Chapter 4

Results and Discussions
CHAPTER-4

RESULTS AND DISCUSSIONS

4.1 General

In this chapter, solid waste generation (SWG) rates and finances required for solid waste management in the case study city of Greater Visakhapatnam Municipal Corporation (GVMC) have been forecasted for the next five years period, say 2012 to 2016,

(five years period is considered as short term planning period) using the,

i) “Double Exponential Smoothing” (DES) statistical model (vide chapter 3.2).

ii) “Double Moving Average” (DMA) statistical model (vide chapter 3.3) for forecasting finances.

iii) Case study city (GVMC) data of population, solid waste quantity generated and expenditure on solid waste management of the past five years period, say 2007 to 2012 (vide chapter 3.4).

The case study city (GVMC) has an extent of 534 sq.km, which has been divided in to six zones namely (zone 1 Madhurawada area (city outskirt), zone 2 (central city), zone 3 (old city), zone 4 (central city), zone 5 (Gajuwaka, merged municipality) and zone 6 (Pendurthi area, city outskirt) as shown in Fig 4.1. The population of this city as per the 2001 census is 0.982 millions and it is approximately 1.75 millions by the year 2011-12.
In this work, Solid waste generation (SWG) rates for the existing data of 2007 to 2011 and also forecasted for the period 2012 to 2016 for all the zones (1 to 6) and also city as a whole, finances for solid waste management (SWM) in the case study city (GVMC) have been discussed, which are as given below.

a) In Section 4.2, for Solid waste generation rates of zones 1 to 6
   i) Solid waste generation rates for the period 2007 to 2011.
   ii) Forecasting solid waste generation rates for the period 2012 to 2016.

b) In Section 4.3, for Solid waste generation rates of city as a whole.
i) Solid waste generation rates for the period 2007 to 2011.

ii) Forecasting solid waste generation rates for the period 2012 to 2016.

c) In Section 4.4, for forecasting the finances for SWM in city as a whole.

i) Per capita rate of expenditure on SWM during the period 2007 to 2011.

ii) Forecasted per capita rate of expenditure on SWM during the period 2012 to 2016.

4.2 Solid Waste generation rates in zones 1 to 6 of case study city (GVMC)

4.2.1 Solid waste generation rates for the period 2007 to 2011.

Using the data of population and solid waste generated of GVMC for the years 2007 to 2011 (vide Table 3.1), waste generation rates have been calculated for the period 2007 to 2011 and presented in Table 4.1 and also shown in Fig.4.2, which is given below.
Table 4.1 Waste generation rates in zones 1 to 6 of GVMC during the years 2007-08 to 2011-12.

<table>
<thead>
<tr>
<th>Year</th>
<th>Zone-1 (Madhurawada, city outskirts)</th>
<th>Zone-2 (Central city)</th>
<th>Zone-3 (old city)</th>
<th>Zone-4 (Central city)</th>
<th>Zone-5 (Gajuwaka, merged municipality)</th>
<th>Zone-6 (Pendurthi, city outskirts)</th>
<th>Total of all zones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Population (tons/ day)</td>
<td>WGR (kg/capita/day)</td>
<td>Population (tons/ day)</td>
<td>WGR (kg/capita/day)</td>
<td>Population (tons/ day)</td>
<td>WGR (kg/capita/day)</td>
<td>Population (tons/ day)</td>
</tr>
<tr>
<td>2007-08</td>
<td>139619</td>
<td>58.39</td>
<td>0.42</td>
<td>243774</td>
<td>117.5</td>
<td>0.48</td>
<td>209798</td>
</tr>
<tr>
<td>2008-09</td>
<td>150035</td>
<td>73.69</td>
<td>0.49</td>
<td>247490</td>
<td>125</td>
<td>0.51</td>
<td>213574</td>
</tr>
<tr>
<td>2009-10</td>
<td>153335</td>
<td>80.05</td>
<td>0.52</td>
<td>250790</td>
<td>136</td>
<td>0.54</td>
<td>216814</td>
</tr>
<tr>
<td>2010-11</td>
<td>156635</td>
<td>85.80</td>
<td>0.55</td>
<td>254090</td>
<td>155.9</td>
<td>0.61</td>
<td>220114</td>
</tr>
<tr>
<td>2011-12</td>
<td>175210</td>
<td>95.65</td>
<td>0.55</td>
<td>272665</td>
<td>170.94</td>
<td>0.63</td>
<td>238689</td>
</tr>
</tbody>
</table>

Average value of SWG rate 0.51 0.55 0.59 0.61 0.52 0.48
Fig 4.2 Waste generation rates in zones 1 to 6 of GVMC during the years 2007-08 to 2011-12
Table 4.2 Forecasted Waste generation rates in zones 1 to 6 of GVMC during the years 2012-13 to 2016-17.

<table>
<thead>
<tr>
<th>Zone-1 (Madhurawada, city outskirts)</th>
<th>Zone-2 (Central city)</th>
<th>Zone-3 (old city)</th>
<th>Zone-4 (Central city)</th>
<th>Zone-5 (Gajuwaka, merged municipality)</th>
<th>Zone-6 (Pendurthi, city outskirts)</th>
<th>Total of all Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Data</td>
<td>Population</td>
<td>Waste generated (tons / day)</td>
<td>WGR (kg/capita/day)</td>
<td>Data</td>
<td>Population</td>
</tr>
<tr>
<td>2012-13</td>
<td>187421</td>
<td>99.67</td>
<td>0.53</td>
<td>294242</td>
<td>189.55</td>
<td>0.64</td>
</tr>
<tr>
<td>2013-14</td>
<td>189649</td>
<td>110.7</td>
<td>0.58</td>
<td>301342</td>
<td>201.31</td>
<td>0.67</td>
</tr>
<tr>
<td>2014-15</td>
<td>193421</td>
<td>120.6</td>
<td>0.62</td>
<td>317923</td>
<td>222.74</td>
<td>0.70</td>
</tr>
<tr>
<td>2015-16</td>
<td>199421</td>
<td>132.75</td>
<td>0.67</td>
<td>321839</td>
<td>244.25</td>
<td>0.76</td>
</tr>
<tr>
<td>2016-17</td>
<td>205903</td>
<td>148.55</td>
<td>0.72</td>
<td>332691</td>
<td>251.33</td>
<td>0.76</td>
</tr>
<tr>
<td>Average value of SWG rate</td>
<td>0.63</td>
<td>0.67</td>
<td>0.67</td>
<td>0.67</td>
<td>0.67</td>
<td>0.71</td>
</tr>
</tbody>
</table>

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Fig 4.3 Forecasted Waste generation rates in zones 1 to 6 during the years 2012-13 to 2016-17
### Table 4.3 Waste generation rate in zone-1 during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in Zone – 1 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0.42</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.49</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.52</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.55</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.55</td>
</tr>
<tr>
<td>Average</td>
<td>0.51</td>
</tr>
</tbody>
</table>

### Table 4.4 Waste generation rate in zone-1 during 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in Zone – I (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>0.53</td>
</tr>
<tr>
<td>2013-14</td>
<td>0.58</td>
</tr>
<tr>
<td>2014-15</td>
<td>0.62</td>
</tr>
<tr>
<td>2015-16</td>
<td>0.67</td>
</tr>
<tr>
<td>2016-17</td>
<td>0.72</td>
</tr>
<tr>
<td>Average</td>
<td>0.63</td>
</tr>
</tbody>
</table>

### Fig 4.4 Waste generation rate in zone during 2007 to 2011

### Fig 4.5 Waste generation rate in zone-1 during 2012 to 2016
<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in zone – 2 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0.48</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.51</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.54</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.61</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.63</td>
</tr>
<tr>
<td>Average</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Table 4.5  Waste generation rate in zone-2 during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in Zone – 2 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>0.64</td>
</tr>
<tr>
<td>2013-14</td>
<td>0.67</td>
</tr>
<tr>
<td>2014-15</td>
<td>0.70</td>
</tr>
<tr>
<td>2015-16</td>
<td>0.76</td>
</tr>
<tr>
<td>2016-17</td>
<td>0.76</td>
</tr>
<tr>
<td>Average</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Table 4.6  Waste Generation rate in zone-2 during 2012 to 2016

Fig 4.6 Waste generation rate in zone-2 during 2007 to 2011

Fig 4.7  Waste Generation in Zone-2 during 2012 to 2016
### Table 4.7  Waste generation rate in zone - 3 during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in zone – 3 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0.53</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.54</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.57</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.64</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.65</td>
</tr>
<tr>
<td>Average</td>
<td><strong>0.59</strong></td>
</tr>
</tbody>
</table>

### Table 4.8  Waste generation rate in zone - 3 during 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in Zone – 3 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>0.58</td>
</tr>
<tr>
<td>2013-14</td>
<td>0.61</td>
</tr>
<tr>
<td>2014-15</td>
<td>0.62</td>
</tr>
<tr>
<td>2015-16</td>
<td>0.68</td>
</tr>
<tr>
<td>2016-17</td>
<td>0.68</td>
</tr>
<tr>
<td>Average</td>
<td><strong>0.63</strong></td>
</tr>
</tbody>
</table>

### Fig 4.8  Waste generation in zone-3 during 2007 to 2011

### Fig 4.9  Waste generations in zone-3 during 2012 to 2016
<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in zone – 4 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0.55</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.58</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.60</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.64</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.65</td>
</tr>
<tr>
<td>Average</td>
<td><strong>0.61</strong></td>
</tr>
</tbody>
</table>

