

## Annexure 2.8: Population Forecast Methods

**Methods of Population Projection****Demographic Method**

Population change can occur only in three ways (i) by births (population gain), (ii) by deaths (population loss), or (iii) by migration (population loss or gain depending on whether movement out or movement in). Annexation of an area may be considered as a special form of migration. Population forecasts are frequently obtained by preparing and summing up of separate but related projections of natural changes and net migration and are expressed as below:

The net effect of births and deaths on population is termed natural increase (natural decrease if deaths exceed births).

Migration also affects the number of births and deaths in an area, so projections of net migration are prepared before projections for natural increase.

This method thus considers the prevailing and anticipated birth rates and death rates of the region or city for the period under consideration. An estimate is also made of the emigration from and immigration to the city, growth of city area wise, and the net increase of population is calculated accordingly considering all these factors, by arithmetical balancing.

**Arithmetical Increase Method**

This method is suitable for a large, well-settled city with considerable development. If it is used for small, average, or comparatively new cities, it may give comparatively lower predictions. In this method, the average increase in population per decade is calculated from the past census reports. This increase is added to the present population to find out the population for the next decade. Thus, it is assumed that the population is increasing at a constant rate. Thus,

$$\text{Population after } n\text{th decade will be } P_n = P + n \cdot X_{av} \quad \text{Eq. (2.1)}$$

Where  $P_n$  is the population after  $n$  decade,  $P$  is the present population, and  $X_{av}$  is the average increase in population per decade.

**Incremental Increase Method**

This method is the modification of the arithmetical increase method. It is suitable for an average size town under the normal condition where the growth rate is found to be in increasing order. This method does not take into account local or government initiatives that may drive the growth in population. Hence, due care must be taken while considering population projection based on this method.

While adopting this method, the increase in arithmetic increment is considered for calculating the future population. The incremental increase is determined for each decade from the past population, and the average value is added to the present population along with the average rate of increase. In some cases, population forecast by this method gives forecasted population less than present population due to negative value of incremental increase ( $Y_{av}$ ). In such cases, this method may be discarded.

Population after  $n^{\text{th}}$  decade will be

$$P_n = P + nX_{av} + \left\{ \frac{n(n+1)}{2} \right\} \times Y_{av} \quad \text{Eq. (2.2)}$$

Where,

P = present population

$P_n$  = Population after  $n^{\text{th}}$  decade

$X_{av}$  = Average increase

$Y_{av}$  = Incremental increase

### Geometrical Increase Method

In this method, the percentage increase in population from decade to decade is assumed to be the rate of growth, and the geometric mean of percentage increases is used to find out the future increment in population. This method can be applied to growing towns and cities having lots of scope for expansion, for example, a new industrial town at the beginning of development for only a few decades. One of the major disadvantages of this method is that if one of the observations is negative, the geometric mean will be imaginary, despite the other set of observations. Another disadvantage is that this method gives excessive population projection which may only be acceptable for the areas which see population explosion.

The population at the end of  $n^{\text{th}}$  decade ' $P_n$ ' can be estimated as

$$P_n = P \left\{ 1 + \frac{r_g}{100} \right\}^n \quad \text{Eq. (2.3)}$$

Where

P = Present population

n = number of decades

$r_g$  = geometric mean (%), i.e.,  $n^{\text{th}}$  root of  $(r_1 * r_2 * r_3 \dots r_n)$

Or,

$$r_g (\%) = (r_1 * r_2 * r_3 * r_4 \dots r_n)^{1/n} \quad \text{Eq. (2.4)}$$

$r$  = percentage growth rate = (increase in population/initial population) \* 100

Step 1: Find an increase in population for each decade

Step 2: Find the growth rate for each decade

Step 3: Find the number of decades (n) between last known year and the required year

Step 4: Find average growth rate ( $r_g$ ) using geometric mean

Step 5: Apply the formula (eq. 2.3)

### Decreasing Rate of Growth Method

In this method, it is assumed that the rate of percentage increase decreases over time, and the average decrease in the rate of growth is calculated. Then the percentage increase is

modified by deducting the decrease in the growth rate. This method is applicable in the cases where the rate of growth of the population shows a downward trend.

Step 1: Find the increase in population.

Step 2: Find the growth rate ( $r$ ) as in the geometrical increase method.

Step 3: Find the decrease in the growth rate.

Step 4: Find the average of decrease in growth rate(s).

Step 5: Apply the formula.

$$P_n = P_{(n-1)} + \left\{ \frac{r_{(n-1)} - S}{100} \right\} P_{(n-1)} \quad \text{Eq. (2.5)}$$

Where,

$P_n$  = population at required decade,

$P_{(n-1)}$  = population at previous decade (predicted or available),

$r_{(n-1)}$  = growth rate at previous decade and,

$S$  = average decrease in growth rate

Note: The formula requires population data from the previous decade, i.e.,  $P_{(n-1)}$ . Thus, this method requires the calculation of population at each successive decade (from the last known decade) instead of directly calculating the population at the required decade.

