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Population Projection for Rajshahi City Corporation: A Comparative Analysis among the Projection Methods for Physical Development Plan

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Abstract

In rapid urbanization era, Physical development plan (commonly used as Master Plan) is considered as all sorts of development guidelines for any urban area. Knowledge about current population and proper assumptions about future population are the base of almost all planning decisions. Population projection have a key role in the preliminary stages of preparing a plan, a proposal as to how land should be used as expansion and renewal proceed in the future. Considering this vast importance of proper population projection, the purpose of the study was to project and compare different population projection methods. Rajshahi City Corporation (RCC) was considered as a case study area and the study was conducted on the basis of secondary data from Bangladesh Bureau of Statistics (BBS). Mathematical trend extrapolation and the cohort-component model were applied for projection. For Analysis and projections, the study considered base population of RCC area 4,49,756 and growth rate 1.25 at 2011 (BBS, 2011) and using the base year population made a projection of the study area population at five yearly intervals up to 2041. After applying different projection methods for the year up to 2041, the study found enormous difference of projected population among the projection methods. In recommendation, one should be more careful to choose proper and suitable projection method in preparation of physical development plan as most of the development proposals depend on future population.

Keywords: Population projection, Urban planning, Physical development plan, Mathematical trend extrapolation, Cohort-component model

AMS Classification: 91D20, 65B05, 62P25, 62J02, 65D10.

1. Introduction

Bangladesh is undoubtedly a densely populated country in comparison to other lower-developed countries in the world. Rapid population growth is an important contributor to poverty, inequality, and lagging development, but it may be considered as a resource. Proper policies and strategies towards future population may help to divert this population into assets. National physical development plan for urban area should prepare in focusing our growth rate and projected future population.

Population Projection deals with the following three questions:

(a) How people are distributed among and within developed and underdeveloped areas?

(b) How their numbers and proportions change?

(c) What political, social and economic causes bring changes in the distribution of population?

Population projection gives a picture of what the future population may look like, based on knowledge of the past and taking, for the future, hypotheses based on fertility, mortality and migrations. The following factors are sincerely considered in population projections.

Birth rate and death rate are the crucial factors that impact the size and shape of the population. In addition to these, factors like marriage rate, belief regarding social status and marriage, age of marriage, early marriage and its effects on the health of the mother and the child, child infanticide rate, and maternal death etc. also affect the population.

Fertility rate (FR) is the number of children who would be born per woman (or per 1,000 women) according to a current schedule of age-specific fertility rates. FR is a more direct measure of the level of fertility than the crude birth rate, since it refers to births per woman. This indicator shows the potential for population change in the country.

Survival rates are widely used in population projection techniques. Survival rates are resultant from census data, and are used to calculate the number of people that will be alive in the future. In Bangladesh, planners can obtain survival rates from a Bangladesh bureau statistics (BBS) office of Department of public health and engineering (DPHE) office.

Urbanization is another factor in the distribution of population within the urban and rural area. The focus in population studies is on factors responsible for urbanization, the problems associated with urbanization and the solutions there to.

Human migration is the movement of people from Rural to urban area with the intentions of settling, permanently or temporarily. Migration and movement are a part of human life. which is causes for a variety of reasons, called push and pull factors. Some common push and pull factors into jobs, war, family, and money. Below is an overview of the different types of human migration.

2. Previous Studies

Planning activity is not fulfilling its proper function unless plan are developed within a context of a continuum of needs extending from the present to the foreseeable future. Knowledge about past populations and assumptions about future populations are fundamental to planning decisions in every aspect of community life (Krueckeberg and Silvers 1974, 259). Analysis and projection of population are at the base of almost all major planning decisions. (Hightower 1968, 51).

Population forecasts have a central role in the initial stages of preparing the land use plan, a proposal as to how land should be used as expansion and renewal proceed in the future" (Chapin 1965, vi). How much land should be devoted to residential, commercial, recreational, and educational purposes, among others, is estimated by combining forecasts of future population with ratios of space needs per capita. The latter typically are based on either current practice, recent trends, or standards promulgated by professional groups or governmental agencies.

Most of the physical development plan of the major cities of Bangladesh (Dhaka, Chattogram, Khulna, and Rajshahi) have been used exponential growth rate and cohort model in population projection. Exponential growth rate model considers only natural growth rate which is changeable with the time. Sometimes experts are assumed future growth rate to run this method. Growth rate is normally fluctuating randomly, as an example, the growth rate of RCC area of 2001 and 2011 are 1.94 and 1.25 respectively (BBS, 2011). So, it will be not wise to project future population with considering only one variable. The cohort component model depends on several variables like fertility rate, mortality rate, survival rate, and migration etc. In Rajshahi Metropolitan Development Plan (RMDP, 2004-2024), Experts Assumed high, medium, and low Cohort component model for RMDP area (RMDP 2004-2024).