Table 4.9 Waste generation rate in zone-4 during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in zone – 4 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>0.64</td>
</tr>
<tr>
<td>2013-14</td>
<td>0.66</td>
</tr>
<tr>
<td>2014-15</td>
<td>0.67</td>
</tr>
<tr>
<td>2015-16</td>
<td>0.68</td>
</tr>
<tr>
<td>2016-17</td>
<td>0.70</td>
</tr>
<tr>
<td>Average</td>
<td><strong>0.67</strong></td>
</tr>
</tbody>
</table>

Table 4.10 Waste generation rate in zone-4 during 2012 to 2016

![Fig 4.10 Waste generation in Zone-4 during 2007 to 2011](image)

![Fig 4.11 Waste generation in zone-4 during 2012 to 2016](image)
Table 4.11 Waste generation rate in zone-5 during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in zone – 5 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0.41</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.49</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.55</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.58</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.59</td>
</tr>
<tr>
<td>Average</td>
<td><strong>0.52</strong></td>
</tr>
</tbody>
</table>

Table 4.12 Waste generation rate in zone-5 during 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in zone – 5 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>0.63</td>
</tr>
<tr>
<td>2013-14</td>
<td>0.66</td>
</tr>
<tr>
<td>2014-15</td>
<td>0.69</td>
</tr>
<tr>
<td>2015-16</td>
<td>0.67</td>
</tr>
<tr>
<td>2016-17</td>
<td>0.69</td>
</tr>
<tr>
<td>Average</td>
<td><strong>0.67</strong></td>
</tr>
</tbody>
</table>

Fig 4.12 Waste generation in zone-5 during 2007 to 2011.

Fig 4.13 Waste generation in zone-5 during 2012 to 2016.
Table 4.13  Waste generation rate in zone-6 during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in zone – 6 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0.40</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.49</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.52</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.53</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.54</td>
</tr>
<tr>
<td>Average</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Table 4.14  Waste generation rate in zone-6 during 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste generation rate in zone – 6 (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>0.66</td>
</tr>
<tr>
<td>2013-14</td>
<td>0.68</td>
</tr>
<tr>
<td>2014-15</td>
<td>0.70</td>
</tr>
<tr>
<td>2015-16</td>
<td>0.74</td>
</tr>
<tr>
<td>2016-17</td>
<td>0.78</td>
</tr>
<tr>
<td>Average</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Fig 4.14  Waste generation rate in zone-6 during 2007 to 2011

Fig 4.15  Waste generation rate in zone-6 during 2012 to 2016.
From Table 4.1 and Fig 4.2, it is observed as follows.

i) Considering the last five years (2007 to 2012), solid waste generation (SWG) rates in zonal areas of the case study city (GVMC) are higher in central city and old town areas (zones 2, 3 and 4) than the city outskirt areas (zones 1, 5 and 6).

ii) The minimum, maximum and average SWG rates in zonal areas of GVMC during past five years (2007 to 2012) is observed as follows.

<table>
<thead>
<tr>
<th>Zonal area number of the case study city (GVMC)</th>
<th>SWG rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>1 (City outskirt)</td>
<td>0.42</td>
</tr>
<tr>
<td>2 (Central city)</td>
<td>0.48</td>
</tr>
<tr>
<td>3 (Old town)</td>
<td>0.53</td>
</tr>
<tr>
<td>4 (Central city)</td>
<td>0.55</td>
</tr>
<tr>
<td>5 (Merged municipality)</td>
<td>0.41</td>
</tr>
<tr>
<td>6 (City outskirt)</td>
<td>0.40</td>
</tr>
</tbody>
</table>

iii) All the values of SWG rates mentioned above (either minimum or average) are within the (0.40 and 0.48 kg / capita / day) national average value of SWG rate (0.2 to 0.6 kg / capita /day for Indian cities, as mentioned in the Manual of Solid Waste Management, published by the Ministry of Urban Development Government of India.
4.2.2 Forecasting of solid waste generation rates for the period 2012 to 2016.

Using the “Double Exponential Smoothing” (DES) statistical model and data of population, solid waste generated in GVMC for the period of 2007 to 2011, forecasting of population and solid wastes to be generated for the years 2012 to 2016 have been calculated. The corresponding forecasted waste generation rates are also calculated and presented in Table 4.2 and also shown in Fig 4.3, which are given below. Typical calculations using statistical model are also given Section 4.2.3 for illustration.

From Table 4.2 and Fig 4.3, it is observed as follows.

i) Considering the next five years (2012 to 2016), the forecasted SWG rates in zonal areas of the case study city (GVMC) are higher in the central part of the city (zone 2 & 4) and outskirt areas. In old city (zone 3), the SWG rates are lesser because of migration of population to the other extended areas due to severe pollution causing in that area by the Visakhapatnam Port Trust. The slums in the old city are numerous and remains settled in that area, hence per capita income is less in this zonal area, which might be causing lower SWG rates than the central city. In zone 5 and 6, forecasted SWG rates are steadily increased because of development of

ii) colonies to be taken place in the outskirt area. So forecasted SWG rates by statistical models can be considered as realistic and concurrent with the city developmental plan of GVMC.

iii) The forecasted minimum and maximum SWG rate in the zonal areas of the GVMC during the next 5 years (2012 to 2016) is observed as follows.
iv) All the values of SWG rates mentioned above (either minimum and average) are also nearer to the extreme value of (0.53, and 0.63 kg / capita / day) national average value of SWG rate (0.2 to 0.6 kg / capita /day) in Indian cities, as mentioned in the Manual of Solid Waste Management, published by the Ministry of Urban Development Government of India.

Considering the observations mentioned in item ii (based on Table 4.1 and Table 4.2) it can be noticed as given below.

| Zonal area number of the case study city (GVMC) | SWG rate | | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| 1 (City outskirt) | 0.53 | 0.72 | 0.63 |
| 2 (Central city) | 0.64 | 0.76 | 0.71 |
| 3 (Old town) | 0.58 | 0.68 | 0.63 |
| 4 (Central city) | 0.64 | 0.70 | 0.67 |
| 5 (Merged municipality) | 0.63 | 0.69 | 0.67 |
| 6 (City outskirt) | 0.66 | 0.78 | 0.71 |

Based on the observations given in the above table, it can be concluded that the average percentage increase of SWG rate of zone wise data is between 24.07 to 24.33.
4.2.3 Typical examples of forecasting Solid waste generation (SWG) rates and solid waste quantity using Double Exponential Smoothing (DES) statistical model.

Example 1 for Table 4.3 (existing data) and Table 4.4 (forecasted data).

<table>
<thead>
<tr>
<th>Year</th>
<th>t</th>
<th>x_t</th>
<th>t * x_t</th>
<th>t^2</th>
<th>S^T</th>
<th>S^{T(2)}</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>1</td>
<td>0.42</td>
<td>0.42</td>
<td>1</td>
<td>0.2797</td>
<td>0.2155</td>
</tr>
<tr>
<td>2008-09</td>
<td>2</td>
<td>0.49</td>
<td>0.98</td>
<td>4</td>
<td>0.3007</td>
<td>0.2313</td>
</tr>
<tr>
<td>2009-10</td>
<td>3</td>
<td>0.52</td>
<td>1.56</td>
<td>9</td>
<td>0.3226</td>
<td>0.2313</td>
</tr>
<tr>
<td>2010-11</td>
<td>4</td>
<td>0.55</td>
<td>2.5</td>
<td>16</td>
<td>0.3453</td>
<td>0.2465</td>
</tr>
<tr>
<td>2011-12</td>
<td>5</td>
<td>0.55</td>
<td>2.75</td>
<td>25</td>
<td>0.3657</td>
<td>0.2555</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>2.53</td>
<td>8.21</td>
<td>55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X_t = b_1 + b_2 t + \epsilon_t
\sum X_t = nb_1 + b_2 \sum t
\sum t * X_t = b_1 \sum t + b_2 \sum t^2
2.53 = 5b_1 + 15b_2 \ldots \ldots \text{Eqn 1}
8.21 = 15b_1 + 55b_2 \ldots \ldots \text{Eqn 2}

solve this two Equations, We get
b_1 = 0.32 = \hat{b}_1(0)
b_2 = 0.062 = \hat{b}_2(0)

S_{(0)} = \frac{\hat{b}_1(0) - \frac{\beta}{\alpha} \hat{b}_2(0)}{\alpha}
= 0.32 - \frac{0.9}{0.1} (0.062)
S_{(0)} = 0.2642
\[ S^{(2)}_{(0)} = \frac{\hat{b}_1(0) - 2\frac{\hat{\beta}}{\alpha}}{0.1} = 0.32 - 2 \times \frac{0.9}{0.1} = 0.2084 \]

\[ S_{(T)} = \alpha X_t + (1 - \alpha)(S_{(T-1)}) \]

\[ S_{(T+1)} = 0.1 \times 0.42 + (0.9)(0.2642) = 0.2797 \]

\[ S_{(T+2)} = 0.1 \times 0.49 + (0.9)(0.2797) = 0.3007 \]

\[ S_{(T+3)} = 0.1 \times 0.52 + (0.9)(0.3007) = 0.3226 \]

\[ S_{(T+4)} = 0.1 \times 0.55 + (0.9)(0.3227) = 0.3453 \]

\[ S_{(T+5)} = 0.1 \times 0.55 + (0.9)(0.3453) = 0.3657 \]
\[S^{2}_{(T)} = \alpha S_{T} + (1 - \alpha)(S^{2}_{(T-1)})\]

\[= 0.1 \times 0.2797 + (0.9)(0.2084)\]

\[= 0.2155\]

\[S^{2}_{(T)} = 0.2155\]

\[S^{2}_{(T)} = \alpha S_{T} + (1 - \alpha)(S^{2}_{(T-1)})\]

