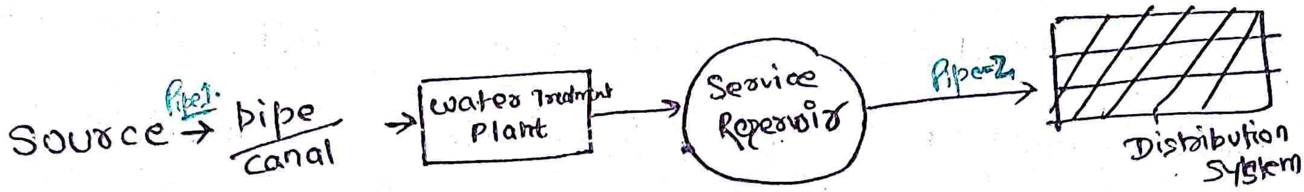
Water Demand

Raw water: The water which is derived from nature.

river - sedimentation.
rain - aeration.
ground water - filtration



(i) Water Demand
(ii) Source of Water
xxx (iii) Quality of Water
xxx (iv) Treatment of Water
(v) Pipes.
(vi) Service reservoir
(vii) Distribution System.

Water Demand/draft:

(i) Annual draft = V
(ii) Annual avg. daily draft = $\frac{V}{365}$
(iii) Annual avg. per capita daily draft = $\frac{V}{365 \cdot P}$, P = present population.

Total Demand $\quad$ l/c/d $\quad$ ✓ Discharge of water.

(i) Domestic Water demand. = 135 – 225 (200) (~~50-60~~)% flushing system.

(ii) Industrial water demand = 50 – 450

(iii) Institution water demand = 20 – 50 l/c/d

(iv) Water for public use = (5 – 6)% of Total demand = (10 – 20)

(v) Fire demand = 1 or emperical. IS code = $100\sqrt{P}$ (~~...~~) ← (Kl)

thousand

[Volume me aayega – India]

Kuchling method = $Q = 3182\sqrt{P}$ l/min $\quad$ P = Population in thousand

Freeman method = $Q = 1136\left(\frac{P}{10} + 10\right)$ l/min $\quad$ P = Pop. in thousand

National Board of fire underwriters method = $Q = 4637\sqrt{P}\,(1 - 0.01\sqrt{P})$ l/min

Buston = $Q = 5663\sqrt{P}$ l/min

~~...~~

(vi) Losses and theft – (10 – 15)% of total demand.

$\boxed{\text{Total demand} = 250 - 350\ (335)}$ l/c/d

Factors Influencing demand of water :-

{Demand remain constant but consumption may vary}

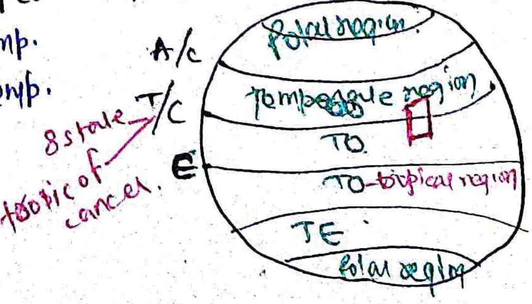
(i) Size of the city.

(ii) Extent of industrialisation.

(iii) Type of sewerage system. (flush system)

(iv) Standard of living / gentry.

(v) Climatic condition. (depend on location of community, latitude
higer latitude – less temp.
lower latitude – high temp.



(vi) Cost of water :- *

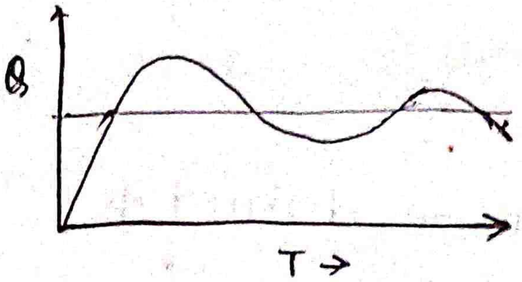
(vii) Quality of water

(ix) Pressure in distribution system.

(x) Type of distribution system. (Continuous and ~~discontinuous~~ intermittent)

$$FI = \frac{Max.\,P}{Avg\ P} = \frac{Avg\ P}{Min\ P}$$

fluctuation



Maximum daily demand = 1.8 Annual average daily demand $\div \frac{V}{365}$

$\frac{x+y}{365}$

Maximum hourly demand of max^m day = 1.5 Avg. hourly demand of max^m day.