Both types of projections also exclude net migration into the project area, which is regarded as a policy-induced variable. This has been done to avoid the uncertainty associated with the number and the age distribution of the net migrants. Micro level (Ward/union wise), migration data is unavailable in Bangladesh. Migration can be incorporated in several ways, but the most common entails use of a net migration rate that summarizes the net effects of in migration and outmigration as a proportion of the surviving females.

Thus, the basic objective of this paper is to project and compare different population projection methods and using the base year population, make a projection of the study area population at five yearly intervals up to 2041 on the basis of plausible assumptions. The study area consists of the Rajshahi City Corporation Area.

3. Methodology of Projection

The Three methods in use today are mathematical trend extrapolation (Linear growth, Exponential growth, and Geometric growth), the cohort-component model, and demographic-economic models. Each of the methods have some limitations. In this study, we described first two methods briefly.

3.1 Basis of Population Projection

According to Population and Housing Census 2011, the total population of Rajshahi City Corporation (RCC) is 449756 of which 232974 are males and 216782 are females. The sex ratio of the RCC is 107. The compound growth rate of RCC area of 2001 and 2011 are 1.94 and 1.25 respectively (BBS, 2011).

3.2 Mathematical trend extrapolation Method

The first type of projections would be simpler and based on the natural growth rates of the two components. The growth rates of both components would be assumed to be declining over the period of projection, however, the rate of decline would be assumed to be somewhat slower for the rural component.

This method is the search for an equation that describes population change over time. The only data necessary are population levels for a number of years, say the census counts from 2001 to 2011. The analytical question, then, is which form of equation fits the data well. Among the candidates are straight lines, exponential curves, second-degree polynomials, and more esoteric forms including the modified exponential and the logistic curve. Implicit in each is a statement of the nature of population change.

3.2.1 Computational steps

A. If there is a constant amount of increase per unit of time, a straight line is used to project population growth. It is expressed as $P_t = P_0 + bt$
where, P_0 = Initial population

P_t = Population t years later

b = Annual amount of population change

B. If the growth assumes a geometric series, it is expressed as $P_t = P_0 (1+ r)^t$
where, P_0 = Initial population

P_t = Population t years later

C. If Growth is constant, but compounding is continuous, it is expressed as $P_t = P_0(e^{rt})$
where, P_0 = Initial population,

P_t = Population t years later

r = Annual rate of growth,

e = Base of the natural logarithm

Table 1: Population projection based on natural growth rate

Method	2011	2016	2021	2026	2031	2036	2041
Individual Growth Rate	449756	483323	519395	558159	599816	644582	692689
National Growth Rate (1.37)	449756	481420	515313	551593	590427	631994	676488
District Growth Rate (1.25)	449756	478577	509246	541879	576604	613554	652872
Average Growth Rate of RCC Area (1.45)	449756	483323	519395	558159	599816	644582	692689

Source: BBS, 2011 and compiled by Authors

3.3 Cohort-component model

The second type of projections would be based on cohort component method and would be made separately for the male and female populations and then combined to provide estimates for the broad five-year groups. The second type of projections are based on parameters selected from the UN Model Life tables (1982) for the Developing Countries. The demographic transition now continuing throughout the nation is likely to be completed by the projection period so that the assumption of declining birth rates in both types of projections appear plausible.

The cohort-component model is an accounting framework used to trace the effects of future birth, death, and migration rates on population size. The population of an area is divided into groups, or cohorts, on the basis of age, sex, and possibly race or other additional characteristics.

The model itself is nothing more than a set of calculations based on the premise that it makes sense to divide the population into groups because birth, death, and migration rates are known to vary with age, sex, and other characteristics. Other than the notion of disaggregation, the model contains no theories regarding the determination of the birth, death, and migration rates. Its merit is "not that it discloses the secret of what the future holds, but rather that it displays the mechanics of the projection in such a way as to make more evident exactly what **is** being assumed" (Duncan 1969, 93).

