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State Space Analysis a Tool for Solid Waste Management

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1 ABSTRACT

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. Ministry of Finance (BAU: 2009) has estimated by 2041 it would be 1400 sq. km which will be equal to the total area of Mumbai, Chennai and Hyderabad city. Present solid waste management practices are shadowed by institutional lacuna, lack of proper funding, lack of management and operational systems, public apathy, lack of municipal will lead day by day increasing practice of dump to dump yard.

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. (Davidson, 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.

A number of technologies are being proposed for reduction of waste quantity through process and disposal of solid waste in general for different city or towns, 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 urban local body in India.

A holistic approach is being therefore, derived through State-Space Model to manage waste by combining and applying a range of suitable techniques, technologies and management programs to achieve less requirement of land near urban areas by accounting area specific number of variables over period of time.

Keywords: tool, system, state space analysis, SWM, carbon footprint

2 INTRODUCTION

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. (Davidson, 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

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waste production can be sustained with adopting an integrated approach for accounting solid waste management. This requirement may vary on the basis of different state vector.

Day by day increasing trend practice of dump to dump yard won't sustain the function for any urban area. Ministry of Finance (BAU:2009) has estimated that Country would occupies landfill area by 2001 237.4 sq.km which is equal to Mumbai; by 2011 at 379.6 sq.km or more i.e 90% of Chennai, by 2021 i.e 590.1 sq.km which is larger than Hyderabad town (583 sq.km) and by 2041 it would be 1400 sq km which will be equal to Mumbai+Chennai+Hyderabad city area. So, there is a requirement of taking integrated policy and technology to use less land as land is precious.

Draft SWM Manual by Central Public Health and Environmental Engineering Organisation (India) (CPHEEO), 2014 and Ministry of Environment & Forest (MoEF) Rule, 2013 have emphasized by 3R principle-Reduce, Recycle and Reuse in SWM. Both the manual has first time stated about Space requirement for different cities. The most important concern currently is reduction of land requirement for disposal by maximize appropriate treatment of different waste streams.

3 SWM SCENARIO IN INDIAN CITY

3.1 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 been 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 1: Per Capita Waste Generation in Different Class of Town in India. Source: Census of India, CPCB Report, Municipal Document

3.2 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 2: Composition of MSW in India and Regional Variation. Source: Census of India, CPCB Report, Municipal Document

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.

3.3 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	Moderate : 10-20% reduction of	Low to Moderate 70 % reduction and produce	Low 90% reduction	Low 7-10% waste inert	Moderate 30%

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Item	Composting/ aerobic Digestion	Sanitary/Bioreactor Landfill	Bio-Methanation /Anerobic Digestion	Incineration	Pelletisation	Pyrolysis
	manure)	waste Quantum	electricity			
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 ton)*	*High ((INR 1000,000 per ton)*

Table 3: Technological Viability with Space and Time in India. Source: CPHEOO Manual

3.4 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

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
	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
	Silvassa	16	CMO	X	✓	✓	No	X	✓	X	X	X

Table 4: 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

3.5 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

There are several methods or technologies exist in market. Every technology has some positive and negative point. Each every technology requires Land i.e. pace, Capital investment i.e. cost, Selection criteria i.e. waste generation (accounting accumulation of per capita waste), Atmospheric pollution load and management practices (Shareholder's capacity to mitigate factor), The comparative assessment of all technology have been framed in one table and find out that every process has inert or reject which requires Space for disposal of waste.

4 STATE SPACE MODEL

To account the best technology for environmental angle, cost befit for urban local body and management practice 'State-Space' model has been chosen to anlayse. In control engineering, '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 known as the "time-domain approach" of Laplace Theorem with linear components.

'State-Space' refers to the space whose axes are the state variables (variables/parameters). 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 : flow dynamic . It has one constant i.e time and output will be space when input variables are different then equation will be

This is simple linear progression method following laplace theorem where time is constant i.e. for 20 years and variable will change in different city and then space requirement will differ.

5 STATE SPACE MODEL ACCOUNTING SWM

Different process for individual study area have been calculated and Space requirement have been calculated basis of state space model. Further Terra Tech model has been chosen for testing the model. Cost Benefit analysis have been drawn to finalize the best option of SWM for individual town. At last Proposal for Space requirement in planning practice have been framed. To account the State-space model variables have been chosen basis of existing use of model in SWM practices and literature review as well as factor and computation formula have been drawn as under:

$$\sum_{i=1}^{5} \alpha X_{it1} + \sum_{j=1}^{4} \alpha X_{jt2} \geq \Psi_{t1} + \Psi_{t2}$$

$$\dot{\mathbf{x}}(t) = \mathbf{A}(t)\mathbf{x}(t) + \mathbf{B}(t)\mathbf{u}(t)$$
$$\mathbf{y}(t) = \mathbf{C}(t)\mathbf{x}(t) + \mathbf{D}(t)\mathbf{u}(t)$$

∑X2 = Total Projected ward Population i-n

where i to n are wards

∑Y1= Collected total waste i to n

∑Y2 = Estimated total waste

i to n

Z1= ∑Y1/∑X1 (per capita waste at present year)

Z2= ∑Y2/∑X2 (per capita waste in projected year)

This is simple linear progression method following laplace theorem where time is constant i.e. for 20 years and variable will change in different city and then space requirement will differ.