$= 1.5 \times \frac{Max^m \text{ daily demand}}{24}$

$= 1.5 \times 1.8 \frac{\text{Annual average daily demand}}{24}$

Max^m hourly demand of max^m day $= 2.7$ Annual average hourly demand

Good rich eqn:-

percentage fluctuation, $P = \frac{Max^m \text{ demand}}{Avg \text{ demand}}$ (in percentage)

$= 180\, t^{-0.1}$ (t = days)

t = time (days) ≥ 1 days and less than 1 year.

Time		Fluctuation
hourly	-	2.7
daily	=	1.8
weekly	=	1.48
Monthly	=	1.28
Yearly	=	1

peak factor

[Bigger the sample lesser the standard deviation]

Population	Peak factor
< 50,000	3
50,000 – 2,00,000	2.5
> 2,00,000	2

Avg 2.7

We know that, raw water scheme designed for maximum hourly design.

(i) Q_{MH} — max^m hourly

(ii) $Q_{MH} + Q_{FD}$ fire demand. (on including fire demand cost increased)

(iii) $Q_{MD} + Q_{FD}$ [coincident demand/draft]

* Design should be done.

(i) Q_{MH}
(ii) $Q_{MD} + Q_{FD}$

$\}$ Max^m

* Design Life and design discharge:-

	Component	Designlife (yrs)	Design Discharge.
life is greater because all things depend on it	Source	50	Q_{MD}
	Pipe-I	30	Q_{MD}
life is less because mechanical component technology changes time to time	Pump & canal	15	Q_{MD}*
	WTP	15	Q_{MD}
	Service Reservoir	15	Volume
	Pipe-II	30	Q_{MH}, $Q_{MD} + Q_{FD}$ } max^m
	Distribution System	30	Q_{MH}, $Q_{MD} + Q_{FD}$ } max^m

Pump & canal - is not used for 24 hrs.

Q $P = 2\times10^5$, AA POD = 300 L/c/d.

(i) find Important type of demand.
(ii) design capacity of all components of RWS.

Q_{MD} : Maximum daily demand = 1.8 AAdD = $1.8 \times 300 \times 2\times10^5 \times 10^{-6} = 108$ MLD

~~Q_{MH} = Max^m hourly demand =~~

~~Q_{FD} fire demand =~~

Q_{MH} = Max^m hourly demand = $2.7\left(\frac{q}{24}\right)$

$= 2.7 \times 300 \times 10^{-5} \times \frac{10^{-6}}{24}$

$= 6.75$ MLH

$= 6.75 \times 24$ MLD $= 162$ MLD

Or, $Q_{MH} = 1.5\, Q_{MD} = 1.5 \times 108 = 162$ MLD

Fire demand

As per NBFUM.

$Q_{FD} = 4637\sqrt{P}\,(1 - 0.01\sqrt{P})$

$= 4637\sqrt{200}\,(1 - 0.01\sqrt{200})$

$= 56303$ l/min

$= 56303 \times 10^{-6} \times 60 \times 24$ MLD

$= 81.07$ MLD

Coincident demand.

$$Q_{CD} = \left.\begin{matrix} Q_{MD} + Q_{FD} \\ = Q_{MH} \end{matrix}\right\} \text{max}^m$$

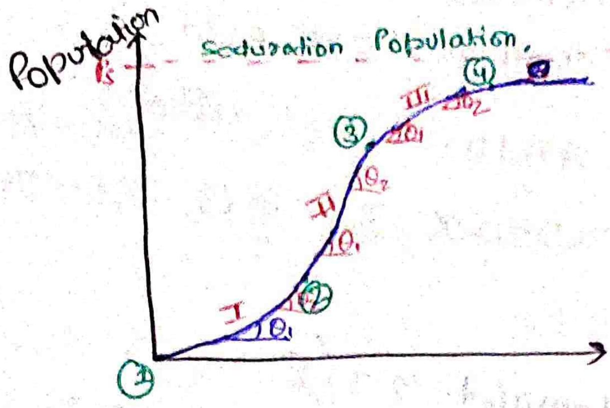
$$\left.\begin{matrix} Q_{MD} + Q_{FD} = 108 + 81 = 189 \text{ MLD} \\ Q_{MH} = 162 \text{ MLD} \end{matrix}\right\} \text{max}^m$$

$Q_{CD} = 189$ MLD

Pipe-II and distribution system design for $Q_{CD} = 189$ MD.