\[= 0.1 \times 0.3007 + (0.9)(0.2155)\]

\[= 0.2219\]

\[S^{2}_{(T)} = 0.2219\]

\[S^{2}_{(T)} = \alpha S_{T} + (1 - \alpha)(S^{2}_{(T-1)})\]

\[= 0.1 \times 0.3226 - 0.9(0.2219)\]

\[= 0.2313\]

\[S^{2}_{(T)} = 0.2313\]

\[S^{2}_{(T)} = \alpha S_{T} + (1 - \alpha)(S^{2}_{(T-1)})\]

\[= 0.1 \times 0.3453 - 0.9(0.2313)\]

\[= 0.2465\]

\[S^{2}_{(T)} = 0.2465\]

\[S^{2}_{(T)} = \alpha S_{T} + (1 - \alpha)(S^{2}_{(T-1)})\]

\[= 0.1 \times 0.3657 + 0.9(0.2465)\]

\[= 0.2555\]

\[S^{2}_{(T)} = 0.2555\]

\[\hat{X}_{s+1}(T) = (2 + \frac{0.1 \times 1}{0.9}) \cdot 0.3657 - (1 + \frac{0.1 \times 1}{0.9})(0.7264)\]

\[= 0.5269\]

\[\hat{X}_{s+2}(T) = (2 + \frac{0.1 \times 2}{0.9}) \cdot 0.3657 - (1 + \frac{0.1 \times 2}{0.9})(0.7264)\]

\[= 0.5827\]

\[\hat{X}_{s+3}(T) = (2 + \frac{0.1 \times 3}{0.9}) \cdot 0.3657 - (1 + \frac{0.1 \times 3}{0.9})(0.7264)\]

\[= 0.6192\]

\[\hat{X}_{s+4}(T) = (2 + \frac{0.1 \times 4}{0.9}) \cdot 0.3657 - (1 + \frac{0.1 \times 4}{0.9})(0.7264)\]

\[= 0.6202\]

\[\hat{X}_{s+5}(T) = (2 + \frac{0.1 \times 5}{0.9}) \cdot 0.3657 - (1 + \frac{0.1 \times 5}{0.9})(0.7264)\]

\[= 0.7264\]
<table>
<thead>
<tr>
<th>Year</th>
<th>Future waste generation quantity forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>0.5269</td>
</tr>
<tr>
<td>2013-14</td>
<td>0.5827</td>
</tr>
<tr>
<td>2014-15</td>
<td>0.6192</td>
</tr>
<tr>
<td>2015-16</td>
<td>0.6202</td>
</tr>
<tr>
<td>2016-17</td>
<td>0.7264</td>
</tr>
</tbody>
</table>
Example 2 for Table 4.15(existing data) and 4.16 (forecasted data).

Double Exponential Smoothing (DES) to find out the forecasted waste generation quantity for the years 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>t (years)</th>
<th>Solid waste $x_t$ (tons/day)</th>
<th>$tx_t$</th>
<th>$t^2$</th>
<th>$S_T$</th>
<th>$S_T^{(2)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>1</td>
<td>737.96</td>
<td>737.96</td>
<td>1</td>
<td>47.65</td>
<td>-645.33</td>
</tr>
<tr>
<td>2008-09</td>
<td>2</td>
<td>822.19</td>
<td>1644.38</td>
<td>4</td>
<td>125.1</td>
<td>-568.28</td>
</tr>
<tr>
<td>2009-10</td>
<td>3</td>
<td>894.23</td>
<td>2682.69</td>
<td>9</td>
<td>210.77</td>
<td>-488.58</td>
</tr>
<tr>
<td>2010-11</td>
<td>4</td>
<td>972.11</td>
<td>3888.44</td>
<td>16</td>
<td>286.904</td>
<td>-411.03</td>
</tr>
<tr>
<td>2011-12</td>
<td>5</td>
<td>1050.06</td>
<td>5250.3</td>
<td>25</td>
<td>363.22</td>
<td>-333.6</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>4476.55</td>
<td>14203.77</td>
<td>55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$X_t = b_1 + b_2 t + \epsilon_t$

$\sum X_t = nb_1 + b_2 \sum t$

$\sum tx_t = b_1 \sum t + b_2 \sum t^2$

4476.55 = $5b_1 + 15b_2 \ldots \ldots$ Eqn 1 divided by 5

14203.77 = $15b_1 + 55b_2 \ldots \ldots$ Eqn 2 divided by 15

$895.31 = b_1 + 3b_2$

$946.92 = b_1 + 3.67b_2$

$b_1 = 664.22 = \hat{b}_1(0)$

$b_2 = 77.03 = \hat{b}_2(0)$

$S_{(0)} = \hat{b}_1(0) - \frac{\beta}{\alpha} \hat{b}_2(0)$

$= 664.22 - \frac{0.9}{0.1}(77.03)$

$S_{(0)} = -29.05$
\[ S^{(2)}_{(0)} = \hat{b}_1(0) - 2 \frac{\hat{b}_2(0)}{\alpha} \]
\[ = 664.22 - 2 \frac{0.9}{0.1} (77.03) \]
\[ S^{(2)}_{(0)} = -772.32 \]
\[ S_{(T1)} = \alpha X_t + (1 - \alpha)(S_{(T-1)}) \]
\[ = 0.1 \times 737.96 + (0.9)(-29.05) \]
\[ = 73.79 - 26.14 \]
\[ = 47.65 \]
\[ S_{(T1)} = 47.65 \]
\[ S_{(T2)} = \alpha X_t + (1 - \alpha)(S_{(T-1)}) \]
\[ = 0.1 \times 822.19 + (0.9)(47.651) \]
\[ = 82.22 + 42.88 \]
\[ = 125.10 \]
\[ S_{(T2)} = 125.10 \]
\[ S_{(T3)} = \alpha X_t + (1 - \alpha)(S_{(T-1)}) \]
\[ = 0.1 \times 894.23 + (0.9)(125.10) \]
\[ = 89.42 + 121.35 \]
\[ = 210.77 \]
\[ S_{(T3)} = 210.77 \]
\[ S_{(T4)} = \alpha X_t + (1 - \alpha)(S_{(T-1)}) \]
\[ = 0.1 \times 972.11 + (0.9)(210.77) \]
\[ = 286.904 \]
\[ S_{(T4)} = 286.904 \]
\[ S_{(T5)} = \alpha X_t + (1 - \alpha)(S_{(T-1)}) \]
\[ = 0.1 \times 1050.06 + (0.9)(286.904) \]
\[ = 363.22 \]
\[ S_{(T5)} = 363.22 \]
\[ S^2_{(T_1)} = \alpha S_{t_1} + (1 - \alpha)(S^2_{(T_1)}) \]

\[ = 0.1 \times 47.65 + (0.9)(-722.32) \]

\[ = -645.33 \]

\[ S^2_{(T_2)} = -645.33 \]

\[ S^2_{(T_2)} = \alpha S_{t_2} + (1 - \alpha)(S^2_{(T_2)}) \]

\[ = 0.1 \times 125.10 + (0.9)(-645.33) \]

\[ = -568.28 \]

\[ S^2_{(T_3)} = -568.28 \]

\[ S^2_{(T_3)} = \alpha S_{t_3} + (1 - \alpha)(S^2_{(T_3)}) \]

\[ = 21.07 - 509.65 \]

\[ = -488.58 \]

\[ S^2_{(T_4)} = -488.58 \]

\[ S^2_{(T_4)} = \alpha S_{t_4} + (1 - \alpha)(S^2_{(T_4)}) \]

\[ = 28.69 - 439.72 \]

\[ = -411.03 \]

\[ S^2_{(T_5)} = -411.03 \]

\[ S^2_{(T_5)} = \alpha S_{t_5} + (1 - \alpha)(S^2_{(T_5)}) \]

\[ = 36.32 - 369.92 \]

\[ = -333.60 \]

\[ S^2_{(T_6)} = -333.60 \]
\[
\hat{X}_{511}(T)=1137.45 \quad \text{(2012-13) Waste generated (tons/day)}.
\]
\[
\hat{X}_{511}(T)=(2+\frac{0.1*1}{0.9})363.22-(1+\frac{0.1*1}{0.9})(-333.60)
\]
= 1136.69
\[
\hat{X}_{512}(T)=1136.69 \quad \text{(2012-13) Waste generated (tons/day)}
\]
\[
\hat{X}_{512}(T)=(2+\frac{0.1*2}{0.9})363.22-(1+\frac{0.1*2}{0.9})(-333.60)
\]
= 807.15 + 407.73
= 1214.88
\[
\hat{X}_{513}(T)=1214.88 \quad \text{(2013-14) Waste generated (tons/day)}
\]
\[
\hat{X}_{513}(T)=(2+\frac{0.1*3}{0.9})363.22-(1+\frac{0.1*3}{0.9})(-333.60)
\]
= 1291.10
\[
\hat{X}_{514}(T)=1291.10 \quad \text{(2014-15) Waste generated (tons/day)}
\]
\[
\hat{X}_{514}(T)=(2+\frac{0.1*4}{0.9})363.22-(1+\frac{0.1*4}{0.9})(-333.60)
\]
= 886.25 + 481.56
= 1367.81
\[
\hat{X}_{515}(T)=1367.81 \quad \text{(2015-16) Waste generated (tons/day)}
\]
\[
\hat{X}_{515}(T)=(2+\frac{0.1*5}{0.9})363.22-(1+\frac{0.1*5}{0.9})(-333.60)
\]
= 928.22 + 518.77
= 1447.13
\[
\hat{X}_{516}(T)=1447.13 \quad \text{(2016-17) Waste generated (tons/day)}
\]

