Course on

Wastewater Pumping Stations Design

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Lecture 2

Population Study

2-1 Population Estimation (forecast / projection)

1- Population project periods may range from 5 to 50 years depending on the particular component of the system that is being designed (e.g. distribution system, treatment plant, pumping stations, etc.)

2- Estimation of population depends on many factors such as:

a- Past census records.

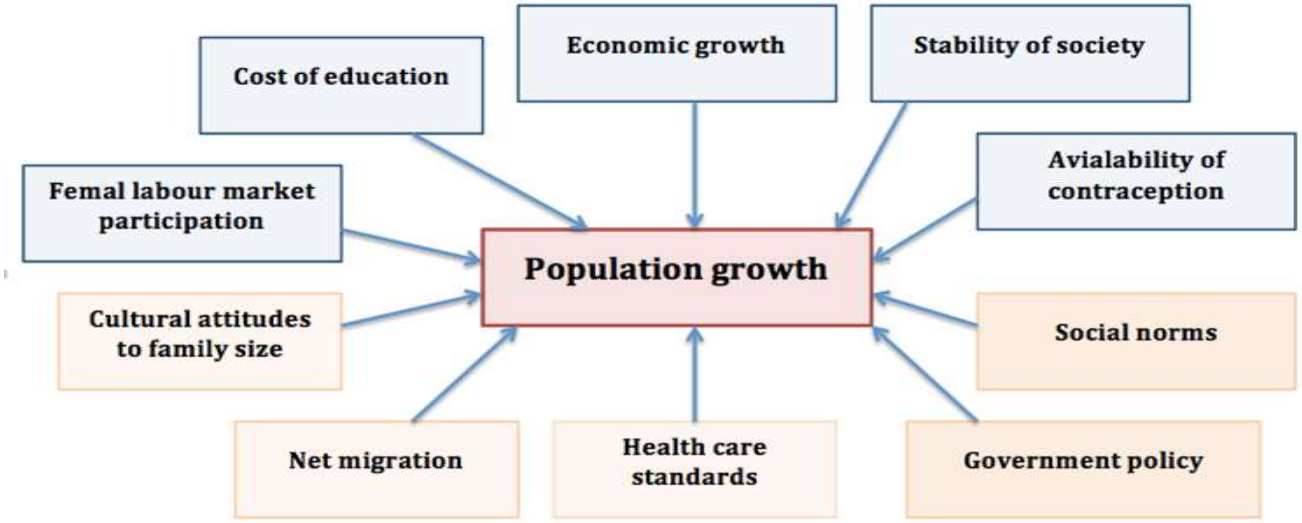
b- Economic conditions.

c- Future growth of the economical and industrial activities in the region

2-1 Population Estimation (Cont.)

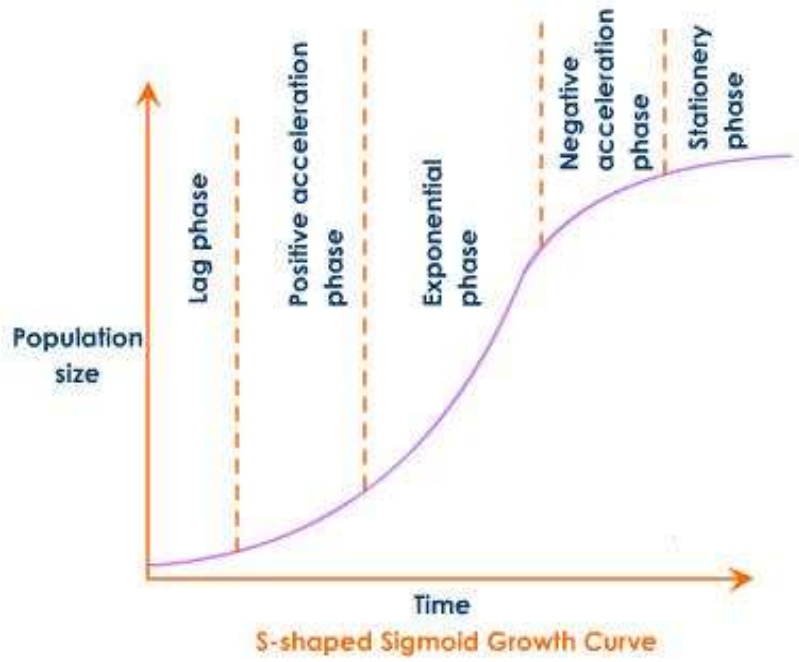
3- The rate of population growth can be expressed as a percent increase per year (e.g. 1.7% per year) (e.g. 17 people per year per 1000 population).