Source, Pipe-I, Pump, WTP, $Q_{MD} = 108$ MLD

* Population forecasting



logistic / Auto catylyt curve.

$y = f(x)$

$P = f(t)$

I $\frac{dy}{dx} = \frac{dP}{dt}$ (↑) In a yong city rate of growth of population increase

$(\theta_2 > \theta_1)$

II In old city rate of development stabilises $\frac{dP}{dt} \simeq C$

$\theta_2 \sim \theta_1$

III Very old City - Population is increasing but its rate is decreasing

$\theta_2 < \theta_1$

$\frac{dP}{dt}$ (↓) $\propto (P_s - P\uparrow)\downarrow$

III

Population of any community depend upon:-

(a) Growth rate. } depend upon city development
(b) Death rate
(c) Migration rate ~(+, -)
(d) Increase due to annexation - [forcefully taking land of other country] eg. china taking land of Honkgong.

DO YOU KNOW?

Panedimic - when it is in every place of world. (covid)
Epidimic - When it was only in wuhan (local area)

Methods of Population forecasting:-

(i) Arithmetic Increase Method.

→ In arithmetic I. Method we consided rate of growth of population is constant. $\boxed{\frac{dP}{dt} = \text{constant}}$

→ In this method, we consider the average increasing of population over the present population.

eg.

Year	1970	1980	1990	2000	2010
Popⁿ -	25	50	100	175	200

increase, x = 25, 50, 75, 25

2020: $200 + 43.75 = 243.75$

2030: $243.75 + 43.75$ = 287.5 ~288

average, $\bar{x} = \frac{25+50+75+25}{4} = 43.75$/decade.

$$t = t_0 \qquad P = P_0$$
$$t = t_1 \qquad P_1 = P_0 + \bar{x}$$
$$t = t_2 \qquad P_2 = P_1 + \bar{x} = P_0 + 2\bar{x}$$
$$\text{-------}$$
$$t = t_n \qquad P_n = P_{n-1} + \bar{x} = P_0 + (n-1)\bar{x} + \bar{x}$$
$$= P_0 + n\bar{x}$$

(ii) Geometric Increase Method/compounding/Uniform Incre... method

→ In this method, percentage rate of growth is constant.

Year → 1970	1980	1990	2000	2010	2020	2030
Population → 25	50	100	175	200	$= P_0(1+r)^1$ $= 314.4$	$= 200\times(1+0.572)^2$ $= 494.23$ ~495

$\frac{50-25}{25}\times 100 = 100\%$ $\frac{100-50}{50}\times 100 = 100\%$ $\frac{175-100}{100}\times 100 = 75\%$ $\frac{200-175}{175}\times 100 = 14.28\%$

$$\boxed{r\% = \frac{dP}{dt}\times\frac{1}{P}\times 100 = \text{const.}}$$

Using Arithmetic mean method, $= \frac{100+100+75+14.28}{4}$ %/decade

$= \cancel{72.32\%}$

$= 72.32$ %/decade

By using Geometry mean method $= \sqrt[4]{100\times100\times75\times14.28}$

$= 57.2\%$/decade.

$t = t_0 \qquad P = P_0$

$t = t_1 \qquad P_1 = P_0 + r \cdot P_0 \cdot 1 = P_0(1+r)$

$t = t_2 \qquad P_2 = P_1 + r \cdot P_1 \cdot 1 = P_1(1+r)$

$= P_0(1+r)(1+r) = P_0(1+r)^2$

$\cdots$

$t = t_n = \quad P_n = P_{n-1} + r \cdot P_{n-1} \cdot 1 = P_{n-1}(1+r)$

$= P_0(1+r)^{n-1}(1+r)$

$= P_0(1+r)^n$

$$\boxed{r\% = \frac{dP}{dt} \times \frac{1}{P} \times 100 = \text{constant}}$$

⇒ To calculate % rate growth (% r)