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecasted solid waste to be generated (tons/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>1137.4</td>
</tr>
<tr>
<td>2013-14</td>
<td>1214.8</td>
</tr>
<tr>
<td>2014-15</td>
<td>1291.1</td>
</tr>
<tr>
<td>2015-16</td>
<td>1367.8</td>
</tr>
<tr>
<td>2016-17</td>
<td>1447.1</td>
</tr>
</tbody>
</table>

Similarly in all the zones (1 to 6) SWGs have been forecasted using DES model, which are given in Table 4.2 to 4.38 and these values have been used for comments of this study.
4.3 Solid waste generation (SWG) rates of the case study city (GVMC) as a whole (but not as zonal wise)

4.3.1 Solid waste quantity (tons/day) during the years 2007 to 2011 and forecasted values for the years 2012 to 2016.

The quantity Solid waste quantity (tons/day) during the years 2007 to 2011 and forecasted values for the years 2012 to 2016 are given below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of solid waste generation (tons/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>733.00</td>
</tr>
<tr>
<td>2008-09</td>
<td>822.90</td>
</tr>
<tr>
<td>2009-10</td>
<td>894.22</td>
</tr>
<tr>
<td>2010-11</td>
<td>972.11</td>
</tr>
<tr>
<td>2011-12</td>
<td>1050.06</td>
</tr>
</tbody>
</table>

Table 4.15 Quantity of solid waste generation during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of solid waste generation (tons/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>1137</td>
</tr>
<tr>
<td>2013-14</td>
<td>1215</td>
</tr>
<tr>
<td>2014-15</td>
<td>1291</td>
</tr>
<tr>
<td>2015-16</td>
<td>1368</td>
</tr>
<tr>
<td>2016-17</td>
<td>1447</td>
</tr>
</tbody>
</table>

Table 4.16 Quantity of solid waste generation during 2012 to 2016

Fig 4.16 Quantity of solid waste generation during 2007 to 2011 (Vide Table 3.8)

Fig 4.17 Quantity of solid waste generation during 2012 to 2016. (forecasted by DES model, Vide 4.2.3)
The solid waste generation (SWG) rates (kg/capita/day) for the city as a whole, during the years 2007 to 2011 and forecasted values for years 2012 to 2016 are calculated as per the data (vide Table 4.15 and Table 4.16) and presented in Table 4.17 and Table 4.18. It is also shown in Fig 4.18 and Fig 4.19.

### Table 4.17 Solid Waste Generation Rates of City as a Whole During 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of solid waste generated (tons/day)</th>
<th>Population (in millions)</th>
<th>SWG Rates (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>733.00</td>
<td>1.55</td>
<td>0.47</td>
</tr>
<tr>
<td>2008-09</td>
<td>822.90</td>
<td>1.58</td>
<td>0.52</td>
</tr>
<tr>
<td>2009-10</td>
<td>894.22</td>
<td>1.60</td>
<td>0.56</td>
</tr>
<tr>
<td>2010-11</td>
<td>972.11</td>
<td>1.62</td>
<td>0.60</td>
</tr>
<tr>
<td>2011-12</td>
<td>1050.06</td>
<td>1.75</td>
<td>0.60</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>0.55</td>
</tr>
</tbody>
</table>

### Table 4.18 Forecasted SWG Rates of City as a Whole During 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of solid waste generated (tons/day)</th>
<th>Population (in millions)</th>
<th>SWG Rates (kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>1137</td>
<td>1.83</td>
<td>0.62</td>
</tr>
<tr>
<td>2013-14</td>
<td>1215</td>
<td>1.86</td>
<td>0.65</td>
</tr>
<tr>
<td>2014-15</td>
<td>1291</td>
<td>1.92</td>
<td>0.67</td>
</tr>
<tr>
<td>2015-16</td>
<td>1268</td>
<td>1.96</td>
<td>0.69</td>
</tr>
<tr>
<td>2016-17</td>
<td>1447</td>
<td>2.02</td>
<td>0.71</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>0.66</td>
</tr>
</tbody>
</table>

![Fig 4.18 Solid Waste Generation Rates of City as a Whole During 2007 to 2011](image)

![Fig 4.19 Forecasted SWG Rates of City as a Whole During 2012 to 2016](image)
From Table 4.17 and Table 4.18, Fig. 4.18 and Fig. 4.19, average SWG rates for the city (considering as a whole) for the years 2007 to 2011 and also forecasted SWG rates obtained by “Double Exponential Smoothing” statistical model for the years 2012 to 2016, are given below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yearly average SWG rate (Kg/capita/day)</th>
<th>Year</th>
<th>Yearly average SWG rate (Kg/capita/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0.47</td>
<td>2012-13</td>
<td>0.62</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.52</td>
<td>2013-14</td>
<td>0.65</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.56</td>
<td>2014-15</td>
<td>0.67</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.60</td>
<td>2015-16</td>
<td>0.69</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.60</td>
<td>2016-17</td>
<td>0.71</td>
</tr>
<tr>
<td>Average</td>
<td>0.55</td>
<td>Average</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Considering the observations mentioned above, it can be calculated as given below.

<table>
<thead>
<tr>
<th>Years</th>
<th>Yearly average SWG rate (Existing data 2007 to 2011)</th>
<th>Forecasted years 2012 to 2016</th>
<th>Forecasted yearly average SWG rate of 2012 to 2016</th>
<th>Percentage Increase of SWG rate for data of column 4 to column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column 1</td>
<td>Column 2</td>
<td>Column 3</td>
<td>Column 4</td>
<td>Column 5</td>
</tr>
<tr>
<td>2007-08</td>
<td>0.47</td>
<td>2012-13</td>
<td>0.62</td>
<td>31.91</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.52</td>
<td>2013-14</td>
<td>0.65</td>
<td>25.00</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.56</td>
<td>2014-15</td>
<td>0.67</td>
<td>19.64</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.60</td>
<td>2015-16</td>
<td>0.69</td>
<td>15.00</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.60</td>
<td>2016-17</td>
<td>0.71</td>
<td>18.33</td>
</tr>
<tr>
<td>Total</td>
<td>2.75</td>
<td></td>
<td>3.32</td>
<td>110.00</td>
</tr>
<tr>
<td>Average</td>
<td>2.75/5 =0.55</td>
<td></td>
<td>3.32/5=0.66</td>
<td>110.00/5 = 22</td>
</tr>
<tr>
<td>% increase of average SWG</td>
<td>100(0.66 – 0.55) / 0.55 = 20</td>
<td></td>
<td></td>
<td>22</td>
</tr>
</tbody>
</table>

Based on the observations given in the above table, it can be concluded that the % increase of average SWG rate of the case study city yearly data is in between 20 to 22. It can be also concluded that population is more than, SWG rates will be more for the city’s population is more than a million.
4.3.2 Solid waste generation rates of different components of solid waste in GVMC.

Based on the data of solid waste generated in GVMC (vide Table 3.2) during the period 2007 to 2011, the solid waste generation rates have been Calculated and presented in Table 4.19.

<table>
<thead>
<tr>
<th>Source</th>
<th>Year 2007-08</th>
<th>Quantity of solid waste (tons/day)</th>
<th>Solid waste generation rate (kg/item)</th>
<th>Year 2008-09</th>
<th>Quantity of solid waste (tons/day)</th>
<th>Solid waste generation rate (kg/item)</th>
<th>Year 2009-10</th>
<th>Quantity of solid waste (tons/day)</th>
<th>Solid waste generation rate (kg/item)</th>
<th>Year 2010-11</th>
<th>Quantity of solid waste (tons/day)</th>
<th>Solid waste generation rate (kg/item)</th>
<th>Year 2011-12</th>
<th>Quantity of solid waste (tons/day)</th>
<th>Solid waste generation rate (kg/item)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Areas</td>
<td>365875</td>
<td>464.00</td>
<td>1.26</td>
<td>381000</td>
<td>513.00</td>
<td>1.34</td>
<td>396600</td>
<td>562.00</td>
<td>1.42</td>
<td>413400</td>
<td>611.00</td>
<td>1.48</td>
<td>415000</td>
<td>660.00</td>
<td>1.59</td>
</tr>
<tr>
<td>Commercial Establishments</td>
<td>60000</td>
<td>36.00</td>
<td>0.60</td>
<td>60002</td>
<td>39.82</td>
<td>0.66</td>
<td>61668</td>
<td>43.62</td>
<td>0.71</td>
<td>63800</td>
<td>47.42</td>
<td>0.74</td>
<td>65000</td>
<td>51.22</td>
<td>0.79</td>
</tr>
<tr>
<td>Street Sweeping</td>
<td>2824.9</td>
<td>61.08</td>
<td>21.62</td>
<td>2826.6</td>
<td>67.70</td>
<td>23.91</td>
<td>2988.8</td>
<td>74.10</td>
<td>24.79</td>
<td>3149</td>
<td>80.50</td>
<td>25.56</td>
<td>3312</td>
<td>86.90</td>
<td>26.23</td>
</tr>
<tr>
<td>Hotels</td>
<td>492</td>
<td>16.79</td>
<td>34.12</td>
<td>521</td>
<td>18.58</td>
<td>35.62</td>
<td>534</td>
<td>20.35</td>
<td>38.10</td>
<td>551</td>
<td>22.12</td>
<td>40.14</td>
<td>578</td>
<td>23.89</td>
<td>41.33</td>
</tr>
<tr>
<td>Drain cleaning</td>
<td>3534</td>
<td>63.28</td>
<td>17.90</td>
<td>3535</td>
<td>70.23</td>
<td>19.67</td>
<td>3654</td>
<td>76.83</td>
<td>21.02</td>
<td>3773</td>
<td>83.43</td>
<td>22.11</td>
<td>3893</td>
<td>90.03</td>
<td>23.12</td>
</tr>
<tr>
<td>Institutions</td>
<td>167</td>
<td>3.94</td>
<td>23.59</td>
<td>163</td>
<td>4.37</td>
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<td>1651.82</td>
<td>46</td>
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<td>1717.83</td>
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<td>24.54</td>
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<td>2.66</td>
<td>8.33</td>
<td>735</td>
<td>2.91</td>
<td>3.96</td>
<td>1139</td>
<td>3.16</td>
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<td>1600</td>
<td>3.41</td>
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</tr>
<tr>
<td>Cinema Halls</td>
<td>33</td>
<td>0.22</td>
<td>6.66</td>
<td>37</td>
<td>0.03</td>
<td>8.64</td>
<td>37</td>
<td>0.40</td>
<td>10.81</td>
<td>38</td>
<td>0.48</td>
<td>12.63</td>
<td>40</td>
<td>0.56</td>
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<td>113.00</td>
<td>123</td>
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<td>167.31</td>
<td>127</td>
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<td>129</td>
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<td>189.92</td>
<td>132</td>
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<td></td>
</tr>
</tbody>
</table>