4- Factors affect rate of increase of population :



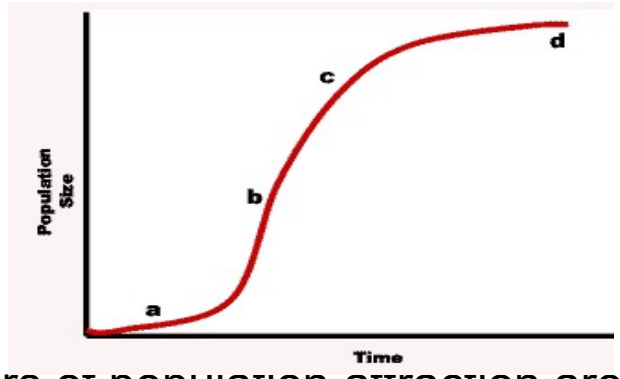
2-1 Population Estimation (Cont.)

- A typical S-Shaped population growth curve has five segments: a Log Phase, Acceleration Phase, Exponential Phase (increase phases), a Negative Acceleration Phase and a Stationary Phase (decreasing rate of increase).
- A Six Phase is newly established named decline/death Phase which has no growth at all, it has only a decrease of population. (as per many Europe Countries nowadays).



2-1 Population Estimation (Cont.)

A typical S-Shaped population growth curve **as per Egyptian Code** has Three segments: start and growth Phase, Stability Phase and a saturation Phase .



- a-b Phase is characterized by increasing population growth in the form of geometric increase.
- b-c Phase stage in which the factors of population attraction are stabilized, which necessitates the expansion of the population at a constant rate and the calculation of the growth rate according to the Arithmetic method.
- c-d Phase of reaching a decreasing in population growth.

2-2 Methods for Estimation the future Population:

A- Arithmetic Increase Method.

B- Incremental Increase Method (Modified Arithmetic Method).

C- Geometric Method (uniform percentage method).

D- Logistic Method (Decreasing Rate of Increase).

E- Graphical Extension Method.

F- Graphical Comparison Method.

G- Estimating the population assuming land use Densities.

2-2 Methods for Estimation the future Population:

A- Arithmetic Method

- Short term population prediction, 1-10 years
- The rate of population growth (dp/dt) is constant:
- $dp/dt = K_a$ = arithmetic constant = $1/n \{\Sigma(\Delta P/\Delta t)\}$
- $P_t = P_o + K_a t$

Where:

P_t : the population at some time in the future

P_o : the present population

t : the period of projection

K_a : the growth rate = $\Delta P/\Delta t$

n : no. of Interval

2-2 Methods for Estimation the future Population (Cont.):

A- Arithmetic Method Example

Based on the previous population record, estimate the population in the year 2020.

Year	1970	1980	1990	2000	2010
Population	70000	82000	95000	105000	115000

Solution

$K_a = 1/n \{\Sigma(\Delta P/\Delta t)\} = 1/4\{(82,000 - 70,000)/10 + (95,000 - 82,000)/10 +$

$(105,000 - 95,000)/10 + (115,000 - 105,000)/10\} = 1125$

Apply **Arithmetic Equation** $P_t = P_o + K_a t$

$P_{2020} = P_{2000} + K_a t = 115,000 + (1125 \times 10) = 126,250$ people

2-2 Methods for Estimation the future Population: (not in EGY. Code)

B- Incremental Increase Method (Modified Arithmetic Method).

- This method is modification of arithmetical method and it is suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method the increase in increment is considered for calculating 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.

- Population after n^{th} decade (interval) is

$$P_n = P + n.X + \{n\,(n+1)/2\}.Y$$

Where, P_n = Population after n^{th} decade

X = Average increase

Y = Incremental increase

2-2 Methods for Estimation the future Population (Cont.):

B- Incremental Increase Method Example.