Sl No	State Variables	Factors influence variables	Equation of State variables for Space Requirement
	Per Capita Waste Generation	*Population* Sector wise / ward wise present population (Initial Year) Population projection in different years (block year) *Socio-Economic Condition* *Social* Family size Education Life style Practice *Economic* Gross Income of family No person employed Type of job	<u>Based on Linear Equation</u> $\sum X_1$ = Total Population of wards i-n Where i to n are wards $\sum X_2$ = Total Projected ward Population i-n where i to n are wards $\sum Y_1$ = Collected total waste i to n $\sum Y_2$ = Estimated total waste i to n <u>Z1= ∑Y1/∑X1 (per capita waste at present year)</u> <u>Z2= ∑Y2/∑X2 (per capita waste in projected year)</u>

Sl No	State Variables	Factors influence variables	Equation of State variables for Space Requirement
2	Waste Composition	*Types of Waste* *Biodegradable* *compostable* *non compostable* *Non Bio Degradable* *recyclable* *debris* *Quantity of each typology waste* *Source* *Segregation* *Waste Reduction* *Quality of waste* *Physical Characteristics* *Chemical Characteristics*	Based on Linear Equation ∑a i-n +∑b i-n +∑c i-n +…….∑Z i-n = ∑Y2 where: ∑a i-n= Composting Waste ∑b i-n= Recycle Waste ∑c i-n= Construction Debris Waste ∑d i-n= WTE Waste ∑Y2= Estimated total waste
3	Technological Option	*Composting* *Sanitary landfill* *Bio Methanation* *Incineration* *RDF* *Pyrolysis*	Based on Linear Equation ∑a i-n= Composting Waste= compost plant ∑b i-n= Recycle Waste= Pyrolysis ∑c i-n= Construction Debris Waste= incineration ∑d i-n= WTE Waste (RDF) ∑ Y2- (∑a i-n +∑b i-n +∑c i-n +…….∑Z i-n) = Sanitary Landfill / Inert Calculation
4	Management Approaches	*Collection* *Source Segregation* *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* *Transportation* *Direct Haul* *Transfer Station* *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* *Yard Waste Composting*	Based on Linear Equation ∑aX it1+ ∑a Xyt2 ≥ T1 + T2 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
5	Costs	*Capital Cost* *Collection Costs* *Transportation Costs* *Operating Costs* *Total Facility Costs (Equipment Cost)* *Debt Service* *Gross Costs* *Net Costs* *Revenue cost* *Tipping Fees* *RDF Sales* *Electricity Sales* *MSW Compost Sales /Yard Waste Compost Sales* *Recyclables/Commodities Sales* *Other Fees if any*	Based on Linear Equation Net cost ≤ Revenue Cost ∑F1Xi-z= Sum of Every HH/Nodes collection cost ∑F2Ti-z-= Sum of Every node to transfer station cost ∑F3Oi-z= sum of Operating cost of different processing plant per unit ∑F4Ei-z= Sum of equipment cost ∑F5Si-z= Sum of salary cost Net Cost= ∑F1Xi-z+ ∑F2Ti-z+∑F3Oi-z+∑F4Ei-z+∑F5Si-z ∑f1X1=Sum of revenue collection from HHs ∑f2R= Sum of RDF sales cost(yearly) ∑f3 E=Sum of electricity sale ∑f4A= Sum of Compost plant sale ∑f5B= sum of recyclablewaste Net revenue= ∑f1X1+∑f2R+∑f3 E+∑f4A+∑f5B

Table 6: Identified Variables and Factor for Computing State-Space Model for SWM. Source: Analyses

6 ANALYSIS

The existing SWM scenarios of three identified urban areas of Gurugram (Class I), Durgapur (Class II) and Solan (Class III) are different. Three classes of towns have been selected i.e. large, medium and small towns in terms of population and climatic location. Waste generation has been differed basis of economic characteristics of towns and compositions which are also varied on the basis of climatic location To account the state space model for individual town SWM for 20 years perspective c following table no. 7 has illustrated for study areas Gurugram, Durgapur and Solan.

