MPSC 2019

Maharashtra Public Service Commission

Assistant Engineer Examination

Civil Engineering

Environmental Engineering

Well Illustrated **Theory** *with*

Solved Examples and **Practice Questions**

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Environmental Engineering

Contents

CHAPTER 01

Water Demand

1.1 Introduction

Following Operations are Necessary for a Water Supply Scheme

- Water Collection
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  - (ii) Precipitation and design of surface reservoirs.
  - (iii) Ground water development.
- Water Transportation
- Water Treatment
  - (i) Water quality parameters
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- Water Distribution

1.2 Water Demand

Estimation of demand for water is the key parameter in planning a water supply scheme. The agriculture sector consumes more than 80 percent of total water potential created in our country. The remaining portion is utilized to meet domestic, industrial and other demands.

The improvement in life-style and associated industrial development of a nation push up the per capita demand for water.

1.3 Various Types of Water Demand

1.3.1 Domestic Water Demand

- The total domestic water consumption usually amounts to *50 to 60% of the total water* consumption.
- The I.S. Code lays down a limit of water consumption between 135 to 225 litre per capita per day (lpcd).
- Under ordinary conditions (as per I.S. code) the minimum domestic water demand for a town or a city with full flushing system should be taken at *200 lpcd*. Although it can be reduced to *135 lpcd for economically weaker sections and LIG colonies* (Low Income Group) depending upon prevailing conditions.

(i) Minimum domestic water Consumption (Annual Average) for Indian Towns and Cities with Full Flushing Systems as per 1172-1993

Use	Consumptions (lpcd)
Drinking	5
Cooking	5
Bathing	75
Washing of clothes	25
Washing of utensils	15
Washing and cleaning of houses and residences	15
Lawn watering and gardening	15
Flushing of water closets, etc.,	45
Total	200

(ii) Minimum domestic water Consumption (Annual Average) for Weaker Section and LIG Colonies in Small Indian Towns and Cities

Use	Consumptions (lpcd)
Drinking	5
Cooking	5
Bathing	55
Washing of clothes	20
Washing of utensils	10
Washing and cleaning of houses and residences	10
Flushing of water closets, etc.,	30
Total	135

1.3.2 Industrial Water Demand

- The industrial water demand represents the water demand of industries which are either existing or likely to be started in future, in the city for which water supply is being planned.
- This quantity varies with the number and types of industries present in the city. This consumption, under ordinary conditions is 50 lpcd.

Water Required by Certain Important Industries

Name of Industry	Unit of Production	Approximate Quantity of Water required per unit of production/raw material in kilo litres
1. Automobiles	Vehicle	40
2. Fertilizers	Tonne	80 - 200
3. Leather	Tonne (or 1000 kg)	40 (or 4)
4. Paper	Tonne	200 - 400
5. Petroleum Refinery	Tonne (Crude)	1 - 2
6. Sugar	Tonne (Crushed cane)	1 - 2
7. Textile	Tonne (goods)	80 - 140
8. Distillery (Alcohol)	kilo litre	122 - 170

1.3.3 Institutional and Commercial Water Demand

- The water requirements of institutions such as hospitals, hotels, restaurants, schools and colleges, railway station etc. should also be assessed and provided for in addition to domestic and industrial water demands discussed above.
- On an average, a per capita demand of 20 lpcd is usually considered to be enough to meet such commercial and institutional water requirements. Although this demand may be as high as 50 lpcd for highly commercialised cities.

Water demand of certain commercial establishments:

(i) Offices — 45 *l*pcd
(ii) Schools — 45 to 135 *l*pcd
(iii) Hostels — 135 *l*pcd
(iv) Hotels — 180 *l*pcd
(v) Hospitals — 450 *l*pcd
(vi) Cinema halls — 15 *l*pcd

1.3.4 Demand for Public Uses

This includes water requirement for parks, gardening, washing of roads etc. On this account a nominal amount not exceeding *5%* of the total consumption may be provided.

1.3.5 Fire Demand

- The quantity of water required for extinguishing fire is not very large, the total amount of water consumption for a city of 50 lakh population hardly **amounts to 1 lpcd.** But this water should be easily available and kept always stored in storage reservoirs.
- Three jet streams are simultaneously thrown from each hydrant; one on the burning property, and one each on adjacent property on either sides of the burning property. The discharge of each stream should be about 1100 litres/minute.
- The minimum water pressure available at fire hydrants should be of the order of 1 to 1.5 kg/cm^2 and should be maintained even after 4 to 5 hours of constant use of fire hydrant.
- Rate of fire demand is worked out by following formulas

1. **Kuichling's Formula:**

$$Q = 3182\sqrt{P}$$

Where, Q = Amount of water required in litres/minute ; P = Population in thousands.

