requirement for waste disposal will be identified on different time perspective. Basis of characterization of the system like waste composition, heating value, material recovery possible treatment method is to be identified. In different perspective this value will change and selection process will change. Overall the cost benefit analysis will determine the feasibility of the choice for town. To account the viability of individual city space can opt the technological choice and account the heat piotentiality from total quantum under each category.

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