(i) Arithmetic mean method. - Used when 3 values given

$$\boxed{\% r = \frac{r_1 + r_2 + r_3 \cdots + r_n}{r_n}}$$

(ii) Geometric mean method. - Used when 3 values given.

$$\boxed{\% r = \sqrt[n]{r_1 \cdot r_2 \cdot r_3 \cdots r_n}}$$

$$\boxed{AM > GM}$$

(iii) $P_n = P_0(1+r)^n$ - when two value given.

$$\boxed{r = \sqrt{\frac{P_n}{P_0}} - 1}$$

Our code says, when you are using geometric increase method you should use geometric mean method.

(iii) Incremental Increase Method. (It require 4 data)

→ In this method we don't assume rate of growth of population constant.

→ In this method we consider an average of incremental over the increase in population.

$t = t_0$ $\quad P = P_0$

$t = t_1$ $\quad P_1 = P_0 + \bar{x} + \bar{y}\cdot 1 = P_0 + \bar{x} + \bar{y}$

$t = t_2$ $\quad P_2 = P_1 + \bar{x} + 2\cdot\bar{y} = P_0 + \bar{x} + \bar{y} + \bar{x} + 2\bar{y}$

$= P_0 + 2\bar{x} + 3\bar{y}$

$t = t_3$ $\quad P_3 = P_2 + \bar{x} + 3\bar{y} = P_0 + 2\bar{x} + 3\bar{y} + \bar{x} + 3\bar{y}$

$= P_0 + 3\bar{x} + 6\bar{y}$

$t = t_n$ $\quad P_n = P_{n-1} + \bar{x} + n\bar{y} = P_0 + n\bar{x} + \boxed{\frac{n(n+1)}{2}\bar{y}}$

Q

Year	1970	1980	1990	2000	2010	2020	2030
Population	30	50	100	130	165		

Increase x = 20, 50, 30, 35

y = 30, −20, 5

$$\bar{x} = \frac{20+50+30+35}{4} = 33.75/\text{decade}.$$

$$\bar{y} = \frac{30+(-20)+5}{3} = 5/\text{decade}.$$

$$P_{2020} = P_0 + n\bar{x} + \frac{n(n+1)}{2}\bar{y}$$

$$= 165 + 1\times 33.75 + \frac{2}{2}\times 5$$

$$= 203.75$$

$$P_{2030} = P_0 + 2\bar{x} + \frac{n(n+1)}{2}\bar{y}$$

$$= 165 + 2\times 33.75 + \frac{2\times 3}{2}\times 5$$

$$= 247.5$$

$P_{2020} + \bar{x} +$

	Population	City
Arithmethic -	lowest	Very old
Geometric -	Highest	Young city
Incremental —	Intermediate.	Old city.

Q

Year	1970	1980	1990	2000	2030
Population	20	24	27	30	?

A

$x =$ 4   3   3

$y =$ -1   0

Arithmetic method:

$$\bar{x} = \frac{4+3+3}{3} = 3.33$$

$$P_{2030} = 30 + 3 \times 3.33$$
$$= 40$$

Geometric method (1) First calculate %r

20   24   27   30

%r $\frac{4}{20}\times 100 = 20\%$ $\frac{3}{24} = 12.5\%$ $\frac{3}{27} = \frac{1}{9} = 11.11\%$

% r is decreasing with time so it is very old city
So use arithmetic increas method.

Q Present population = 56000, water demand = 8400 m^3/day
It is expected that after population after 20 years = 88000 we have to provide water supply scheme.
o Water treatment plant capacity = 12000 m^3/day.
No. of years plant will reach its design capacity. Assume geometric growth.