2. **Freeman Formula:**

$$Q = 1136\left[\frac{P}{5}+10\right]$$

3. **National Board Formula:**

(A) For a central congested high valued city:
  (i) When population ≤ 2 lakhs: $Q = 4637\sqrt{P}\left[1-0.01\sqrt{P}\right]$
  (ii) When population ≥ 2 lakhs: A provision for 54600 litres per minute may be made with an additional provision of 9100 to 36400 litres/minute for a second fire.

(B) For a residential city:
  (i) For small or low buildings: Q = 2200 litres/minute.
  (ii) For large or higher buildings: Q = 4500 litres/minute.

4. **Buston's Formula:**

$$Q = 5663\sqrt{P}$$

P and Q have the same meaning as above.

NOTE

- For Indian conditions only 2-3 hours storage is fairly adequate where as for USA 5-6 hours storage is needed.
- Above formula are not related to type of district served which give same results for industrial and non industrial cities, however industrial cities are more prone to fire.

Example 1.1 Compute the 'fire demand' for a city of 2 lakh population by any two formulae (including that of the National Board of Fire Underwriters)

Solution:

(i) The rate of fire demand as per National Board of Fire Underwriters Formula for a central congested city whose population is less than or equal to 2 Lakh is given by

$$Q = 4637\sqrt{P}\left[1-0.01\sqrt{P}\right] = 4637\sqrt{200}\left[1-0.01\sqrt{200}\right]$$

$$= 56303.08 \ l/\text{min} = \frac{56303.08 \times 60 \times 24}{10^6}\text{MLD} = \mathbf{81.08\ MLD}$$

(ii) Kuchling's formula, $Q = 3182\sqrt{P} = 3182\sqrt{200}\ l/\text{min}$; $R = 45000.27\ l/\text{m} = \mathbf{64.8\ MLD}$

1.3.6 Water Demand for losses & theft

This may be as high as 15% of total demand.

1.4 Percapita Demand (*q*)

It is the annual average amount of daily water required by one person and includes the domestic use, industrial and commercial use, public use, wastes, thefts etc.

Mathematically:

$$q = \frac{\text{Total yearly water requirement of the city in litres } (V)}{365 \times \text{design population}}$$

1.4.1 Factors Affecting Water Demand or Percapita Demand

Total water demand is affected by following factors.

1. Size of the City

Demand increases with size of city.

Table: 1.1 Variation in Per Capita Demand (q) with population in India

S. No.	Population	Per Capita Demand in Liters/day/Person
1.	Less than 20000	110
2.	20000 - 50000	110 - 150
3.	50000 - 2 Lakhs	150 - 240
4.	2 Lakhs - 5 Lakhs	240 - 275
5.	5 Lakhs - 10 Lakhs	275 - 335
6.	Over 10 Lakhs	335 - 360

- Above figures can have variation up to 25%
- I.S. code permits maximum value of 335 lpcd for Indian condition.

2. Climatic Conditions

At hotter and dry places, the consumption of water is generally more, because more of bathing, clearing, air-coolers, air-conditioning etc. are involved. Similarly, in extremely cold countries, more water may be consumed, because the people may keep their taps open to avoid freezing of pipes and there may be more leakage from pipe joints since metals contract with cold.

3. Types of Gentry and Habits of People

Rich and upper class communities generally consume more water due to their affluent living standards.

4. Industrial and Commercial Activities

The pressure of industrial and commercial activities at a particular place increase the water consumption by large amount.

5. Quality of Water Supplies

If the quality and taste of the supplied water is good, it will be consumed more, because in that case, people will not use other sources such as private wells, hand pumps, etc. Similarly, certain industries such as boiler feeds, etc., which require standard quality waters will not develop their own supplies and will use public supplies, provided the supplied water is upto their required standards.

6. Pressure in the Distribution Systems

If the pressure in the distribution pipes is high and sufficient to make the water reach at 3rd or even 4th storage, water consumption shall be definitely more.

This water consumption increases because of two reasons:

(i) People living in upper storage will use water freely as compared to the case when water is available scarcely to them.

(ii) The losses and waste due to leakage are considerably increased if their pressure is high. For example, if the pressure increase from 20 m head of water (i.e. 200 kN/m^2) to 30 m head of water (i.e. 300 kN/m^2), the losses may go up by 20 to 30 percent.

7. Development of Sewerage Facilities

The water consumption will be more, if the city is provided with 'flush system' and shall be less if the old 'conservation system' of latrines is adopted.

8. System of Supply

Water may be supplied either continuously for all 24 hours of the day, or may be supplied only for peak period during morning and evening. The second system, i.e. intermittent supplies, may lead to some saving in water consumption due to losses occurring for lesser time and a more vigilant use of water by the consumers.

9. Cost of Water

If the water rates are high, lesser quantity may be consumed by the people. This may not lead to large savings as the affluent and rich people are little affected by such policies.

10. Policy of Metering and Method of Charging

When the supplies are metered, people use only that much of water as much is required by them. Although metered supplies are preferred because of lesser wastage, they generally lead to lesser water consumption by poor and low income group, leading to unhygienic conditions.