Table: 4.19 Solid waste generation rates of different components of solid waste in GVMC during 2007 to 2011
Based on the data of solid waste generated in GVMC (vide Table 3.2) during the period 2012 to 2016, forecasted solid waste generation rates have been calculated using “Double Exponential Smoothing” model (vide Chapter 3.2) and presented in Table 4.20.

<table>
<thead>
<tr>
<th>Source</th>
<th>Year 2012-13</th>
<th>Year 2013-14</th>
<th>Year 2014-15</th>
<th>Year 2015-16</th>
<th>Year 2016-17</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Quantity of solid waste (tons/day)</td>
<td>Solid waste generation rate (kg/item)</td>
<td>Number</td>
<td>Quantity of solid waste (tons/day)</td>
</tr>
<tr>
<td>Residential Areas</td>
<td>545276</td>
<td>699.14</td>
<td>1.28</td>
<td>562412</td>
<td>766.53</td>
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<td>69924</td>
<td>61.796</td>
</tr>
<tr>
<td>Street Sweeping</td>
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<td>21.52</td>
<td>4512</td>
<td>94.36</td>
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<td>45.62</td>
<td>614</td>
<td>33.62</td>
</tr>
<tr>
<td>Drain cleaning</td>
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<td>105.00</td>
<td>25.85</td>
<td>4209</td>
<td>112.42</td>
</tr>
<tr>
<td>Institutions</td>
<td>198</td>
<td>7.54</td>
<td>38.08</td>
<td>209</td>
<td>8.91</td>
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<td>Parks &amp; Gardens</td>
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<td>6.84</td>
<td>129.09</td>
<td>64</td>
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<td>1500.65</td>
<td>72</td>
<td>97.54</td>
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<td>33.03</td>
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<td>5.09</td>
<td>2.35</td>
<td>2214</td>
<td>6.74</td>
</tr>
<tr>
<td>Cinema Halls</td>
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<td>2.12</td>
<td>39.25</td>
<td>68</td>
<td>3.26</td>
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<tr>
<td>Function Halls</td>
<td>162</td>
<td>29.34</td>
<td>1.45</td>
<td>68</td>
<td>3.26</td>
</tr>
</tbody>
</table>

| Total                    | 1137.46      | 1214.83      | 1367.00      | 1447.49      |               |               |               |               |               |               |               |               |               |               |               |

Table: 4.20 Forecasted Solid waste generation rates of different components of solid waste in GVMC during 2012 to 2016.
Solid waste generation rates for the data of period 2007 to 2011 (vide Table 4.19) and also forecasted solid waste generation rate for the data of period 2012 to 2016 (vide Table 4.20) have been calculated for the components of solid waste which causes serious health hazard. These are presented in Table 4.21 to Table 4.33 and also shown in Fig 4.20 to Fig. 4.32.

Table 4.21 Waste generation rate of Residential areas during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>No of Residential areas</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in Residential areas (kg/each/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>365875</td>
<td>464.00</td>
<td>1.26</td>
</tr>
<tr>
<td>2008-09</td>
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<td>1.34</td>
</tr>
<tr>
<td>2009-10</td>
<td>396600</td>
<td>562.00</td>
<td>1.42</td>
</tr>
<tr>
<td>2010-11</td>
<td>413400</td>
<td>611.00</td>
<td>1.48</td>
</tr>
<tr>
<td>2011-12</td>
<td>415000</td>
<td>660.00</td>
<td>1.59</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>1.42</td>
</tr>
</tbody>
</table>

Table 4.22 Waste generation rate of Residential areas during 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>No of Residential areas</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in Residential areas (kg/each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>545276</td>
<td>699.14</td>
<td>1.28</td>
</tr>
<tr>
<td>2013-14</td>
<td>562412</td>
<td>766.53</td>
<td>1.33</td>
</tr>
<tr>
<td>2014-15</td>
<td>583421</td>
<td>778.04</td>
<td>1.36</td>
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<td>2015-16</td>
<td>589622</td>
<td>816.16</td>
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<td>2016-17</td>
<td>610421</td>
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</tr>
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</table>

Fig 4.20 Waste generation rate of Residential areas during 2007 to 2011

Fig 4.21 Waste generation rate of Residential areas during 2012 to 2016
### Table 4.23 Waste generation rate of Commercial Establishments during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>No of Commercial Establishments</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in Commercial Establishments (kg/each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>60000</td>
<td>36.00</td>
<td>0.60</td>
</tr>
<tr>
<td>2008-09</td>
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</tr>
<tr>
<td>2009-10</td>
<td>61668</td>
<td>43.62</td>
<td>0.71</td>
</tr>
<tr>
<td>2010-11</td>
<td>63800</td>
<td>47.42</td>
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</tr>
<tr>
<td>2011-12</td>
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<td>0.70</td>
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Table 4.23 Waste generation rate of Commercial Establishments during 2007 to 2011

### Table 4.24 Waste generation rate of Commercial establishments during 2012 to 2016

<table>
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<tr>
<th>Year</th>
<th>No of Commercial Establishments</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in Commercial Establishments (kg/each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
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<td>0.88</td>
</tr>
<tr>
<td>2013-14</td>
<td>69924</td>
<td>61.79</td>
<td>0.89</td>
</tr>
<tr>
<td>2014-15</td>
<td>71374</td>
<td>68.74</td>
<td>0.96</td>
</tr>
<tr>
<td>2015-16</td>
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<td>73.49</td>
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Table 4.24 Waste generation rate of Commercial establishments during 2012 to 2016

### Fig 4.22 Waste generation rate of commercial establishments during 2007 to 2011

### Fig 4.23 Waste generation rate of Commercial establishments during 2012 to 2016
Table 4.25 Waste generation rate of Hotels during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>No of Hotels &amp; Restaurants</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in hotels (kg/each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
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<td>521</td>
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<td>35.66</td>
</tr>
<tr>
<td>2009-10</td>
<td>534</td>
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</tr>
<tr>
<td>2010-11</td>
<td>551</td>
<td>22.12</td>
<td>40.14</td>
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Table 4.26 Waste generation rate of Hotels during 2012 to 2016

<table>
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<tr>
<th>Year</th>
<th>No of Hotels &amp; Restaurants</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in hotels (kg/each)</th>
</tr>
</thead>
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Fig 4.24 Waste generation rate of Hotels during 2007 to 2011

Fig 4.25 Waste generation rate of Hotels during 2012 to 2016
### Table 4.27 Waste generation rate of drain cleaning during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Drain length (In km)</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in drain cleaning (kg/each km)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>70.23</td>
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<td>2009-10</td>
<td>3654</td>
<td>76.83</td>
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<td>3773</td>
<td>83.43</td>
<td>22.11</td>
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<td>2011-12</td>
<td>3896</td>
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### Table 4.28 Waste generation rate of drain cleaning during 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Drain length (In km)</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in drain cleaning (kg/each km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>4062</td>
<td>105.04</td>
<td>25.85</td>
</tr>
<tr>
<td>2013-14</td>
<td>4209</td>
<td>112.42</td>
<td>26.70</td>
</tr>
<tr>
<td>2014-15</td>
<td>4314</td>
<td>117.62</td>
<td>27.26</td>
</tr>
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### Fig 4.26 Waste generation rate of drain cleaning during 2007 to 2011

### Fig 4.27 Waste generation rate of drain cleaning during 2012 to 2016
Table 4.29 Waste generation rate of markets during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>No of markets</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in markets (kg/each)</th>
</tr>
</thead>
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<tr>
<td>2007-08</td>
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<td>2008-09</td>
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<td>2009-10</td>
<td>44</td>
<td>73.25</td>
<td>1664.77</td>
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<td>2010-11</td>
<td>46</td>
<td>79.02</td>
<td>1717.83</td>
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Table 4.30 Waste generation rate of markets during 2012 to 2016

<table>
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<tr>
<th>Year</th>
<th>No of markets</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in markets (kg/each)</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
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<td>59</td>
<td>102.25</td>
<td>1733.05</td>
</tr>
<tr>
<td>2016-17</td>
<td>61</td>
<td>114.50</td>
<td>1877.05</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td>17.51</td>
</tr>
</tbody>
</table>