Q per person 6.6666 m^3/day

(no.)	Quantity m^3/day
56000	8400
80000	12000
88000	?

$$r\% = \sqrt{\frac{P_n}{P_0}} - 1$$

$$= \sqrt{\frac{88000}{56000}} - 1$$

$$r\% = 19.52$$

$$80000 = 56000(1+0.1952)^n$$

Solution

$$P_0 = 56000$$

$$WD = 84000\ m^3/d$$

$$\text{APWP} = \frac{84000 \times 10^3}{56000} = 150\ l/c/d.$$

$$\text{Design population} = \frac{12000 \times 10^3}{150} = 80000.$$

%r ∃

$$P_2 = P_0(1+r)^2$$

$$88000 = 56000(1+r)^2$$

$$1.25 = 1 + r$$

$$r = \cancel{25\%}\ 0.25$$

$$r\% = 2\cancel{5}5.35\%$$

$$P_n = P_0(1+r)^n$$

$$80000 = 56000(1+0.2535)^n$$

$$\frac{10}{7} = (1.2535)^n$$

$$\log(10/7) = n(\log 1.2535)$$

$$n = 1.578 \text{ decades} = 15.78 \text{ years}.$$

(iv) Decreasing Rate of Growth Method.

Year	Population (10^5)	% r	decrease in % r
1970	50		
1980	60	20% = $\frac{60-50}{50}$	3.33%
1990	70	16.67%	16.67 − 14.28 = 2.36%
2000	80	14.28%	14.28 − 18.75 = −4.47
2010	95	18.75	
2020	?	18.75 − 0.416 = 18.334	
2030	?	18.33 − 0.416 = 17.918%	

avg of decrease in % r

$$= \frac{3.33 + 2.386 + (-4.47)}{3}$$

$$\boxed{= 0.416\%}$$

$$P_{2020} = P_{2010} + 18.334\% \, P_{2020}$$

$$= 95 + 18.334\% \text{ of } 95$$

$$= 112.41 \times 10^5$$

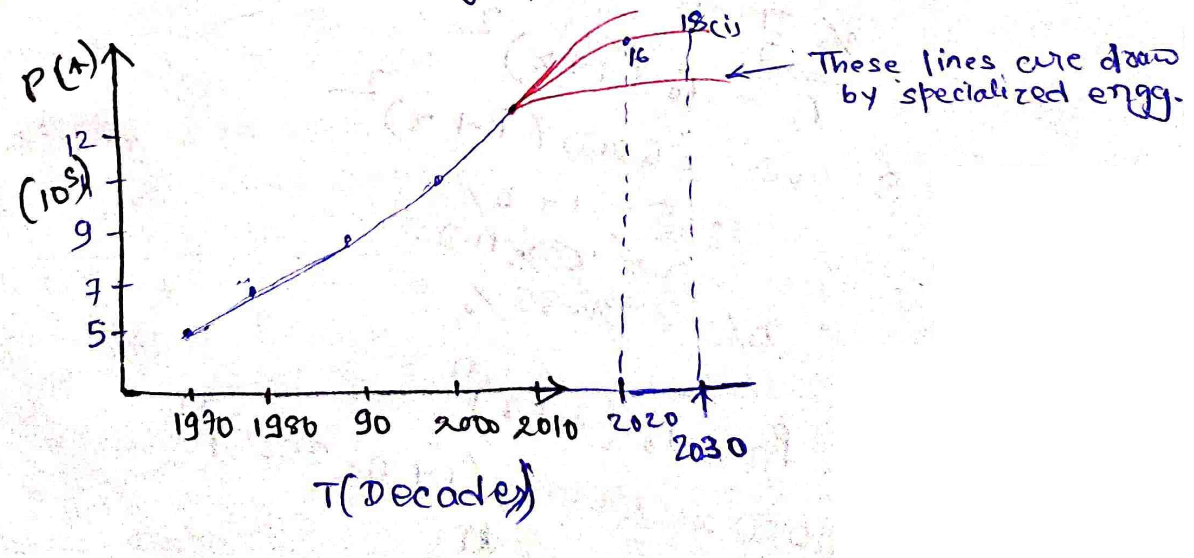
$$2030 = 112.41 + 17.918\% \text{ of } P_{2020}$$