### Graphical Method

In this approach, there are two methods. In one, only the city in question is considered, and in the second, other similar cities are also taken into account.

#### Graphical Method Based on Single City

In this method, the population curve of the city (i.e., the Population vs. Past Decades) is smoothly extended to get future value. This extension has to be done carefully, and it requires vast experience and good judgment. The line of best fit may be obtained by the method of least squares.

#### Graphical Method Based on Cities with Similar Growth Pattern

In this method, the city in question is compared with other cities which have already undergone the same phases of development that the city in question is likely to undergo, and based on this comparison, a graph between population and decades is plotted.

### Logistic Method

This method is used when the growth rate of population due to births, deaths, and migrations takes place under normal situation and it is not subjected to any extraordinary changes like an epidemic, war, earthquake or any natural disaster, etc. the population follow the growth curve characteristics of living things within limited space and economic opportunity. If the population

of a city is plotted with respect to time, the curve so obtained under normal conditions looks like an S-shaped curve and is known as a logistic curve.

### **Method of Density**

In this approach, a trend in the rate of density increase of population for each sector of a city is found out, and a population forecast is done for each sector based on the above approach. The addition of sector-wise population gives the population of the city.

### **Curvilinear Method**

In this method, it is assumed that the population of a city will grow in the same manner as in other cities in the past. This similarity between the cities includes geographical proximity, the similarity of economic base, access to similar transportation systems, etc.

### **Floating Population**

The floating population is to be considered in the areas with daily/seasonal employment and tourist influx. It should be calculated by estimating the market potential of the city/town/village. Population indicators like utility consumption can be used for the transient census. The floating population should be got certified by the Chief Officer/Deputy Commissioner of ULB. Data from Tourist Bureau, Check/ Entry Tax points, Mandi associates, etc., should be obtained and extrapolated/projected. In absence of floating population data, it should be taken as 1-3% of base population judiciously considering the tourist inflow.

### **Final Forecast**

While the forecast of the prospective population of a projected area at any given time during the period of design can be derived by any one of the foregoing methods appropriate to each case, the density and distribution of such population within the several areas, zones, or districts will again have to be evaluated with a discerning judgment on the relative probabilities of expansion within each zone or district, according to its nature of development and based on existing and contemplated town planning regulations.

Wherever population growth forecast, or master plans prepared by town planning or other appropriate authorities are available, the decision regarding the design population may consider their figures. Using the methods discussed above, we make a population forecast of a city.

**Distribution of Forecasted Population:** After deciding the total population of the city by using the above methods, it is important to distribute it ward-wise so that the total demand is realistically determined. As pipelines are to be designed for ultimate stage population, distribution of ultimate stage population is required for getting realistic diameters of the proposed distribution system. Distribution of immediate stage population is required for getting realistic capacities of service tanks that are constructed for the immediate stage.

An illustrative example of the population forecast of a city is resented below:

**Illustrative Example:** Consider a town whose population figures as per census records are given in Table 1 for the decades 1971 to 2011. Assuming that the water supply scheme will

commence to function from 2025, it is required to estimate the population of 30 years, i.e., the present stage in the year 2025, an intermediate stage in the year 2040, and the ultimate stage in the year 2055.

Solution: Increase in population per decade, the total increase in population from the year 1971 to the year 2011, and an average increase in population (X) per decade are shown in column 3 of Table 1. Incremental increase per decade and average incremental increase (Y) are calculated and shown in Column 4 of Table 1. The rate of growth (r) per decade is calculated and given in Column 5. The geometric mean is calculated from the equation (2.4). The number of decades for =different stages is shown in Table (2).

**Table 1: Census data**

Year	Population	Increment X	Incremental Increase-Y	Rate of growth per decade
1	2	3	4	5
1971	27,279			
1981	39,068	11,789		$(11,789/27,279)*100 = 43.2\%$
1991	68,019	28,951	17,162	$(28,951/39,068)*100 = 74.1\%$
2001	80,625	12,606	-16,345	$(12,606/68,019)*100 = 18.5\%$
2011	112,085	31,460	18,854	$(31,460/80,625)*100 = 39.02\%$
Average	65,415	21,202	6,557	
				rg= 39.01%

### Arithmetic Increase method

Step 1: Find the increase (X) in population each decade.

It is computed in Col 3 of Table 1.

Step 2: Find the average rate of increase of population (Xav)

$$X_{av} = (11,789 + 28,951 + 12,606 + 31,460)/4 = 21,202$$

Step 3: Find the number of decades (n) between the last known year and the required year.

**Table 2: Number of decades for different stages**

Sr. No.	Year	Number of years	Number of Decade
1	2025	14 (=2025-2011)	1.40
2	2040	29 (=2040-2011)	2.90
3	2055	44 (=2055-2011)	4.40

Step 4: Apply the formula (Eq. 2.1)  $P_n = P + n \cdot X_{av}$

Therefore, population in the year 2025, 2040 and 2055 are as below:

$$P(2025) = P(2011) + 1.4 (21,202) = 1,12,085 + 1.4(21,202) = 141,768$$

$$P(2040) = P(2011) + 2.9 (21,202) = 1,12,085 + 2.9(21,202) = 173,571$$

$$P(2055) = P(2011) + 4.4 (21,202) = 1,12,085 + 4.4(21,202) = 205,374$$

#### Incremental Increase Method

**Step 1:** Find the increase in population in each decade.

It is computed in Col 3 of Table 1.