Factors Affecting Losses and Wastes: The various factors on which losses depend and the measure to control them are below:

(i) Water Tight Joints
(ii) Pressure in the Distribution system
(iii) System of supply
(iv) Metering
(v) Unauthorized connections

NOTE

- In intermittent supply system, water is generally stored by consumers in tanks, drums etc. for non-supply periods. This water is thrown away by them even if unutilised as soon as the fresh supply is restored. This increase the wastage and losses considerably.
- Cost of water is inversely proportional to consumption of water.
- The loss of wastes due to leakage are considerably increased if pressure is high.

1.4.2 Variation in the demand

Smaller towns have more variation in the demand. The shorter the period of draft, the greater is the departure from the mean.

(A) Maximum daily Consumption:

Maximum daily consumption = 1.8 × Avg. daily consumption = 1.8 q

(B) Maximum hourly consumption:

- This is taken as 150% of its average.
- Maximum hourly consumption of maximum daily

$$\text{(Peak Demand)} = 1.5 \times \left[1.8 \times \frac{q}{24}\right] = 2.7\left(\frac{q}{24}\right)$$

(C) Maximum weekly demand:

Maximum weekly consumption = 1.48 × Avg. weekly = 2.7 (Annual average hourly demand)

(D) Maximum monthly demand:

Maximum monthly consumption = 1.28 × Avg. monthly

NOTE

- 'Good rich' formula to find peak demand to average demand ratio

$$p = 180 \cdot t^{-0.1}$$

where p = percent of the annual average draft for the time 't' in days.

- $$\frac{\text{Maximum daily demand}}{\text{Average daily demand}} = 180\%$$
- $$\frac{\text{Maximum weekly demand}}{\text{Average weekly demand}} = 148\%$$
- $$\frac{\text{Maximum monthly demand}}{\text{Average monthly demand}} = 128\%$$

1.5 Coincident Draft

For general community purposes, the total draft is not taken as the sum of maximum hourly demand and fire-demand, but is taken as sum of maximum daily demand and fire demand or the maximum hourly demand, which ever is more. The maximum daily demand when added to the fire demand is known as the *'coincident draft'*.

Example 1.2 A water supply scheme has to be designed for a city having a population of 1,00,000. Estimate the important kinds of drafts which may be required to be recorded for an average water consumption of 250 *l*pcd. Also record the required capacities of the major components of the proposed water works system for the city using a river as the source of supply. Assume suitable data.

Solution:

(i) Average daily draft = (per capita average consumption in litre/person/day) × population

$= 250 \times 1,00,000$ litres/day $= 250 \times 10^5$ litres/day = 25 MLD

(ii) Maximum daily draft may be assumed as 180% of annual average daily draft

$$\therefore \text{ Maximum daily draft } = \frac{180}{100}[25 \text{ MLd}] = 45 \text{ MLD}$$

(iii) Maximum hourly draft of the maximum day: It may be assumed as 270 percent of annual average hourly draft

$$\therefore \text{ Maximum hourly draft of maximum day } = \frac{270}{100}[25 \text{ MLd}] = 67.5 \text{ MLD}$$

(iv) Fire flow may be worked out from

$$Q = 4637\sqrt{P}\left[1-0.01\sqrt{P}\right] = 4637\sqrt{100}\left[1-0.01\sqrt{100}\right] = 41733 \text{ litre/min}$$

where P = in thousand population

$$= \frac{41733 \times 60 \times 24}{10^6} \text{ million litres/day} = 61 \text{ MLD}$$

Coincident draft = maximum daily draft + fire draft

= 45 + 61 = **106 MLD**

which is greater than the maximum hourly draft of 67.5 MLD

1.6 Design Period Values

Water supply projects, generally may be designed for 30 years. This 30 years should be counted after completion period of about 2 years.

Table 1.2 : Design Period of Various Components of Water Supply Project

S.No.	Units	Design (Parameters) Discharge	Design Period
1.	Water Treatment Unit	Maximum daily demand	15 Years
2.	Main supply pipes (Water mains)	Maximum daily demand	30 Years
3.	Wells and Tube wells	Maximum daily demand	30-50 Years
4.	Demand Reservoir (Overhead or ground level)	Average annual demand	50 Years
5.	Distribution system	Maximum hourly demand/ Coincident draft	30 Years

- The *sources of supply* (such as wells) may be designed for maximum daily consumption or some times for average daily consumption.
- The *pipe mains* (to take water from source to service reservoir) and *filter and other treatment units* are designed for maximum daily draft.
- *Pumps* may be designed for maximum daily draft plus some additional reserve for break down and repair.

- *The distribution system* (to carry water from service reservoir to water taps) should be designed for maximum hourly draft of maximum day' or coincident draft with fire, which ever is more.
- *The service reservoir* is designed to take care of hourly fluctuations, fire demands and emergency reserves.