$$= (112.41 + 17.9818\% \text{ of } 112.41) \times 10^5$$

$$= 132.62 \times 10^5.$$

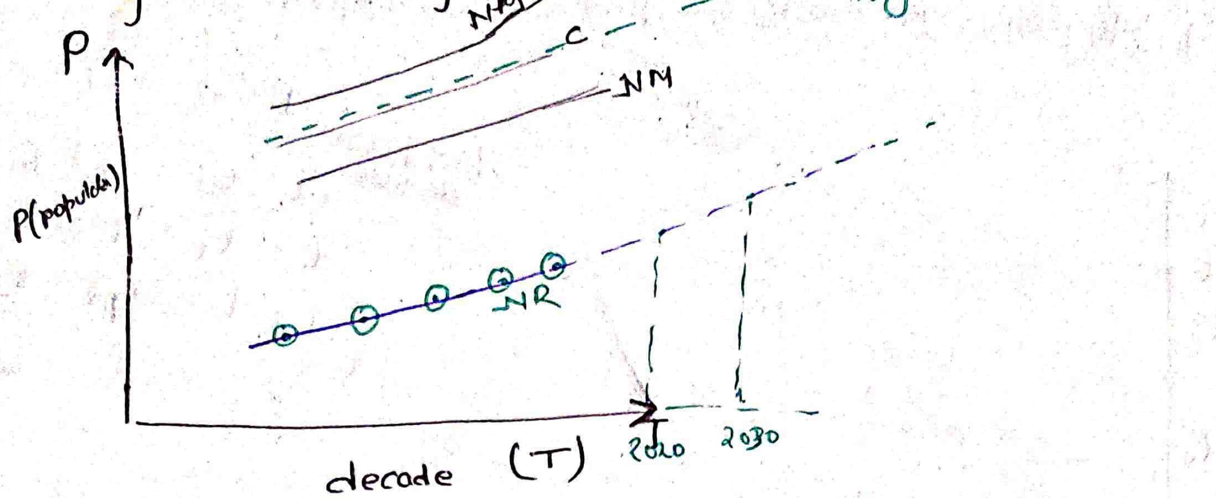
(v) Graphical Method.

In this, we ~~method~~ plot the grap of population for a community.



→ If past data is missing, this method is used.

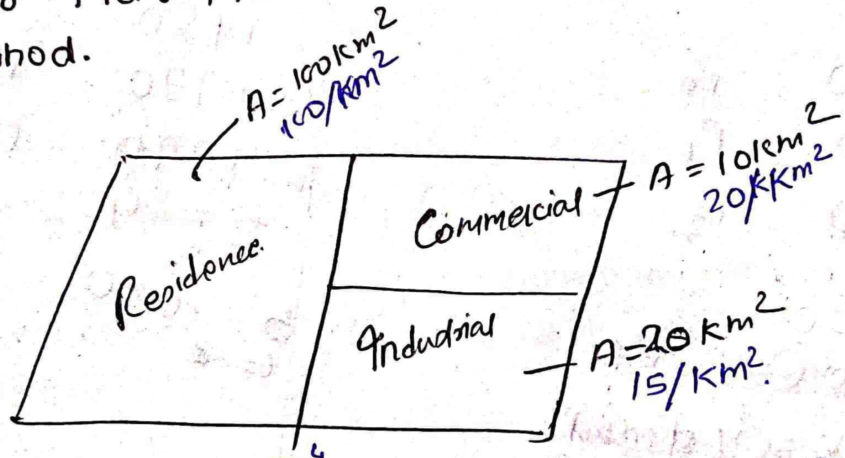
(vi) Comparative Graphical Method



* Comparative graphical method is more accurate as compare to Graphical method.

(vii) Master Plan Method.

→ Best method.