**Step 2:** Find the incremental increase, i.e., increase of increase.

It is computed in Col 4 of Table 1.

**Step 3:** Find  $X_{av}$  and  $Y_{av}$  as average of Increase in population and Incremental increase values, respectively.

$$X_{av} = 21,202$$

$$Y_{av} = \{17,162 + (-16,345) + 18,854\} / 3 = 6,557$$

**Step 4:** Find the number of decades (n) between the last known year and the required year.

It is computed in Table 2.

**Step 5:** Apply the formula (Eq. 2.2)  $P_n = P + nX_{av} + \left\{ \frac{n(n+1)}{2} \right\} \times Y_{av}$ .

$$P(2025) = 112,085 + 1.4(21,202) + \{1.4(1.4+1)/2\} (6557) = 152,783$$

$$P(2040) = 112,085 + 2.94(21,202) + \{2.9(2.9+1)/2\} (6557) = 210,650$$

$$P(2055) = 112,085 + 4.4(21,202) + \{4.4(4.4+1)/2\} (6557) = 283,271$$

#### Geometric Progression method

**Step 1:** Find the increase in population each decade.

It is computed in Col 3 of Table 1.

**Step 2:** Find the growth rate.

It is computed in Col 5 of Table 1.

**Step 3:** Find the geometric mean (r) using the equation,

$$rg (\%) = (r_1 * r_2 * r_3 * r_4 \dots r_n)^{1/n}$$

$$R_g = (43.216 * 74.104 * 18.533 * 39.020)^{(1/4)} = 39.01\%$$

**Step 4:** Find the number of decades (n) between the last known year and the required year.

It is computed in Table 2.

**Step 5:** Apply the formula  $P_n = P \left\{ 1 + \frac{r_g}{100} \right\}^n$

$$P(2025) = 112085 \left\{ 1 + \frac{0.39}{100} \right\}^{1.4} = 1,77,752$$

$$P(2040) = 112085 \left\{ 1 + \frac{0.39}{100} \right\}^{2.9} = 2,91,330$$

$$P(2055) = 1,12,085 \left\{ 1 + \frac{0.39}{100} \right\}^{4.4} = 4,77,482$$

Note: If, in a given year, the value of the rate of growth per decade (r) is observed to be zero or negative, then that value of population and rate of growth per decade (r) may be neglected.

Decreasing Rate of Growth Method

Find the population for the years 2025, 2040, and 2055.

Step 1: Find the increase in population.

It is computed in Col 3 of Table 3.

**Table 3: Decrease in growth rate**

Year	Population	Increase in population	Rate of growth per decade	Decrease in growth rate
1	2	3	4	5
1971	27,279			
1981	39,068	11,789	43.216	
1991	68,019	28,951	74.104	74.104-43.216 = 30.89%
2001	80,625	12,606	18.533	18.533-74.104 = (-)55.57%
2011	112,085	31,460	39.02	39.02-18.533 = 20.49%

**Step 2:** Find the growth rate (r) as in the geometrical increase method.

It is computed in Col 4 of Table 3.

**Step 3:** Find the decrease in the growth rate.

It is computed in Col 5 of Table 3.

**Step 4:** Find the average of decrease in growth rate(s).

$$S = (30.89-55.57+20.49)/3= -1.40\%$$

**Step 5:** Apply the formula  $P_n = P_{(n-1)} + \left\{ \frac{r_{(n-1)} - S}{100} \right\} P_{(n-1)}$

Where

$P_n$  = population at required decade

$P_{(n-1)}$  = population at previous decade (predicted or available)

$r_{(n-1)}$  = growth rate at previous decade

$S$  = average decrease in growth rate

Note: The formula has a typical nature. Hence, it requires population data from the previous decade, i.e.,  $P_{(n-1)}$ . Thus, this method requires the calculation of population at each successive decade (from the last known decade) instead of directly calculating the population at the required decade.

Find the population at successive decade till the population at required data is arrived.

Table 4: Population at Successive Decades

Year	Net percentage increase in population	Population
2021	39.02 - 1.40 = 37.620	112,085 + (37.620/100)*112,085 = 154,251
2031	37.62 - 1.40 = 36.22	154,251+ (36.22/100)*154,251 = 210,121
2041	36.22 - 1.40 = 34.82	210,121+ (34.82/100)*210,121 = 283,285
2051	34.82 - 1.40 = 33.42	283,285 + (33.42/100)*283,285 = 377959
2061	33.42 - 1.40 = 32.02	377,959 + (32.02/100)*377,959 = 498,981

The population of 2025, 2040, and 2055 can be computed by interpolation, which is shown in Table 5.

Table 5: Interpolated population

Year	Population
2025	175,000
2040	275,000
2055	423,000