NOTE: The design period should neither be too long nor should it be too short. The design period can not exceed the useful life of the structure.

1.7 Population Fore-Casting Methods

Methods are based on laws of probability and growth curve.

Growth Curve

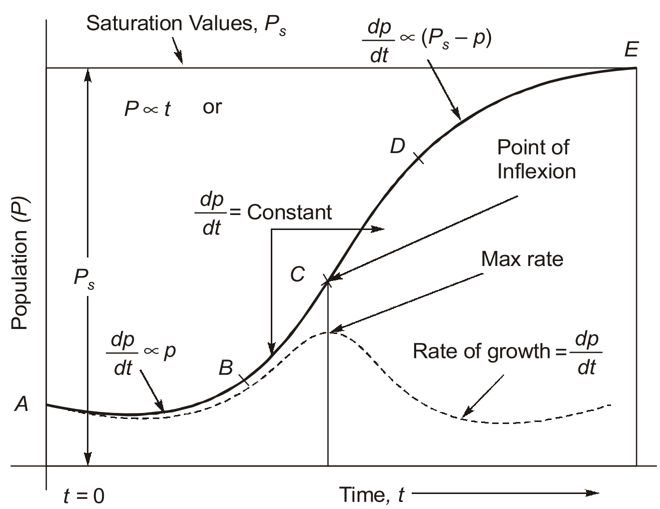

Fig. 1.1 Growth Rate Curve

1.7.1 Arithmetic Increase Method

This method assumes that the population increases at a constant rate.

$$\frac{dp}{dt} = \text{Constant}$$

Forecasted population (P_n) after 'n' decades from the last known census is given by

$$P_n = P_o + n\bar{x}$$

where, P_0 = Population at last known census.

$\bar{x}$ = Average (Arithmetic mean) of population increase in the known decades.

n = Number of decades between last census and future.

Example 1.3 The population of 5 decades from 1930 to 1970 are given in the table. Find out the population after one, two and three decades beyond the last known decade, by using arithmetic increase method.

Year	Population
1930	25,000
1940	28,000
1950	34,000
1960	42,000
1970	47,000

Solution:

The given data in the table is extended in table 1.8, so as to compute the increase in population (x) for each decade (col. 3), the total increase, and average increase per decade ($\bar{x}$), as shown.

The future populations are now computed by using equation as

$P_n = P_0 + n \cdot \bar{x}$

∴ (a) Population after 1 decade beyond 1970

$= P_{1980} = P_1 = P_{1970} + 1 \cdot \bar{x}$

$= 47{,}000 + 1 \times 5500 = 52{,}500$

(b) Population after 2 decades beyond 1970

$= P_{1990} = P_2 = P_{1970} + 2 \cdot \bar{x}$

$= 47{,}000 + 2 \times 5500 = 58{,}000$

(c) Population after 3 decades beyond 1970

$= P_{2000} = P_3 = P_{1970} + 3 \cdot \bar{x}$

$= 47{,}000 + 3 \times 5500 =$ **63,500**

Year (1)	Population (2)	Increase in population (x) (3)
1930	25,000	
1940	28,000	3000
1950	34,000	6000
1960	42,000	8000
1970	47,000	5000
Total		22,000
Average increase per decade ($\bar{x}$)		$\bar{x} = \frac{22000}{4} = 5{,}500$

1.7.2 Geometric Increase Method

- This is compounding rate method also called *'uniform increase method'*.
- The forecasted population (P_n) after n decades is given by

$$P_n = P_0\left(1 + \frac{r}{100}\right)^n$$

Where, P_0 = Population at last known census ; r = Assumed growth rate (%)

r can be calculated by following methods.

(i) $r = \left(\frac{P_n}{P}\right)^{\frac{1}{n}} - 1$

(ii) $r = \frac{\text{Increase in population}}{\text{Original population}} \times 100$ for each decade

Knowing $r_1, r_2, r_3 \ldots r_n$ for each decade the average value of r can be found by

(a) Arithmetic average method: $r = \frac{r_1 + r_2 + r_3 + \ldots + r_n}{n}$

(b) Geometric average method: $r = (r_1 \times r_2 \times r_3 \times \ldots \times r_n)^{\frac{1}{n}}$

Example 1.4 Determine the future population of a satellite town by the Geometric increase method for the year 2011, given the following data (Table-1.9)

Table

Year	Population in Thousand
1951	93
1961	111
1971	132
1981	161
......	......
2011	?

Solution:

The given data is analysed in table to determine growth rates for each decade.