Fig 4.28 Waste generation rate of markets during 2007 to 2011

Fig 4.29 Waste generation rate of markets during 2012 to 2016
### Table 4.31: Waste generation rate of meat stalls during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>No of Meat stalls</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in meat stalls (kg/each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>465</td>
<td>4.91</td>
<td>10.55</td>
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<td>505</td>
<td>5.96</td>
<td>11.80</td>
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<tr>
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<td>514</td>
<td>6.47</td>
<td>12.59</td>
</tr>
<tr>
<td>2011-12</td>
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<td>6.98</td>
<td>13.12</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
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</table>

**Fig 4.30** Waste generation rate of meat stalls during 2007 to 2011

### Table 4.32: Waste generation rate of meat stalls during 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>No of Meat stalls</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in meat stalls (kg/each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>602</td>
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<td>16.06</td>
</tr>
<tr>
<td>2013-14</td>
<td>642</td>
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<tr>
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<td>679</td>
<td>12.14</td>
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<tr>
<td>2015-16</td>
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<td>13.67</td>
<td>18.96</td>
</tr>
<tr>
<td>2016-17</td>
<td>764</td>
<td>14.92</td>
<td>19.53</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
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<td>17.98</td>
</tr>
</tbody>
</table>

**Fig 4.31** Waste generation rate of meat stalls during 2012 to 2016
### Table 4.33 Waste generation rate of slaughter houses during 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>No of slaughter houses</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in slaughter houses kg/each</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>285</td>
<td>2.40</td>
<td>8.42</td>
</tr>
<tr>
<td>2008-09</td>
<td>312</td>
<td>2.66</td>
<td>8.52</td>
</tr>
<tr>
<td>2009-10</td>
<td>341</td>
<td>2.91</td>
<td>8.53</td>
</tr>
<tr>
<td>2010-11</td>
<td>363</td>
<td>3.16</td>
<td>8.70</td>
</tr>
<tr>
<td>2011-12</td>
<td>389</td>
<td>3.41</td>
<td>8.76</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td>8.59</td>
</tr>
</tbody>
</table>

### Table 4.34 Waste generation rate of slaughter houses during 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>No of slaughter houses</th>
<th>Waste generated (tons/day)</th>
<th>Waste generation rate in slaughter houses kg/each</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>438</td>
<td>3.89</td>
<td>8.86</td>
</tr>
<tr>
<td>2013-14</td>
<td>458</td>
<td>4.10</td>
<td>8.94</td>
</tr>
<tr>
<td>2014-15</td>
<td>491</td>
<td>4.44</td>
<td>9.04</td>
</tr>
<tr>
<td>2015-16</td>
<td>510</td>
<td>5.14</td>
<td>10.06</td>
</tr>
<tr>
<td>2016-17</td>
<td>536</td>
<td>5.45</td>
<td>10.17</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td>9.41</td>
</tr>
</tbody>
</table>
The percentage increase of the average solid waste generation rates for the components of solid waste during the period 2007 to 2011 and also for the forecasted period of 2012 to 2016 in the case study city (GVMC) are given below as Tabular form.

<table>
<thead>
<tr>
<th>Component of the solid waste</th>
<th>Yearly average of the SWG rate for period 2007 to 2011</th>
<th>Yearly average of the forecasted SWG rate for period 2012 to 2016</th>
<th>Percentage increase of the average SWG rate for the periods 2007 to 2011 and 2012 to 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential areas</td>
<td>1.42</td>
<td>1.35</td>
<td>- 4.9</td>
</tr>
<tr>
<td>Commercial establishments</td>
<td>0.70</td>
<td>0.95</td>
<td>35.70</td>
</tr>
<tr>
<td>Hotels</td>
<td>37.87</td>
<td>53.77</td>
<td>42.00</td>
</tr>
<tr>
<td>Drains</td>
<td>20.8</td>
<td>26.88</td>
<td>29.23</td>
</tr>
<tr>
<td>Markets</td>
<td>13.38</td>
<td>17.51</td>
<td>30.87</td>
</tr>
<tr>
<td>Meat stalls</td>
<td>11.84</td>
<td>17.98</td>
<td>51.86</td>
</tr>
<tr>
<td>Slaughter houses</td>
<td>8.59</td>
<td>9.41</td>
<td>9.55</td>
</tr>
</tbody>
</table>

Based on the above observations from the above Table it can be concluded about the percentage increase of SWG rate, as follows.

a) The percentage increase of SWG rate in residential area is - 4.9, due to high SWG rate (1.59) during 2011 to 2012 (vide Table 4.21). But the SWG rate trend is in increasing order as it can be seen from Fig 4.20 and Fig 4.21.

b) The percentage increase of SWG rate in commercial establishments is 35.70. This increase is due to expected commercial activity increase as the city population and industrial activity in the case study city increases. The trend of the SWG rate is in the increasing order, as it can be seen from Fig 4.22 and Fig 4.23.

c) The percentage increase of SWG rate of hotels is 42. The migration of the people to the city and increase of per capita income of the people due to employment,
for which more demand for hotel business. The trend of the SWG rate is also in increasing order, as it can be seen from Fig 4.24 and Fig 4.25.

d) The percentage increase of SWG rate in drain cleaning is 29.23. This increase indicates that the civic sense of the citizens about the usage of the drains and also dust condition on roads and shoulders of the road. The tropical climate condition of the city is also reflect the dust deposition in the drain. The trend of the SWG rate is also in increasing order, as it can be seen from Fig 4.26 and Fig 4.27.

e) The percentage increase of SWG rate in markets is 30.87. This increase indicates the population growth of the case study city, as the population increases the demand for markets is also increases. The trend of the SWG rate is also in increasing order, as it can be seen from Fig 4.28 and Fig 4.29.

f) The percentage increase of SWG rate for meat stalls is 51.86. This increase indicates Non-vegetarian population growth of the case study city, as the migrant population might be due to construction and skilled workers working class people. The trend of the SWG rate is also in increasing order, as it can be seen from Fig 4.30 and Fig 4.31.

g) The percentage increase of SWG rate in slaughter houses is 9.55. This marginal increase of slaughter houses in the case study city indicates the difficulty of land availability in the million population cities. However the trend of the SWG rate is also in increasing order, as it can be seen from Fig 4.32 and Fig 4.33.
4.4 Finances forecasting for solid waste management in the case study city of (GVMC) for the period (2012 to 2016)

4.4.1 General

As per the established statistically time series methods, the method which gives “least mean square error” is considered as reliable forecasting method. For forecasting finances for solid waste management in the case study city (GVMC) for the period (2012 to 2016), Double Exponential Smoothing (DES) model has been proposed because its least mean square error is less. In addition to DES model “Double Moving Average” DMA statistical model has also been considered in this study.

4.4.2 Per capita rate of expenditure on solid waste management during the year 2007 to 2011

Using the data of finances for solid waste management in GVMC for the years 2007-2011 (vide Table 3.8), per capita rate of expenditure on solid waste management during the year 2007 to 2011 has been calculated and presented in Table 4.34 and Table 4.35. It is also shown in Fig 4.33 and Fig 4.34.
Table 4.35: Expenditure on SWM in GVMC for the period 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure (Rs in Millions)</th>
<th>Total population of the GVMC (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>327.27</td>
<td>1.5514</td>
</tr>
<tr>
<td>2008-09</td>
<td>425.47</td>
<td>1.5804</td>
</tr>
<tr>
<td>2009-10</td>
<td>501.81</td>
<td>1.6001</td>
</tr>
<tr>
<td>2010-11</td>
<td>574.38</td>
<td>1.6191</td>
</tr>
<tr>
<td>2011-12</td>
<td>625.46</td>
<td>1.752</td>
</tr>
</tbody>
</table>

Fig 4.34: Expenditure on SWM in GVMC for the period 2007 to 2011

Table 4.36: Per capita expenditure on SWM in GVMC for the period 2007 to 2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure (Rs/capita/year)</th>
<th>Per capita expenditure (Rs/capita/day)</th>
<th>% Increase of per capita Expenditure/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>211</td>
<td>0.58</td>
<td>-</td>
</tr>
<tr>
<td>2008-09</td>
<td>269</td>
<td>0.73</td>
<td>26</td>
</tr>
<tr>
<td>2009-10</td>
<td>313</td>
<td>0.85</td>
<td>16</td>
</tr>
<tr>
<td>2010-11</td>
<td>354</td>
<td>0.97</td>
<td>10</td>
</tr>
<tr>
<td>2011-12</td>
<td>357</td>
<td>0.98</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig 4.35: Per capita expenditure on SWM in GVMC for the period 2007 to 2011
4.4.3 Forecasted per capita rate of expenditure on solid waste management during the year 2012 to 2016.

Forecasted per capita rate (Rs per capita /day) of expenditure on solid waste management in GVMC for the years 2012 to 2016 have been calculated using “Double Exponential Smoothing” (DES) statistical model (vide chapter 3.2) and “Double Moving Average” (DMA) statistical model (vide chapter 3.3). The results are given in Table 4.36 to 4.39 and also shown in Fig. 4.35 to 4.38. A typical calculations of forecasted finances for solid waste management by the above mentioned statistical models are given in Section 4.4.4 for illustration.