- **Data required**

a. Initial (base) population by age and sex
b. Assumptions on mortality - survival ratios by age and sex
c. Assumptions on Age-Specific Fertility Rates (ASFRs)
d. Net migration population

- **Computational steps:**

a. Project forward the base population in each age group in order to estimate the number still alive at the beginning of the next interval
b. Compute the number of births for each age group over the time interval, and compute the number who survive to the beginning of the next interval
c. Add migrants and subtract emigrants in each age group or compute the number of births to these migrants during the interval, and project forward the number of migrants and number of births that will survive to the beginning of the next interval

$$\text{Population}_{t+n} = \text{Population}_{t-1} + \text{Births} - \text{Deaths} + \text{Net migrants}$$

$$\text{Net migrants} = (\text{Population}_{t+n} - \text{Population}) - (\text{Births-Deaths})$$

Where, Population_{t+n} = Current Population

Population_{t} = The last census, 2011

- **Population aged 5 years and over:**

a. Obtain the survivors at the end of each projection interval (except for the open age group) by multiplying the survival ratio to the number of persons at the beginning of the interval, remembering to move the result one row down. In life table terms, nLx specifies the mid-year pop. between age x and x+n. Therefore, the survival ratio, the proportion of persons surviving from age x to x+n, is given by xLx+5/xLx (& Tx+5/Tx for the open age group)
b. The number of survivors in the open age group is obtained by adding the survivors from the preceding age group to the survivors of the open age group

- **Population below age 5:**

a. The pop. below age 5 at the end of the 5-year projection interval consists of children born during the interval.
b. To obtain this pop., it is first necessary to compute the number of births by sex occurring during this interval and then apply survival ratios to this pop.
c. The number of births is calculated from the ASFRs, the number of women in the childbearing ages and the sex ratio at birth.
d. The female population exposed to this fertility schedule in each age group is the mean of the initial pop. & the projected pop. since both groups contribute births to the age group 0-4
e. Total births = $n/2\sum(fP + fP')*ASFR$, where fP and fP' are initial and projected female populations respectively.
f. Male births = Total births * SRB/(100 + SRB), where SRB = Sex ratio at birth
g. Female births = Total births * 100/(100 + SRB)
h. 5P'o = Births * survival ratio (i.e. 5Lo/5lo)

Table 2: Cohort component model

Age	nLx	nPx	nPx+5
0-4	5Lo	5Po	B* 5Lo/5lo
5-9	5L5	5P5	5Po * 5L5/5Lo
10-14	5L10	5P10	5P5 * 5L10/5L5
15-19	5L15	5P15	5P10 * 5L15/5L10
……..	……..	……..	……..
……..	……..	……..	……..
x - x+5	5Lx	5Px	5Px-5 * 5Lx/5Lx-5

3.3.1 Results of the Cohort Projection

Like projection based on natural growth rates, cohort component projections are also giving projections by five-year age groups. Projections are made first for the male and female populations separately and then combined to obtain the projected study area populations. The projected populations are also aggregated to obtain population of working age (15-64 years of age) and the projected demographic burdens (population of 0-14 and 60+ years of age). Summary results of the projections based on cohort-component method are provided below.

Table 3: Reclassified Age Group Wise Population Distribution of RCC Area

Age	Calculation		Total	Reclassified	Graphed	Gender			
	Pop^n 2011	(%)		Population	Population	Male	%	Female	%
0-4	449756	6.8	30583	30583	30583	15842	51.8	14741	48.2
5-9	449756	8.0	35980	35980	35980	18638	51.8	17343	48.2
10-14	449756	9.9	44526	44526	44526	23064	51.8	21461	48.2
15-19	449756	12.2	54870	54870	54870	28423	51.8	26447	48.2
20-24	449756	13.3	59818	59818	59818	30986	51.8	28832	48.2
25-29	449756	10.2	45875	45875	45875	23763	51.8	22112	48.2
30-34	449756			30246	42000	21756	51.8	20244	48.2
35-39	449756	26.9	120984	30246	33984	17604	51.8	16380	48.2
40-44	449756			30246	26000	13468	51.8	12532	48.2
45-49	449756			30246	19000	9842	51.8	9158	48.2
50-54	449756	6.7	30134	15067	16000	8288	51.8	7712	48.2
55-59	449756			15067	14134	7321	51.8	6813	48.2
60-64	449756	2.4	10794	10794	10794	5591	51.8	5203	48.2
65+	449756	3.6	16191	16191	16191	8387	51.8	7804	48.2
		100.0	**449756**	**449756**	**449756**	**232974**		**216782**	

Source: BBS, 2011 and compiled by Authors

Resistant Smoothing method is used to reclassify the age group-wise population. Smoothing is useful for discovering and summarizing both data trends and outliers. Resistant Smooth offers two smoothing methods: 4253H, twice and 3RSSH, twice (P.F. Velleman (1980). Irregular fluctuations can be removed from time series by smoothing. The MINITAB EDA function resistant smooth is a very easy-to-use, highly recommended technique that can be applied to a wide range of time series using Resistant smooth in EDA. By default, resistant smooth automatically sets the degree of smoothing and deals with any aberrant or outlying points.