Table

Year	Population in thousand	Increase in Population in thousand	%age increase in population = growth rate $= \frac{\text{col(3)}}{\text{col(2)}} \times 100$
1951	93		
1961	111	18	19.35
1971	132	21	18.92
1981	161	29	21.97

Constant growth rate, assumed for future

r = geometric mean of past growth rates = $\sqrt[3]{19.35 \times 18.92 \times 21.97}$ = 20.03 % per decade

The population after n decades in now given by equation

$$P_n = P_0\left(1+\frac{r}{100}\right)^n$$

P_{2011} = Population after 3 decades from 1981

$$= P_{1981}\left(1+\frac{20.03}{100}\right)^3 = 1{,}61{,}000(1.2003)^3 = \mathbf{2{,}78{,}417}$$

NOTE: The Field Engineers adopt arithmetic average method since it gives more values than the geometric average method. However GOI manual on water supply recommends 'geometric mean' method.

1.7.3 Incremental Increase Method : (The Method of varying increment)

- The rate of growth is not assumed constant. Where as it was assumed constant in arithmetic and geometric methods.
- The population after n decades from present (i.e. last known Census) is given by

$$P_n = P_o + n\overline{x} + \frac{n(n+1)}{2}\overline{y}$$

NOTE

The geometric progression method, gives highest values of forecasted population, evidently gives higher results for developed cities which do not expand in future at compound rate, although it may be suitable for new younger cities expanding at faster rates. For old cities, the arithmetic method may be better, although, incremental method is considered to be the best for any city, whether old or new.

Example 1.5 As per the census records for the years 1911 to 1971, the population of a town is given below in the table. Assuming that the scheme of water supply was to commence in 1996, it is required to estimate the population of 10 years hence i.e. in 2006 and also the intermediate population after 15 year since commencement.

Year	1911	1921	1931	1941	1951	1961	1971
Population	40185	44522	60395	75614	98886	124230	158800

Solution: Let us try to get the solutions using all the three methods to which you have been introduced by now. The incremental population and increase in incremental population are summed up in table below:

Year	Population	Increment	Incremental increase(y)
1911	40185	–	–
1921	44522	4337	–
1931	60395	15873	+ 11536
1941	75614	15219	– 654
1951	98886	23272	+ 8053
1961	124230	25344	+ 2072
1971	158800	37570	+ 9226

From the above table, the following parameters can be worked out as

Total increase in population = 118,615

Total of incremental/decrease = 30,233

$$\text{Average incremental value decade } (\bar{x}) = \frac{1}{6} \times 118615 = 19769$$

$$\text{Average incremental increase per decade } (\bar{y}) = \frac{1}{5} \times 30233 = 6047$$

1.7.4 Decreasing Rate of Growth Method

Since the rate of increase in population goes on reducing as the cities reach towards saturation, this method is suitable. In this method, the average decrease in the percentage increase is worked out, and is then subtracted from the latest percentage increase for each successive decade.

NOTE:
- This method is applicable only when the rate of growth shows a downward trend.
- In this method calculations are made for each successive decade.

Steps:
(i) Find increase in population.
(ii) Find % increase (r) for last count P_o
(iii) Find decrease in the % increase in population. (r_1) is actually decreasing then it is taken +ve and If r_1 is increasing it is –ve.
(iv) The expected population

$$P_1 = P_o + \frac{r - r_1}{100} \times P_o \quad ; \quad P_2 = P_1 + \frac{(r - r_1) - r_1}{100} \times P_1$$

Example 1.6 The census record of a particular town is shown in table. Estimate the population for the year 2020 by decreasing growth rate method

S.No.	Year	Population	% increase in Growth rate	% Decrease in Growth rate
1.	1960	55500		
2.	1970	63700	14.77%	
3.	1980	71300	11.93%	+ 2.84%
4.	1990	79500	11.50%	+ 0.43%

Solution:

We know that, $P_1 = P_0 + \left(\frac{r_0 + r'}{100}\right) \times P_0$

r_0 = growth rate of last known census = 11.80%

r' = Average decrease in growth rate $= \frac{2.84 + 0.43}{2} = 1.635\%$

$$P_{2020} = P_{2010} + \left(\frac{r_0 - 3r'}{100}\right) \times P_{2010}$$

$$P_1 = P_{2000} = 79500 + \left(\frac{11.5 - 1.635}{100}\right) \times 79500$$

$$P_{2000} = 87343$$

$$P_2 = P_{2010} = 87343 + \left(\frac{11.5 - 2 \times 1.635}{100}\right) \times 87343$$

$$P_{2010} = 94531$$

$$P_3 = P_{2020} = 94531 + \left(\frac{11.5 - 3 \times 1.635}{100}\right) \times 94531$$

$$P_{2020} = 100{,}765$$

1.7.5 Simple Graphical Method

A graph is plotted from the available data between time and population, the curve is then smoothly extended up to the desired year.