The comparison statement of % increase of expenditure of SWM and also the % increase of per capita expenditure for the period of 2007 to 2011 and also forecasted period of 2012 to 2016 are given in the Table 4.40 and Table 4.41.
Table 4.37 Forecasted finances for SWM in GVMC for the period 2012 to 2016 using Double Exponential smoothing model

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecasting finances required for SWM for the years 2012 to 2016 (Rs in Millions)</th>
<th>Total population of the GVMC (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>692.79</td>
<td>1.8317</td>
</tr>
<tr>
<td>2013-14</td>
<td>761.35</td>
<td>1.8661</td>
</tr>
<tr>
<td>2014-15</td>
<td>829.91</td>
<td>1.9239</td>
</tr>
<tr>
<td>2015-16</td>
<td>898.47</td>
<td>1.9607</td>
</tr>
<tr>
<td>2016-17</td>
<td>967.03</td>
<td>2.0215</td>
</tr>
</tbody>
</table>

Table 4.38 Per capita expenditure on SWM in GVMC for the period 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure (Rs/capita/year)</th>
<th>Per capita expenditure (Rs/capita/day)</th>
<th>% Increase of per capita Expenditure/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>378</td>
<td>1.03</td>
<td>-</td>
</tr>
<tr>
<td>2013-14</td>
<td>408</td>
<td>1.11</td>
<td>7.8</td>
</tr>
<tr>
<td>2014-15</td>
<td>431</td>
<td>1.18</td>
<td>6.3</td>
</tr>
<tr>
<td>2015-16</td>
<td>458</td>
<td>1.28</td>
<td>8.5</td>
</tr>
<tr>
<td>2016-17</td>
<td>478</td>
<td>1.31</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Fig 4.36 Forecasted finances for SWM in GVMC for the period 2012 to 2016 using Double Exponential smoothing model

Fig 4.37 Per capita expenditure on SWM in GVMC for the period 2012 to 2016

Fig 4.37 Per capita expenditure on SWM in GVMC for the period 2012 to 2016
Table 4.39 Forecasted finances for SWM for the period 2012 to 2016 by Double moving average method (Rs in Millions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecasted finances for SWM for the period 2012 to 2016 by Double moving average method (Rs in Millions)</th>
<th>Total population of the GVMC (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>624.57</td>
<td>1.8317</td>
</tr>
<tr>
<td>2013-14</td>
<td>636.90</td>
<td>1.8661</td>
</tr>
<tr>
<td>2014-15</td>
<td>649.27</td>
<td>1.9239</td>
</tr>
<tr>
<td>2015-16</td>
<td>661.58</td>
<td>1.9607</td>
</tr>
<tr>
<td>2016-17</td>
<td>673.98</td>
<td>2.0215</td>
</tr>
</tbody>
</table>

Table 4.40 Per capita expenditure on SWM in GVMC for the period 2012 to 2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure (Rs/capita/year)</th>
<th>Per capita expenditure (Rs/capita/day)</th>
<th>% Increase of per capita Expenditure/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>341</td>
<td>0.93</td>
<td>-</td>
</tr>
<tr>
<td>2013-14</td>
<td>342</td>
<td>0.93</td>
<td>0.0</td>
</tr>
<tr>
<td>2014-15</td>
<td>338</td>
<td>0.92</td>
<td>-1.0</td>
</tr>
<tr>
<td>2015-16</td>
<td>337</td>
<td>0.92</td>
<td>0.0</td>
</tr>
<tr>
<td>2016-17</td>
<td>333</td>
<td>0.91</td>
<td>-1.0</td>
</tr>
<tr>
<td>GVMC data of expenditure for Solid waste management</td>
<td>Forecasted expenditure for Solid waste management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Double Exponential Smoothing model</td>
<td>Double Moving Average model</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>(Rs. millions/year)</td>
<td>Year</td>
<td>(Rs. millions/year)</td>
</tr>
<tr>
<td>2007-08</td>
<td>327.27</td>
<td>2012-13</td>
<td>692.79</td>
</tr>
<tr>
<td>2008-09</td>
<td>425.47</td>
<td>2013-14</td>
<td>761.35</td>
</tr>
<tr>
<td>2009-10</td>
<td>501.81</td>
<td>2014-15</td>
<td>829.91</td>
</tr>
<tr>
<td>2010-11</td>
<td>574.38</td>
<td>2015-16</td>
<td>898.47</td>
</tr>
<tr>
<td>2011-12</td>
<td>625.46</td>
<td>2016-17</td>
<td>967.03</td>
</tr>
</tbody>
</table>

\[
\text{Difference of expenditure for 5 years period} = (625.46 - 327.27) = 298.19
\]

\[
\text{% Increase of expenditure for 5 years period} = \frac{298.19}{327.27} \times 100 = 91.11
\]

Table 4.41 Comparison statement of % increase of expenditure of SWM for the existing (2007 to 2011 period) and forecasted (2012 to 2016).
Forecasted expenditure using statistical models for Solid waste management

### GVMC data of expenditure for Solid waste management

<table>
<thead>
<tr>
<th>Year</th>
<th>Per capita expenditure (Rs/capita/day)</th>
<th>% Increase of per capita expenditure/day</th>
<th>Year</th>
<th>Per capita expenditure (Rs/capita/day)</th>
<th>% Increase of per capita expenditure/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0.58</td>
<td>-</td>
<td>2012-13</td>
<td>1.03</td>
<td>-</td>
</tr>
<tr>
<td>2008-09</td>
<td>0.73</td>
<td>26</td>
<td>2013-14</td>
<td>1.11</td>
<td>7.8</td>
</tr>
<tr>
<td>2009-10</td>
<td>0.85</td>
<td>16</td>
<td>2014-15</td>
<td>1.18</td>
<td>6.3</td>
</tr>
<tr>
<td>2010-11</td>
<td>0.97</td>
<td>10</td>
<td>2015-16</td>
<td>1.28</td>
<td>8.5</td>
</tr>
<tr>
<td>2011-12</td>
<td>0.98</td>
<td>1</td>
<td>2016-17</td>
<td>1.31</td>
<td>2.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Increase of for 5 years</th>
<th>% Increase of for 5 years</th>
<th>% Increase of for 5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>= (0.98-0.58) / 0.58*100</td>
<td>= (1.31-1.03) / 1.03*100</td>
<td>= (0.91-0.93) / 0.93*100</td>
</tr>
<tr>
<td>= 69</td>
<td>= 27.18</td>
<td>= -2.15</td>
</tr>
</tbody>
</table>

Table 4.42 Comparison statement of per capita expenditure of SWM for the existing (2007 to 2011 period) and forecasted (2012 to 2016) data.
From the Table 4.34 to Table 4.39 and Fig 4.33 to 4.38 the following are observed

i) The expenditure of Solid waste management in the case study city of GVMC for the period 2007 to 2011 has been found as Rs 212 to Rs 357 / capita / year or Rs 0.58 to Rs 0.98 /capita / day.

ii) The forecasted expenditure of Solid waste management in the case study city of GVMC for the period 2012 to 2016, using “Double Exponential Smoothing” statistical model has been found as Rs 378 to Rs 478 / capita / year or Rs 1.03 to 1.31 /capita / day.

iii) The forecasted expenditure of Solid waste management in the case study city of GVMC for the period 2012 to 2016, using “Double Moving Average statistical model has been found as Rs 333 to Rs 341 / capita / year or Rs 0.91 to 0.93 /capita / day.

Considering the above values it can be concluded that the per capita finances forecasted using “Double Exponential Smoothing model” may be considered reliable than “Double Moving Average method because of the trend of the forecasted values for the period 2012 to 2016, as it can be seen from Fig 4.36 and Fig 4.38.

iv) From Table 4.40 it is observed that the percentage increase of expenditure of solid waste management for five years period (2007 to 2011) data as 91.11, where as for the forecasting period (2012 to 2016) as per the DES model data is 39.58 and as per the DMA model data is 7.91.
v) From Table 4.41, it is observed that the percentage increase of per capita expenditure of solid waste management per day, for five years period (2007 to 2011) data as 69, where as for the forecasting. Considering the above points of (IV) and (v), it can be concluded that the percentage increase per capita expenditure of solid waste management per day is considered as is a rational for scientific management of solid waste for any city.
Section 4.4.4.

Typical calculations of forecasting finance for solid waste management in
GVMC using Double Exponential Smoothing (DES) statistical model.

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure for SWM in GVMC for the period 2007 to 2011 (Rs in Millions)</th>
<th>Total population of the GVMC (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>327.27</td>
<td>1.5414</td>
</tr>
<tr>
<td>2008-09</td>
<td>425.47</td>
<td>1.5804</td>
</tr>
<tr>
<td>2009-10</td>
<td>501.81</td>
<td>1.6001</td>
</tr>
<tr>
<td>2010-11</td>
<td>574.38</td>
<td>1.6191</td>
</tr>
<tr>
<td>2011-12</td>
<td>625.46</td>
<td>1.7314</td>
</tr>
</tbody>
</table>

Forecasting calculations:

<table>
<thead>
<tr>
<th>Year</th>
<th>t</th>
<th>$x_t$</th>
<th>$tx_t$</th>
<th>$t^2$</th>
<th>$S^T$</th>
<th>$S^T_{(2)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>1</td>
<td>3270.27</td>
<td>3270.27</td>
<td>1</td>
<td>-2781.06</td>
<td>-8996.82</td>
</tr>
<tr>
<td>2008-09</td>
<td>2</td>
<td>4254.78</td>
<td>8509.56</td>
<td>4</td>
<td>-2077.48</td>
<td>-8304.89</td>
</tr>
<tr>
<td>2009-10</td>
<td>3</td>
<td>5018.15</td>
<td>15054.45</td>
<td>9</td>
<td>-1367.92</td>
<td>-7611.19</td>
</tr>
<tr>
<td>2010-11</td>
<td>4</td>
<td>5743.83</td>
<td>22975.32</td>
<td>16</td>
<td>-656.74</td>
<td>-6915.74</td>
</tr>
<tr>
<td>2011-12</td>
<td>5</td>
<td>6254.63</td>
<td>30031.95</td>
<td>25</td>
<td>9.56</td>
<td>-6223.20</td>
</tr>
</tbody>
</table>