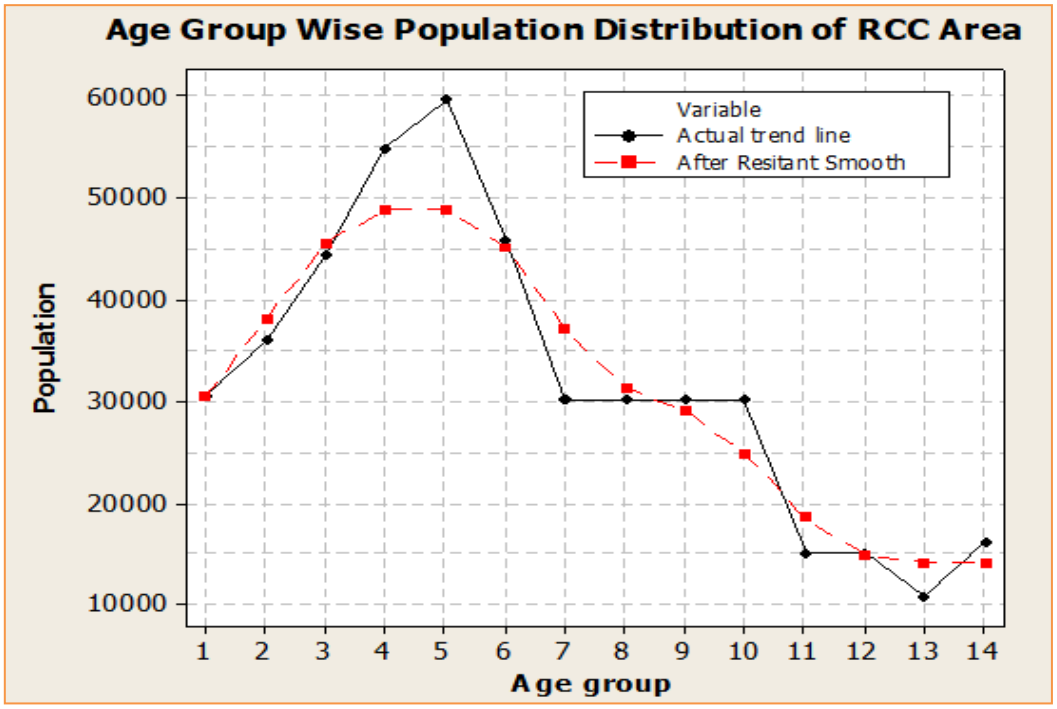

Figure-1: Reclassified age group-wise population using resistant smoothing method on Minitab software

Source: BBS, 2011 and compiled by Authors

Table 4: Calculation of Survival Birth Population

Age cohort	Male, 2011	Female, 2011	Fertility Rate	F2011 *ASFR	Live Birth (0-5)	Survival Rate	Survival	Male	Female
0-4	15842	14741							
5-9	18638	17343							
10-14	23064	21461							
15-19	28423	26447	46	12166	12166	0.946	11509	5962	5547
20-24	30986	28832	139	40076	40076	0.942	37752	19556	18196
25-29	23763	22112	112	24765	24765	0.935	23155	11995	11161
30-34	21756	20244	70	14171	14171	0.928	13150	6812	6339
35-39	17604	16380	34	5569	5569	0.920	5124	2654	2470
40-44	13468	12532	13	1629	1629	0.909	1481	767	714
45-49	9842	9158	5	458	458	0.899	412	213	198
50-54	8288	7712							
55-59	7321	6813							
60-64	5591	5203							
65+	8387	7804							
Total	**232974**	**216782**				**0.926**	**92583**	**47958**	**44625**

Source: BBS, 2011 and compiled by Authors

Table 5: Calculation of Projected Population for the Year 2016

Age group wise survival population (2011-2015)			Projected population for 2016	
Age cohort	**Male**	**Female**	**Male, 2016**	**Female, 2016**
Survival Birth	47958	44625		
0-4	14663	13644	47958	44625
5-9	17251	16052	14663	13644
10-14	21348	19864	17251	16052
15-19	26307	24479	21348	19864
20-24	28679	26686	26307	24479
25-29	21995	20466	28679	26686
30-34	20137	18737	21995	20466
35-39	16294	15161	20137	18737
40-44	12466	11599	16294	15161
45-49	9109	8476	12466	11599
50-54	7671	7138	9109	8476
55-59	6777	6306	7671	7138
60-64	5175	4816	6777	6306
65+	7763	7223	5175	4816
Total	215634	200647	255829	238049