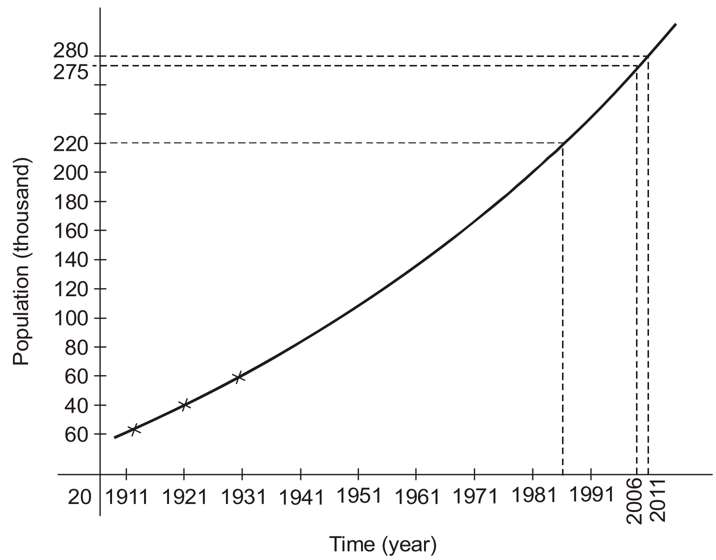

Fig. 1.2 Graphical Projection Method

1.7.6 Comparative Graphical Method

Cities of similar conditions and characteristics are selected which have grown in similar fashion in the past, and their graph is plotted, and then mean graph is also plotted. This method gives quite satisfactory results.

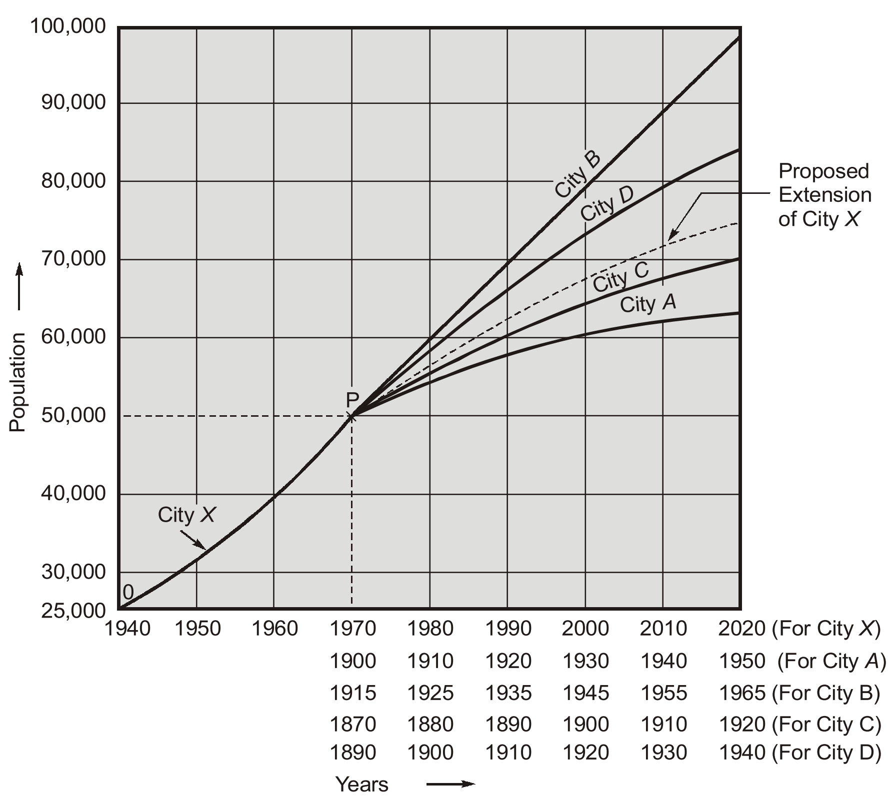

Fig. 1.3

1.7.7 Master Plan Method or Zoning Method

Big and Metropolitan cities are generally controlled by development authorities in a planned manner, Only those expansions are allowed which are permitted or proposed in the master plan of that city and the populations are also fixed.

Say for (example) 5 persons living in a flat etc.

1.7.8 The Ratio Method or Apportionment Method

- In this method the city's census population record is expressed as the % of the population of the whole country, in order to do so, the local population and the countries population for last 4-5 decades is obtained from the census records, The ratios of local population to national population is worked out a graph is then plotted between those ratios and time and extended up to the design period and then ratio is multiplied by expected national population at the end of design period.
- This method does not take into consideration abnormalities in local areas.

1.7.9 The Logistic Curve Method

- This method is given by P.F. Verhulst. This method is mathematical solution for logistic curve.
- The population at any time t from the start is given by

$$P = \frac{P_s}{1 + m \cdot \log_e^{-1}(nt)}$$

where, P_s =Saturation population ; P = Population at any time t from start point
P_o =Population at the start point of the curve

$$m = \frac{P_s - P_0}{P_0} = \text{constant}$$

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$$

$$n = \left(\frac{1}{t_1}\right)\log_e\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$$

P_o, P_1, P_2, are population at times $t = t_0$, t_1 and $t_2(= 2t_1)$.