$X_t = b_1 + b_2 t + \varepsilon_t$

$\sum X_t = nb_1 + b_2 \sum t$
\[ \sum tX_i = b_1 \sum t + b_2 \sum t^2 \]

24293.40 = 5b_1 + 15b_2 .......... Eqn 1 divided by 5

4858.68 = b_1 + 3b_2

79841.55 = 15b_1 + 55b_2 .......... Eqn 2 divided by 15

5322.77 = b_1 + 3.6b_2

4858.68 = b_1 + 3b_2

5322.77 = b_1 + 3.6b_2

hence \[ b_1 = 2780.60 \]

\[ b_2 = 692.67 \]

\[ S_{(0)} = b_1(0) - \frac{\beta}{\alpha} \hat{b}_2(0) \]

\[ = 2780.67 - \frac{0.9}{0.1} (692.67) \]

\[ = -3453.43 \]

\[ S^{(2)}_{(0)} = b_1(0) - 2 \frac{\beta}{\alpha} \hat{b}_2(0) \]

\[ = 2780.67 - 2 \frac{0.9}{0.1} (692.67) \]

\[ = -9687.46 \]
\[ S_{(T)} = \alpha X_t + (1 - \alpha)S_{(T-1)} \]
\[ = 0.1 \times 3270.27 + (0.9)(-3453.43) \]
\[ = -2781.06 \]
\[ S_{(T)} = -2781.06 \]
\[ S_{(T+1)} = \alpha X_t + (1 - \alpha)S_{(T)} \]
\[ = 0.1 \times 4254.78 + (0.9)(-2781.06) \]
\[ = -2077.48 \]
\[ S_{(T+1)} = -2077.48 \]
\[ S_{(T+2)} = \alpha X_t + (1 - \alpha)S_{(T+1)} \]
\[ = 0.1 \times 5018.15 + (0.9)(-2077.48) \]
\[ = -1367.92 \]
\[ S_{(T+2)} = -1367.92 \]
\[ S_{(T+3)} = \alpha X_t + (1 - \alpha)S_{(T+2)} \]
\[ = 0.1 \times 5743.83 + (0.9)(-1367.92) \]
\[ = -656.745 \]
\[ S_{(T+3)} = -656.745 \]
\[ S_{(T+4)} = \alpha X_t + (1 - \alpha)S_{(T+3)} \]
\[ = 0.1 \times 6006.39 + (0.9)(-656.74) \]
\[ = 9.56 \]
\[ S_{(T+4)} = 9.56 \]
\[ S^2_{(T1)} = \alpha S_{(1)} + (1 - \alpha)(S^2_{(T1)}) \]
\[ = 0.1*(-2781.06) + (0.9)(-9687.46) \]
\[ = -8996.42 \]

\[ S^2_{(T1)} = -8996.42 \]

\[ S^2_{(T2)} = \alpha S_{(2)} + (1 - \alpha)(S^2_{(T1)}) \]
\[ = 0.1*(-2077.48) + (0.9)(-8996.42) \]
\[ = -8304.89 \]

\[ S^2_{(T2)} = -8304.89 \]

\[ S^2_{(T3)} = \alpha S_{(3)} + (1 - \alpha)(S^2_{(T1)}) \]
\[ = 0.1*(-1367.92) + (0.9)(-8304.89) \]
\[ = -7611.19 \]

\[ S^2_{(T3)} = -7611.19 \]

\[ S^2_{(T4)} = \alpha S_{(4)} + (1 - \alpha)(S^2_{(T1)}) \]
\[ = 0.1*(-656.74) + (0.9)(-7611.19) \]
\[ = -6915.74 \]

\[ S^2_{(T4)} = -6915.74 \]

\[ S^2_{(T5)} = \alpha S_{(5)} + (1 - \alpha)(S^2_{(T1)}) \]
\[ = 0.1*(9.56) + (0.9)(-7611.19) \]
\[ = -6223.20 \]

\[ S^2_{(T5)} = -6223.20 \]
\[ \hat{X}_{5+1}(T) = (2 + \frac{0.1 \times 1}{0.9})9.56 - (1 + \frac{0.1 \times 1}{0.9})(-6223.20) = 6927.92 \]
\[ \hat{X}_{5+2}(T) = (2 + \frac{0.1 \times 2}{0.9})9.56 - (1 + \frac{0.1 \times 2}{0.9})(-6223.20) = 7613.52 \]
\[ \hat{X}_{5+3}(T) = (2 + \frac{0.1 \times 3}{0.9})9.56 - (1 + \frac{0.1 \times 3}{0.9})(-6223.20) = 8299.13 \]
\[ \hat{X}_{5+4}(T) = (2 + \frac{0.1 \times 4}{0.9})9.56 - (1 + \frac{0.1 \times 4}{0.9})(-6223.20) = 8984.73 \]
\[ \hat{X}_{5+5}(T) = (2 + \frac{0.1 \times 5}{0.9})9.56 - (1 + \frac{0.1 \times 5}{0.9})(-6223.20) = 9670.33 \]

Forecasting finances required for SWM for the years 2012 to 2016 (Rs in Millions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecasting finances required for SWM for the years 2012 to 2016 (Rs in Millions)</th>
<th>Total population of the GVMC (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>692.79</td>
<td>1.8317</td>
</tr>
<tr>
<td>2013-14</td>
<td>761.35</td>
<td>1.8661</td>
</tr>
<tr>
<td>2014-15</td>
<td>829.91</td>
<td>1.9239</td>
</tr>
<tr>
<td>2015-16</td>
<td>898.47</td>
<td>1.9607</td>
</tr>
<tr>
<td>2016-17</td>
<td>967.03</td>
<td>2.0215</td>
</tr>
</tbody>
</table>
Typical calculations of forecasting finance for solid waste management in GVMC using Double Moving Average (DMA) statistical model. Data:

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure for SWM in GVMC for the period 2007 to 2011 (Rs in Millions)</th>
<th>Total population of the GVMC (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>327.27</td>
<td>1.5414</td>
</tr>
<tr>
<td>2008-09</td>
<td>425.47</td>
<td>1.5804</td>
</tr>
<tr>
<td>2009-10</td>
<td>501.81</td>
<td>1.6001</td>
</tr>
<tr>
<td>2010-11</td>
<td>574.38</td>
<td>1.6191</td>
</tr>
<tr>
<td>2011-12</td>
<td>625.46</td>
<td>1.7314</td>
</tr>
</tbody>
</table>

Forecasting Calculation:

Moving average = Average of span of time
Double Moving = Moving of moving average method

Moving average formula
\[ M_T = \frac{X_T + X_{T-1} + \ldots + X_{T-N+1}}{N} \]

\[ M_{3270.27} = \frac{3270.7 + 4254.78}{2} \]

\[ 3762.525 \]

Double moving average formula
\[ M_T^{(2)} = M_T + M_{T+1} + \ldots + M_{T+N-1} / (N) \]

To forecast the values, the future forecasting of “h” period is

\[ X^{(T)}_{T+H} = 2M_T^{(2)} - M_T^{(2)} + h \left[ \frac{2}{(N-1)} \left( M_T^{(2)} - M_T^{(2)} \right) \right]\]

Where \( T = 5 \) years, \( h = 1, 2, 3, 4, 5 \) future forecasting years
\[ X_{s+1}^\wedge (T) = 2(5875.11) - 5628.05 + 1 \left[ \frac{2}{5-1} (5875.11 - 5628.25) \right] \]
\[ = 6122.17 + 123.43 \]
\[ X_{s+1}^\wedge (T) = 6245.70 \] (2012 – 13 Budget forecasting value)

\[ X_{s+2}^\wedge (T) = 2(5875.11) - 5628.05 + 2 \left[ \frac{2}{5-1} (5875.11 - 5628.25) \right] \]
\[ = 6122.17 + 246.93 \]
\[ X_{s+2}^\wedge (T) = 6369.03 \] (2013 – 14 Budget forecasting value)

\[ X_{s+3}^\wedge (T) = 2(5875.11) - 5628.05 + 3 \left[ \frac{2}{5-1} (5875.11 - 5628.25) \right] \]
\[ = 6122.17 + 370.29 \]
\[ X_{s+3}^\wedge (T) = 6492.76 \] (2014 – 15 Budget forecasting value)

\[ X_{s+4}^\wedge (T) = 2(5875.11) - 5628.05 + 4 \left[ \frac{2}{5-1} (5875.11 - 5628.25) \right] \]
\[ = 6122.17 + 493.72 \]
\[ X_{s+4}^\wedge (T) = 6615.89 \] (2015 – 16 Budget forecasting value)

\[ X_{s+5}^\wedge (T) = 2(5875.11) - 5628.05 + 5 \left[ \frac{2}{5-1} (5875.11 - 5628.25) \right] \]
\[ = 6122.17 + 617.15 \]
\[ X_{s+5}^\wedge (T) = 6739.82 \] (2016 – 17 Budget forecasting value)
<table>
<thead>
<tr>
<th>Year</th>
<th>Forecasted finances for SWM for the period 2012 to 2016 by Double moving average method (Rs in Millions)</th>
<th>Total population of the GVMC (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>624.57</td>
<td>1.8317</td>
</tr>
<tr>
<td>2013-14</td>
<td>636.90</td>
<td>1.8661</td>
</tr>
<tr>
<td>2014-15</td>
<td>649.27</td>
<td>1.9239</td>
</tr>
<tr>
<td>2015-16</td>
<td>661.58</td>
<td>1.9607</td>
</tr>
<tr>
<td>2016-17</td>
<td>673.98</td>
<td>2.0215</td>
</tr>
</tbody>
</table>