$P_R = 100 \times 100 = 10^4$

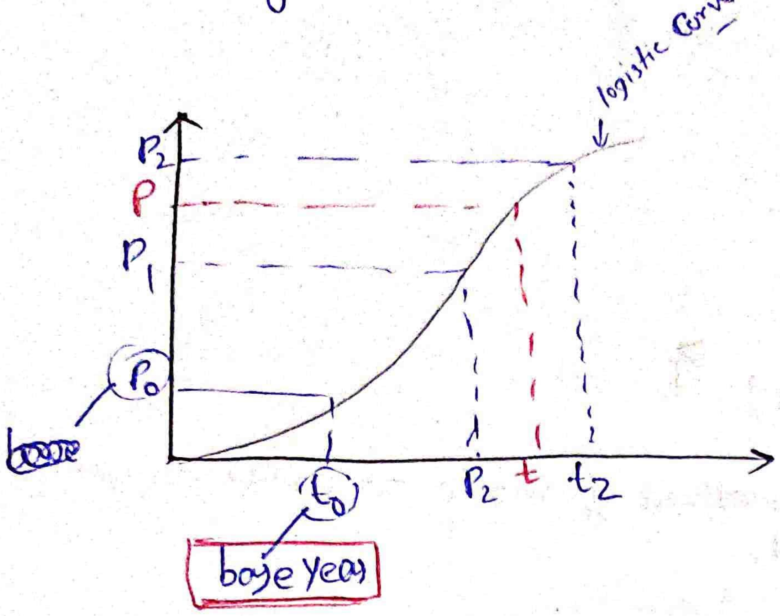
$P_C = 10 \times 20 = 200$

$P_I = 20 \times 15 = 300$

10500

(viii) Logistic Method.

→ In logistic method, we find eqn of logistic curve.



$P(x, y) \rightarrow (T, P)$

→ last known decade $t = t_0$ $P = P_0$

$t = t_1$ $P = P_1$

$t = t_2 = 2t_1$, $P = P_2$

eg.

1950	P_0
1970	P_1
2010	P_2

$t_0 = 1950$

$t_1 = 2$ decade

$t_2 = 6$ decade

t_2

19

	1950	P_0
$t_1 = 2$	1970	P_1
$t_2 = 4$	1990	P_2
	$t_2 = 2t_1$	
$t = 8$	2030	

$y = f(x)$

$y = f(t)$

Equation of logistic curve,

$$\ln\left(\frac{P_s - P}{P}\right) - \ln\left(\frac{P_s - P_0}{P_0}\right) = -K P_s t$$

P_s = saturation population

P_0 = base year population

P = Population at any time

K = constant depend upon P_0, P, P_s

$P_s, P, K = ?$

$t = t_1$

$$\ln\left(\frac{P_s - P_1}{P_1}\right) - \ln\left(\frac{P_s - P_0}{P_0}\right) = -k P_s t_1 \quad \text{—(ii)}$$

$$\ln\left(\frac{P_s - P_2}{P_2}\right) - \ln\left(\frac{P_s - P_0}{P_0}\right) = -k P_s t_2 \quad \text{—(iii)}$$

$$\boxed{\ln^{-1} = e}$$

or, $$P = \frac{P_s}{1 + m \ln^{-1}(nt)}$$

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

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

$$n = \frac{1}{t} \cdot \ln\left[\frac{P_0 (P_s - P_1)}{P_1 (P_s - P_0)}\right]$$

Q

Year	Population
1991	80000 : P_0 = 8
t_1 = 1 decade 2001	250000 = P_1 = 25
t_2 = 2 decade 2011	480000 = P_2 = 48
2031	

(i) P_s = ?
(ii) Eq^n of logistic curve.
(iii) Population 2031

$P_0 = 25000$ $\quad P_1 = 30000$ $\quad P_2 = 37000$
$t = 0$ $\quad t_1 = 10$ years $\quad t_2 = 20$ year.

P_s = saturation Population = $\dfrac{2P_0 P_1 P_2 - P_1^2 (P_0 + P_2)}{P_0 P_2 - P_1^2}$

$$= \frac{2 \times 8 \times 25 \times 48 - (25)^2 (8 + 48)}{8 \times 48 - (25)^2}$$

$= 655602$

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

(1) $$m = \frac{P_s - P_0}{P_0} = \frac{655602 - 80000}{80000} = 7.195$$

$$\Rightarrow n = \frac{1}{t} \ln\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$$

$$= \frac{1}{10} \ln\left[\frac{80000(655602 - 250000)}{25000(655602 - 80000)}\right]$$

Years

$$= -0.149 = \text{sir take } -1.49$$

$$\Rightarrow P = \frac{655602}{1 + 7.195 \ln^{-1}(-1.49 \times t)}$$

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

$t = 4$ decades

$$P = \frac{655602}{1 + 7.195 \ln^{-1}(-1.49 \times 4)}$$

$$P = \frac{655602}{1 + 7.195 e^{-5.96}}$$

$$P = 643654$$

$$\boxed{\begin{aligned} \ln^{-1} t &= x \\ t &= \ln x \\ x &= e^t \end{aligned}}$$

$$\boxed{\begin{aligned} &\ln^{-1}(-1.596) \\ &= e^{-5.96} \end{aligned}}$$