Example 1.7 In two periods of each 20 years, a city has grown from 30,000 to 1,70,000 and then to 3,00,000. Determine (a) The saturation population, (b) The equation of logistic curve, (c) The expected population after the 60 years from the start.

Solution:

(a) In this equation, we have

P_0 = 30,000, P_1 = 1,70,000, P_2 = 3,00,000

t = 0, t = 20 years, t = 40 years

Using equation, P_s = Saturation Population = $\dfrac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$ = **3,26,000**

(b) $m = \dfrac{P_s - P_0}{P_0} = \dfrac{3,26,000 - 30,000}{30,000} = 9.87$

$$n = \frac{1}{30}\log_e\left[\frac{30,000(3,26,000-1,70,000)}{1,70,000(3,26,000-30,000)}\right] = -0.1119$$

∴ Equation of logistic curve is

$$P = \frac{P_s}{1+m\log_e^{-1}(nt)} = \frac{3,26,000}{1+9.87\log_e^{-1}(-0.119t)}$$

(c) If t = 60 years

then, $$P = \frac{3,26,000}{1+9.87\,log_e^{-1}(-0.119\times 60)} = \mathbf{3,23,470}$$

■■■■

STUDENT'S ASSIGNMENTS

Q.1 Which one of the following method gives the best estimate of population growth of a community with limited land area for future expansion?
(a) Arithmetical increase method
(b) Geometrical increase method
(c) Incremental increase method
(d) Logistic method

Q.2 If the average daily water consumption of a city is 24000 cum, the peak hourly demand (of the maximum day of course) will be
(a) 1000 cu m/hr (b) 1500 cu m/hr
(c) 1800 cu m/hr (d) 2700 cu m/hr

Q.3 The suitable method of forecasting population for an old developed large city, is
(a) arithmetic mean method
(b) geometric mean method
(c) comparative graphical method
(d) None of these

Q.4 The suitable method for forecasting population for a young and a rapidly developing city is
(a) arithmetic mean method
(b) geometric mean method
(c) comparative graphical method
(d) None of these

[RPSC-2013]

Q.5 A compared to the geometrical increase method of forecasting population, the arithmetical increase method gives
(a) lesser value (b) higher value
(c) equal value
(d) may vary, as it may depend on the population figures

Q.6 The growth of population can be conveniently represented by a curve, which is amenable to mathematical solution. The type of this curve is
(a) semi-log curve
(b) straight line curve
(c) logistic curve
(d) exponential curve

Q.7 If the population of a city is 2 lakh, and average water consumption is 200 lpcd, then the capacity of the pipe mains, should be
(a) 108 MLD (b) 72 MLD
(c) 60 MLD (d) 40 MLD

Q.8 If the population of a central congested high valued city in 2,00,000 and the fire demand is computed to be 45,000 litres per minute, the formula used for the calculation must have been
(a) Freeman's formula
(b) National Board of Underwriters formula
(c) Kuichling's formula
(d) Buston's formula

Q.9 If the average water consumption of a city is 300 lpcd, and its population is 4,00,000 the maximum hourly draft of the maximum day will be
(a) 120 Mld (b) 216 Mld
(c) 324 Mld (d) None of these

Q.10 The per capita demand of water for an average Indian as per IS is
(a) 250 lpcd (b) 300 lpcd
(c) 270 lpcd (d) 200 lpcd

Q.11 The distribution mains are designed for
(a) maximum daily demand
(b) maximum hourly demand
(c) average daily demand
(d) maximum hourly demand or maximum daily demand

Q.12 Water losses in water supply system are assumed as
(a) 5% (b) 7.5%
(c) 15% (d) 25%

Q.13 Which of the following factors has maximum effect on figure of per capita demand of water supply of a given town?
(a) Method of charging of the consumption
(b) Quality of water
(c) System of supply intermittent or continuous
(d) Industrial demand

Q.14 Total domestic consumption in a city water supply, is assumed
(a) 20% (b) 30%
(c) 40% (d) 60%

Q.15 The distribution system in water supplies is designed on the basis of :
(a) average daily demand
(b) peak hourly demand
(c) coincident of draft
(d) greater of (b) and (c)
[SSC-JE : 2010]

Q.16 The total water requirement of a city is generally assessed on the basis of
(a) maximum hourly demand
(b) maximum daily demand + fire demand
(c) average daily demand + fire demand
(d) greater of (a) and (b)
[SSC-JE : 2007]

Q.17 Water supply includes
(a) collection, transportation and treatment of water
(b) distribution of water to consumers
(c) provision of hydrants for fire fighting
(d) All the above
[SSC-JE : 2008]

Q.18 Pollution potential of domestic sewage generated in a town and its industrial sewage can be compared with reference to
(a) their BOD value (b) population equivalent
(c) their volume (d) the relative density
[SSC-JE : 2015]