Source: BBS, 2011 and projected by Authors

Table 6: Age Group Wise Population of RCC Area Based on Cohort Projection

Age cohort	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**
0-4	30583	92583	94324	88227	76816	79322	111561
5-9	35980	28307	91256	92972	86962	75715	78185
10-14	44526	33303	27901	89948	91639	85715	74630
15-19	54870	41212	32825	27501	88658	90326	84487
20-24	59818	50786	40621	32355	27107	87387	89031
25-29	45875	55365	50058	40039	31891	26719	86135
30-34	42000	42461	54572	49341	39465	31434	26336
35-39	33984	38874	41852	53789	48633	38899	30983
40-44	26000	31455	38317	41252	53018	47936	38341
45-49	19000	24065	31004	37767	40661	52258	47249
50-54	16000	17586	23720	30559	37226	40078	51509
55-59	14134	14809	17334	23380	30121	36692	39503
60-64	10794	13082	14597	17085	23045	29689	36166
65+	16191	9991	12894	14388	16840	22714	29264
Total	449756	493878	571275	638603	692083	744885	823379

Source: BBS, 2011 and projected by Authors

Table 7: Projected Active Labour Force and Dependency Ratio in RCC Area

Age group → Year	**0-14**	**15-60**	**60+**	**Total**	**Dependency Ratio (%)**
2011	111090	311681	26985	449756	44.30
2016	154193	316613	23073	493878	55.99
2021	213482	330302	27491	571275	72.96
2026	271147	335983	31473	638603	90.07
2031	255417	396781	39885	692083	74.42
2036	240752	451729	52404	744885	64.90
2041	264375	493574	65430	823379	66.82

Source: BBS, 2011 and projected by Authors

4. Comparison of the Results of the Projections

Results of the two types of projections of the RCC population are compared in the following table:

Table 8: Comparison of the Results of the Projections

Method	2011	2016	2021	2026	2031	2036	2041
Cohort Method	449756	493878	571275	638603	692083	744885	823379
Growth rate Method							
Individual Growth Rate	449756	483323	519395	558159	599816	644582	692689
National Growth Rate (1.37)	449756	481420	515313	551593	590427	631994	676488
District Growth Rate (1.25)	449756	478577	509246	541879	576604	613554	652872
Average Growth Rate of RCC Area (1.45)	449756	483323	519395	558159	599816	644582	692689

Among these projection result, there are vast difference between natural growth rate method and cohort component model. Although there is little distortion if we consider national, district and ward-level growth rate. Growth rate is normally fluctuating randomly due to rapid urbanization, so we should only consider natural growth rate to project future population.

5. Impact on physical development plan

In physical development plan, we estimate urban services according to the projected population. So, it is very crucial to estimate future population carefully and professionally. Below table shows the required facilities for our design year both in natural growth rate method and cohort component model.

Table 9: Comparison of Projected Social Services for 2041

SL. No	Type of Services	Planning Standard	Existing Number in RCC area, 2011	Required number for 2041	
				Growth rate method	Cohort method
A	**Population**	Gross: 200/acre Net: 220/acre	449756	692689	823379
B	**Urban Services**				
1	Katcha Bazar	One for 5,000 pop.	39	139	165
2	Fire Station	One for 20,000 pop.	3	35	41
3	Post Office	One for 20,000 pop.	19	35	41
4	Mosque	One for 2,000 pop.	340	346	412
5	Stadium/Playground	One for 20,000 pop.	8	35	41
C	**Education Facilities**				
6	Primary School	One for 4,000 pop.	61	174	206
7	Secondary School	One for 6,000 pop.	46	116	137
8	College	One for 30,000 pop.	31	24	27
D	**Health Facilities**				
9	Hospital	One for 20,000 pop.	34	35	41
10	Health Center/Community Clinic	One for 20,000 pop.	44	35	41
11	Hospital Bed	354 persons per bed	540	1957	2326

Source, BBS, 2011 and projected by Authors

6. Conclusion

The paper discusses the demographic setting of the RCC Area in the context of the long-term urbanization process of the country to provide a logical framework for the projection of the population of the study area. Standard demographic techniques were applied to develop plausible long-term projections of the study area population.

This study will be helpful for demographers, planners and researchers to precisely project their study area population. Population projection help us to know the urbanization pattern, development trend, trend of socio-demographic change, and future needs of particular area. We try to explain the importance of proper projection of population in preparing a plan like physical development plan. As all the plans, policies and proposals prepared by assessing future need and demand of common people, so we should give more emphasize on proper projection methods

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