Predict the population for the years 2021, 2031, and 2041 from the following population data using incremental increase method.

Year	1961	1971	1981	1991	2001	2011
Population	858545	1015672	1201553	1691538	2077820	2585862

- Solution

Population required is,

P_{2021} = 2585862 + (345463 x 1)
+ {(1 (1+1))/2} x 87729
= 3019054

P_{2031} = 2585862 + (345463 x 2)
+ {(2 (2+1)/2)} x 87729
= 3539975

P_{2041} = 2585862 + (345463 x 3)
+ {(3 (3+1)/2)} x 87729
= 4148625

Year	Population	Increase (X)	Incremental increase (Y)
1961	858545	--	--
1971	1015672	157127	--
1981	1201553	185881	+28754
1991	1691538	489985	+304104
2001	2077820	386282	-103703
2011	2585862	508042	+121760
	Total	1727317	350915
	Average	345463	87729

2-2 Methods for Estimation the future Population:

C- Geometric Method (uniform percentage method)

- In this method the percentage increase in population from decade to decade is assumed to remain constant. Geometric mean increase is used to find out the future increment in population.
- Short term population prediction, 1-10 years
- The rate of population growth (dp/dt) is proportional to population (exponential growth)

$$dp/dt \propto P$$

$$dp/dt = K_g P$$

Integrating both sides yields:

$$\ln P_t = \ln P_o + K_g \Delta t \qquad K_g = (\ln (P2 / P1))/\Delta t$$

$$P_t = P_o e^{Kg \Delta t}$$

2-2 Methods for Estimation the future Population (Cont.):

C- Geometric Method Example

Based on the population record, estimate the population in the year 2020.

Year	1970	1980	1990	2000	2010
Population	70000	82000	95000	105000	115000

Solution

K_g (1970:1980) = (ln (82/70)) / 10 = 0.0158

K_g (1980:1990) = (ln (95/82)) / 10 = 0.0147

K_g (1990:2000) = (ln (105/95)) / 10 = 0.0100

K_g (2000:2010) = (ln (115/105)) /10 = 0.0091

Average K_g = 0.0124

Apply **Geometric Method Equation** $P_t = P_o\, e^{Kg\,\Delta t}$

$P_{2020} = 115{,}000\, e^{(0.0124 \times 10)} = 130{,}182$ people

2-2 Methods for Estimation the future Population:

D- Logistic Method (Decreasing Rate of Increase)

- Long term population prediction, 10-50 years
- It is assumed that the population growth curve has an S shape and the city has a saturation that will not be exceeded (limiting population)
- From the available population record, we choose three values, two near the two ends of the record (P_o and P_2) and one in the middle of the record (P_1)

$$P = P_{sat} / [1 + e^{\gamma + b \Delta t}]$$

$$P_{sat} = [2 P_o P_1 P_2 – P_1^2 (P_o + P_2)] / (P_o P_2 – P_1^2)$$

$$\gamma = \ln [(P_{sat} - P_2) / P_2]$$

$$b = [1/n] \ln [P_o (P_{sat} – P_1)/ P_1 (P_{sat} – P_o)]$$

Where

n = the time interval between succeeding censuses (e.g. 10, 20 years)

$\Delta t = t - t_o$ Short term population prediction, 1-10 years

2-2 Methods for Estimation the future Population (Cont.):

D- Logistic Method Example

Estimate the population in 2020, If the population record of a city is:

Year	1970	1990	2010
Population	30,000	90,000	250,000

Solution

$\Delta t = t - to = 2020 - 1970 = 50$ years

$n = 20$ years = interval bet. two record.

$P_o = 30000$ & $P_1 = 90000$ & $P_2 = 250000$

$P_{sat} = [2 P_o P_1 P_2 – P_1^2 (P_o + P_2)] / (P_o P_2 – P_1^2) = 1530000$

$\gamma = \ln [(P_{sat} - P_2) / P_2] = 1.633$

$b = [1/n] \ln [P_o (P_{sat} – P_1) / P_1 (P_{sat} – P_o)] = - 0.057$

Apply **Logistic Method Equation**

$P_{2020} = P_{sat} / [1 + e^{\gamma + b \Delta t}]$

$P_{2020} = 1180449 \approx 1181000$ people

2-2 Methods for Estimation the future Population:

E- Graphical Extension Method.