Q.19 As per Indian Standard Specifications, the peak discharge for domestic purposes per capita per minute, is taken
(a) 1.80 litres for 5 to 10 users
(b) 1.20 litres for 15 users
(c) 1.35 litres for 20 users
(d) All options are correct [SSC-JE : 2017]

Q.20 Which of the following represents the value of hourly variation factor?
(a) 1.2 (b) 1.5
(c) 1.7 (d) 2.5
[SSC-JE : 2018]

Q.21 When was water (prevention and control of pollution) act enacted by the India Parliament?
(a) 1970 (b) 1974
(c) 1980 (d) 1965

Q.22 On which of the following factors does the populating growth in a town normally depends?
1. Birth and death rates
2. Migration
3. Probabilistic growth
4. Logistic growth
(a) 1 and 4 only (b) 1 and 2 only
(c) 1, 2 and 3 only (d) 2 and 3 only

Q.23 The population of a town as per census records were 2,00,000; 2,10,000 and 2,30,000 for the year 1981, 1991 and 2001 respectively. Find the population of the town in the year 2011 using arithmetic mean method.
(a) 250000 (b) 255000
(c) 240000 (d) 245000
[SSC - JE : 2012]

Q.24 The population of a town as per census records were 200000, 210000 and 230000 for the years 1981, 1991 and 2001 respectively. The population of the town as per geometric mean method in the year 2011 is
(a) 244872 (b) 245872
(c) 246820 (d) None of the above
[SSC : JE : 2013]

ANSWER KEY — STUDENT'S ASSIGNMENTS

1. (d)	**2.** (d)	**3.** (a)	**4.** (b)	**5.** (a)
6. (c)	**7.** (b)	**8.** (c)	**9.** (c)	**10.** (d)
11. (b)	**12.** (c)	**13.** (d)	**14.** (d)	**15.** (d)
16. (d)	**17.** (d)	**18.** (b)	**19.** (d)	**20.** (b)
21. (b)	**22.** (b)	**23.** (d)	**24.** (b)	

HINTS & SOLUTIONS / STUDENT'S ASSIGNMENTS

1. (d)

Since the area is limited and there is no time period specified for population estimation, such as young or old city. Therefore logistic curve method will be best.

2. (d)

Peak hourly demand = $\frac{2.7 \times 24000}{24}$ = 2700 cum/hr

7. (b)

Average water consumption per day

$= 200 \times 2 \times 10^5 = 40 \times 10^6$

$\therefore$ Max. water consumption per day

$= 1.8 \times 40 \times 10^6 = 72$ Mld

8. (c)

Kuichling's formula:

$Q = 3182\sqrt{P}$

$Q \rightarrow$ Amount of water required in litres/minute

$P \rightarrow$ Population in thousand

Given: $P = 200000 = 200$ thousand

$Q = 3182\sqrt{200}$

$Q = 45000$ litres/minute

10. (d)

The IS code lays down a limit on domestic water consumption between 135 to 225 l/c/d.

Under ordinary conditions, minimum domestic water demand is 200 l/c/d. Although it can be reduced upto 135 l/c/d for economically weaker section.

11. (b)

Sources of supply are designed for maximum daily consumption. Distribution systems are designed for maximum hourly demand.

14. (d)

Total domestic consumption in a city water supply is assumed to be 55 to 60%.

15. (d)

The distribution system in water supply is designed for the maximum of (i) peak hourly demand and (ii) Coincidental draft, which is the summation of fire demand and peak daily demand.

16. (d)

The maximum daily demand along with fire demand is known as coincident draft. The total water demand of the city is the maximum of either the coincident draft or maximum hourly demand.

18. (b)

The number of persons which produce the amount of BOD at a rate of 80 grams per person per day (average standard BOD of domestic sewage) equal to that produced by the industrial sewage is called population equivalent.

20. (b)

In water supply scheme,
maximum hourly demand
= 1.5 × average demand hourly of maximum day

22. (b)

Birth rate: Number of line births per thousand of population per year.

Death rate: The ratio of deaths to the population of a particular area or during a particular period of time usually calculated as number of deaths per one thousand people per year.

23. (d)

Year	Population	Increment
1981	200000	—
1991	210000	10000
2001	230000	20000

Average increment = $\frac{10000 + 20000}{2} = 15000$

Population in 2011 = 230000 + 15000 = 245000

24. (b)

Year	Population	Increment	Growth rate per decade
1981	200000	—	—
1991	210000	10000	$\frac{10000}{200000} \times 100 = 5\%$
2001	230000	20000	$\frac{20000}{210000} \times 100 = 9.5\%$

Geometric mean of growth rate,

$I = (0.05 \times 0.095)^{1/2} = 0.069$ or 6.9%

$\therefore$ Population in year 2011

$= 230000 \times (1 + 0.069)^1 = 245870$