Title	Unit	Gurugram	Durgapur	Solan
Base year population (2011)	Number	886,159	566,517	39,256
Projected year population (2031)	Number	4,250,000	793,124	58,746
Per Capita MSW Genration in 2011	gm	565	370	350
Per Capita MSW Genration in 2031	gm	600	400	550
Total Waste Generation by 2011	TPD	551	227	14
Total Waste Generation by 2031	TPD	2550	398	34
Total compostable waste by 2031	%	33%	45%	60%
Total recyclable waste by 2031	%	10%+20%RDF	12%	12%
Total Inert by 2031	%	37%	35%	20%
Total disposable RDF & Leachate by 2031	%	20% +2%	8%	8%
Total Area required for composting	Ha	6	1.79	7
Total area required for recycle	Ha	2	4.289	0
Total area required for Inert disposable	Ha	8	8.13	5.59
Total area required for Plant (Waste to Energy)	Ha	1	0	0
Total area Required for Haul Areas	Ha	2.07	1.9	0.01
Total area required for collection bins	Ha	1.003	1.0428	0.015
Total expenditure	Rs.in lakh	675.3	76.7	66.0
Ultimate Total Revenue	Rs.in lakh	1002.6	101.8	65.7
Net Revenue	Rs.in lakh	32.7	25.1	-.03
State-Space Model Accounting				
Selection of Best option	Technology	WTE+Compost+SLF	RDF+ Compost+SLF	RDF+ Aerpbic Compost+SLF
Total estimated area	Ha	17	11.59	12.51
Local Body report				
Technological Option	Technology	Incineration +compost+SLF	SLF	Compost+ SLF (regional SLF)
Estimated area	Ha	19.904	21	21

Table 7: Comparative assessment of State Space Model of Three Selected Study Areas. Source: Author, 2015

From above table it is clearly vivid that 'State Space' model is illustrating the space requirement for Solid waste disposal for three towns by accounting best suitable methods for individual town for disposal waste and further space requirement for landfill site for 20 years. This model also accounts major factors like socio-economic condition where food habits accounts waste generation, economic condition has helped to analyse capacity of residents for taxation, climatic condition helps to choose best method for processing waste. Further terra tech model helps to validate the calculation.

Mega city Gurugram has exponential population growth has indicated the huge amount of waste generation over period where as Solan, a hilly town is restricted to growth in terms of spatial expansion as well as only incremental population growth has been noticed. Industrial town Durgapur is back logging with economic issue and growth dynamic is also very nominal. Migration from rural to urban area has influx population and less purchasing power has shown the less capability to share the burden of cost for SWM. The population and economic growth has impacted the per capita generation of solid waste on this case study area. Where, Gurugram has marked the highest per income, but Durgapur city stands the lowest rank in income generation whereby population category city is placed at second position. The comparative statement of these two towns has extensively shown the economic influence in waste generation and management scenario. Percentage of composting waste also varies in these cities. The maximum potentially has been found in Solan town. Hilly town is humid climate with heavy rainfall has maximum potentiality for composting technology followed by Durgapur and minimum at Gurugram. Although, inert i.e. residue is maximum in big city comparative to small town among case study areas and so disposable quantity of waste is huge in mega city Gurugram, followed by Durgapur and comparatively less in Solan town. This is helping to predict space requirement for particular technological use for waste process in city on specific basis of its state variable factors. By using state space analysis model total estimated area requirement for individual case study area are 17 ha for

Gurugram City, 12 ha for Durgapur City and 12.5 ha for Solan town whereas, municipality of individual town has estimated area i.e. 19 ha for Gurugram, 21 ha for Durgapur and Solan town each.

Based on the analysis of the selected cities, their different contexts and approaches, it is seen that there is not a single technology is suitable. It can be sustained with adopting a suitable technique for processing waste for further landfilling the inert an integrated approach for accounting several variables should be adopted for solid waste management in city planning. The State Space Model is a problem solution method for particular town with dynamic variables. Mainly three areas of concerned have been approached in this 'State-Space' analysis model for Solid Waste Management as described below.

(a) Technological design: Basis of less space requirement of output value X on t time and less cost use with local body's management capacity suitable technology shall be chosen

(b) Space Design: estimated area requirement have been calculated for individual case study area. This model has also been tested for three towns through computer aided Terra-model tool Pack.

(c) Time Design This State Space model can be calculated by two methods

- First order differential equation i.e. Linear Method where time is invariant,
- Second order differential equation method i.e. Standard Deviation Method where time is variant.

7 CONCLUSION

The 'State-Space' model for Solid Waste Management analysis for town 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 or net residue can be accounted. After calculating the net residue generation net inert area requirement for waste disposal will be identified on different time perspective.

Positive aspects of State-Space model provide an important body of techniques for analyzing time-series data but their use requires estimating unobserved states variables. This Laplace-Gaussian Filter (LGF) gives fast, recursive, deterministic 'state' or parameter estimates.

Whereas Negative Aspect of Model is the central statistical problem in applying state-space models is that of filtering, i.e., estimating the unobserved state from the observations. There are several factors which are unobserved for computing may change the output.

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