In this method, the populations of last few decades are correctly plotted to a suitable scale on graph (Figure D.1). The population curve is smoothly extended for getting future population. This extension should be done carefully and it requires proper experience and judgment.

The best way of applying this method is to extend the curve by comparing with population curve of some other similar cities having the similar growth condition.

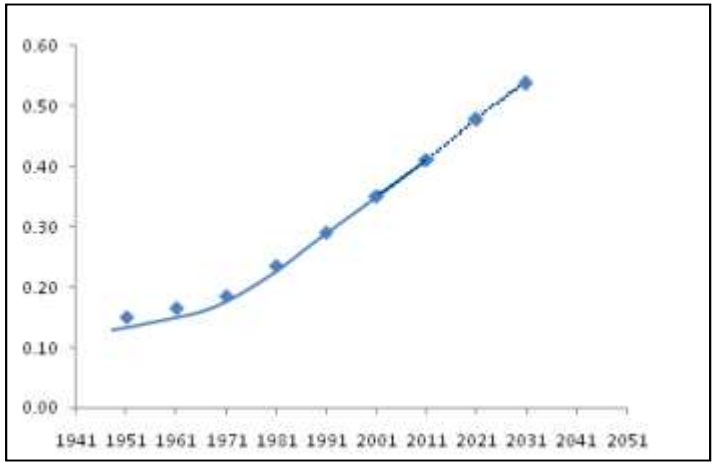


Figure D.1 Graphical method of population forecasting

2-2 Methods for Estimation the future Population:

F- Graphical Comparison Method.

In this method the census populations of cities already developed under similar conditions are plotted. The curve of past population of the city under consideration is plotted on the same graph. The curve is extended carefully by comparing with the population curve of some similar cities having the similar condition of growth.

The advantage of this method is that the future population can be predicted from the present population even in the absence of some of the past census report.

2-2 Methods for Estimation the future Population:

F- Graphical Comparison Method Example.

The populations of a new city X given for decades 1970, 1980, 1990 and 2000 were 32,000; 38,000; 43,000 and 50,000, respectively. The cities A, B, C and D were developed in similar conditions as that of city X. **It is required to estimate the population of the city X in the years 2010 and 2020**. The population of cities A, B, C and D of different decades were given below:

(i) City A: 50,000; 62,000; 72,000 and 87,000 in 1960, 1972, 1980 and 1990, respectively.

(ii) (ii) City B: 50,000; 58,000; 69,000 and 76,000 in 1962, 1970, 1981 and 1988, respectively.

(iii) (iii) City C: 50,000; 56,500; 64,000 and 70,000 in 1964, 1970, 1980 and 1988, respectively.

2-2 Methods for Estimation the future Population:

F- Graphical Comparison Method Example.(Cont.)

Solution: Population curves for the cities A, B, C, D and X are plotted (Figure E.1). Then an average mean curve is also plotted by dotted line as shown in the figure. The population curve X is extended beyond 50,000 matching with the dotted mean curve.

From the curve, the populations obtained for city X are 58,000 and 68,000 in year 2010 and 2020.

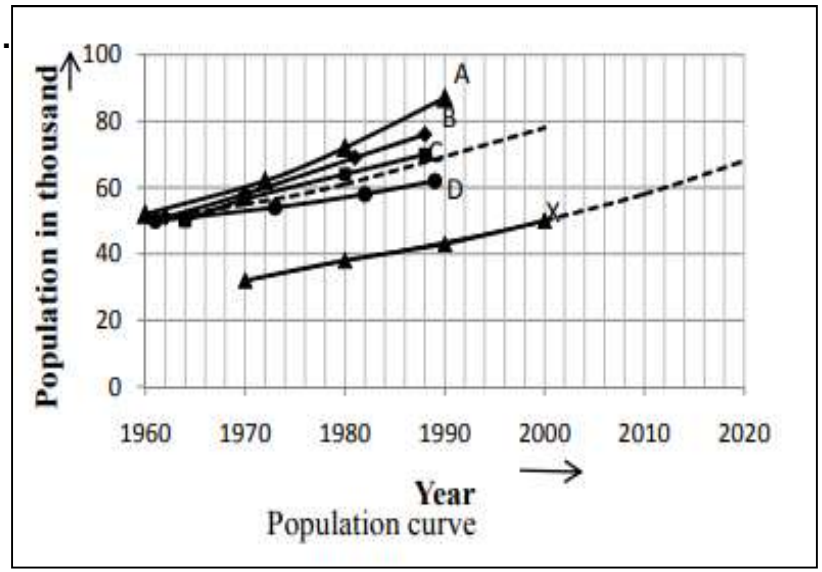


Figure E.1

2-3 Methods for Estimation the future Population:

G- Estimating the Population assuming Land Use densities.

- Population density describes the physical distribution of population (people/ hectare or Km).
- Population densities may be estimated from data collected on already developed areas or from zoning master plans for undeveloped areas.
- The following table presents the range of population densities found in areas of different **Land Use** . (as per Egyptian Code 101 page 9)

Land Use classification	Population density (capita/hectare)
First class villas	20 : 50
Second class villas	50 : 100
Small residential buildings	100 : 250
Middle residential buildings	250 : 700
Large residential buildings	700 : 1200 (or more)
Commercial areas	50 : 75
Industrial areas	20 : 30

2-3 Methods for Estimation the future Population:

G- Estimating the Population assuming Land Use densities Example.

Estimate the expected average water consumption rate (Lpcd) for the area shown below. Data on the expected saturation population densities and water demands are also given. (1 hectare = 10000 m^2 = 2,47 acre)

Land use	Area (ha)	Population density	consumption rate
Industrial Area	30		30,000 L/he.d
Mosque	2	2000 c	50 Lpcd
High rise Buildings	50	350 c/ha	450 Lpcd
Hospital	10 (200 beds)	(200 beds) 400 employees	700 Lpd/bed 300 Lpd/employee
School	5	1500 students	200 Lpcd
Commercial Area	120	75 people/ha	30,000 L/he.d
Park and Playground	15		15,000 L/he.d
University	60	10,000 students	200 Lpcd
Single-family Villa	200	50 person/ha	450 Lpcd

2-3 Methods for Estimation the future Population:

G- Estimating the Population assuming Land Use densities Example.

Solution: from attached table: Average water consumption

= 19026 / 34850

= 0.546 m^3/c.d

= 546 Lpcd.

Land use	Area (ha)	Population	Cons. (Lphe.d)	Cons. (Lpcd)	Total cons. (m^3/d)
Industrial Area	30	-	30000	-	900
Mosque	2	2000	-	50	100
High rise Buildings	50	350x50=1750	-	450	7875
Hospital	10	200 beds 400 employee	-	700 300	140 120
School	5	1500	-	200	300
Commercial Area	120	75x120=9,000	30000	-	3600
Park and Playground	15	-	15000	-	225
University	60	10000	-	200	2000
Single-family Villa	200	50x200=10,000		400	4000
Total		34850			19026

Population Study Questions:

Questions 1.

The population data for a town is given below. Find out the population in the year 2021, 2031 and 2041 by (a) arithmetical (b) geometric (c) Logistic Method.

Year	1971	1981	1991	2001	2011
Population	84000	115000	160000	205000	250000

Questions 2.

In three consecutive decades the population of a town is 40000; 100000 and 130000. Determine: (a) Saturation population; (b) Expected population in next decade using logistic method.

Questions 1&2 Solutions to be submit and discuss below the same post.

To get your own Three Pumping station Design Excel Sheet

You are invited to fill your own Solution on Excel Sheet after each Lecture

	No.	**Items**	**PS 1**	**PS 2**	**PS 3**	
Population Study	**1**	**Population at year 1997**	**10000**	**30000**	**120000**	**Capita**
	2	**Population at year 2007**	**15000**	**40000**	**160000**	**Capita**
	3	**Population at year 2017**	**18000**	**48000**	**210000**	**Capita**
	4	**Method of Calculation**	**Arithmatic**	**Geometric**	**Logistic**	
	4	**Population at year 2027**	**?**	**?**	**?**	
	5	**Population at year 2037**	**?**	**?**	**?**	

Please fill required places.

Next

Lecture - 03

Water and Wastewater

Consumption.

Thank You