SIMULATION STUDIES OF POPULATION GROWTH WITH DIFFERENT CONTROL MEASURES

A DISSERTATION
submitted in partial fulfilment of the
requirements for the award of the Degree
of
MASTER OF ENGINEERING
in
ELECTRICAL ENGINEERING
(System Engineering & Operations Research)

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CERTIFICATE

Certified that the dissertation entitled "Simulation Studies of Population Growth with Different Control Measures" which is being submitted by Mr. Peeyush Kumar, in partial fulfilment for the award of degree of Master Of Engineering in System Engineering & Operational Research of the University of Roorkee is a record of student's own work carried out by him under my guidance and supervision. The matter presented in this dissertation has not been submitted for the award of any other degree or diploma.

This is further to certify that he has worked for a period of about eight months from January to August 1984 for preparing this dissertation at this University.

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ROORKEE (PEEYUSH KUMAR)

ABSTRACT

In developing countries population growth is causing a lot of undesirable problems. During recent years long term population policy has become the matter of great interest due to population explosion. This work is an attempt to simulate the effect of various control efforts on population growth in Indian context. The study is done by considering arbitrary uniform reduction in birth rate, increase in minimum age of marriage & family planning efforts. The results show that minimum age of marriage effects the population growth in initial part of the time herizen while family planning efforts effect the population in later years. Population study upto year 2041 in a interval size of 5 years has been considered & the population levels by considering above various efforts have been simulated. In this work only female population have been considered by assuming it as 48% of the total population. The input data have been taken from the Prelim Census estimate of India 1981.

CONTENTS

CHAPTER - 1

INTRODUCTION

The rapid growth of population in developing countries is hampering economic development, causes unemployment and other problems. The population explosion is an off shoot of poverty and has to be tackled as part of the over all design for a better life. To reach the demographic goals and to integrate family planning, with the overall strategy of socio-economic development, a number of programmes have to be initiated. There has been an adequate recognition of the interaction between population and development in programmes relating to limiting the rate of population growth, but experience has exploded the fallacy that development will take care of the growing numbers. Socio-economic progress may contribute for adoption of the small family norm by couples. But if there is a strong in-built linkage between fertility control measures and economic development processes, the battle against growing numbers will be won sooner than expected (8).

Socio-economic programmes relating to literacy improvement involvement of women in work, enhancing the status of women in society are considered important in the context of a long term policy of reduction in fertility. To the extent that improvement in socio-economic sector influence fertility behaviour, the need for integrating family welfare programmes with other development programmes must be recognised while family planning is more appropriately a programme of family welfare, the later has two essential phases. The first is the action programme in the family planning and the second would be the continuing efforts to integrate family planning and welfare programmes in associated sectors of development.

During recent years long term population policy has become the matter of great interest due to population explosion. In India during last few decades the birth rate has decreased However, there has also been a considerable reduction in mortality rate due to better health care system. Thus the resultant population growth rate has not significantly reduced. Population beyond certain level (termed as a bearing capacity of land) creates many undersirable problems like depleting economy, unemployment and other related social difficulties (4).

In this context population planning becomes very important to acheive the target of desirable population size (a population size which can be borne by land). If the population level is higher than the desirable one, then the first problem is to acheive the target of zero population growth and then the desirable size (4).

The urban areas have by now become conscious about the need for small families but in rural areas a large family is still considered as asset . (8). The extinction of population is an interesting topic in study of population modelling. In deterministic models, if the net growth rate is always non-negative then the population number can never reach zero. If the growth rate is dependent on population level then the population can either become extinct or not depending on the initial population number and is predictable (12).

A variety of stochastic models for population changes have been developed (9). Since stochastic models incorporate uncer uncertainty into the for mulation, the time forextinction is a random variable. Thus the time for extinction needs to be obtained in a probabilistic sense, this makes the study of population extinction in stochastic models a more difficult problem. However, these models are complex and in the context of Indian population, which has been studied in the present thesis, deterministic models have been utilized.

Statement of Problem: To simulate the effect of various control efforts on population growth and demographic (age) distribution for India.

In this work Chap.2 deals with the study of modelling and simulation, Model development and computer simulation of dynqmic models are also discussedin this Chapter. In Chap. 3 discrete population models in time and age has been described. Population policy for a closed population with specific example of India, is considered as a control problem. In this problem, age-specific fertility is a control variable. Different ways of controlling fertility have been described under the choice of fertility control. In Chap. 4, simulation results have been reported for different types of fertility control. In Chap. 5 thesis work has been concluded with some suggestions.

CHAPTER - 2

MODELLING & SIMULATION

2.1 Philosophy of Modelling

Modelling plays an important role in understanding the dynamics of the system. Once a satisfactory model for a given system is developed, the properties and behaviour of the system can be studied. Modelling is a part of the overall research programme to gain deeper understanding of the system. Modelling cannot provide new knowledge about the system, but can serve to integrate the available knowledge of the system (5).

A 'model' is defined as the body of information about a system gathered for the purpose of studying the system. Since the purpose of the study will determine the nature of information that is gathered, there is no unique model of a system. Different models for the same system will be produced by different analysts interested in different aspects of the system (15).

Models are valuable to the extent that they raise new questions, suggests new relationship and lead to the new experiments that might not otherwise have been considered. In most of the cases models predict new relevant properties of the system. Models also suggest constraints existing in the system being modelled. Thus the model computes, extrapolates and predicts the new facts which accelerates the process of learning about the actual system.

2.2 Types of Models

Models used in system studies have been classified in many ways. The classification that would be used in this work, is shown in Fig. 1. Models will first be separated into physical models and mathematical models (5).

Physical models are based on some analogy between such systems as electrical and hydraulic. The system activities are reflected in the physical laws that drive the model. Mathematical models use symbolic notations and mathematical equations to represent a system. The system activities are represented by mathematical functions.

The selection of a particular type of model depends upon the easiness, simplicity required the accuracy needed, the purpose of study, the data available and such other factors (15). In the context of current study, the choice is restricted to a mathematical model. In fact a mathematical model which can be simulated on a computer.

A 'good computer model' is one which satisfies three criteria to be useful, in education and research.

1. It must agree structurally with the actual system but must be modest in size.
2. Its parameter must be measurable or estimable.
3. It must fit computer simulation capabilities.

Obtaining the model parameters values is a difficult task. Parameters may be estimated by performing experiments or

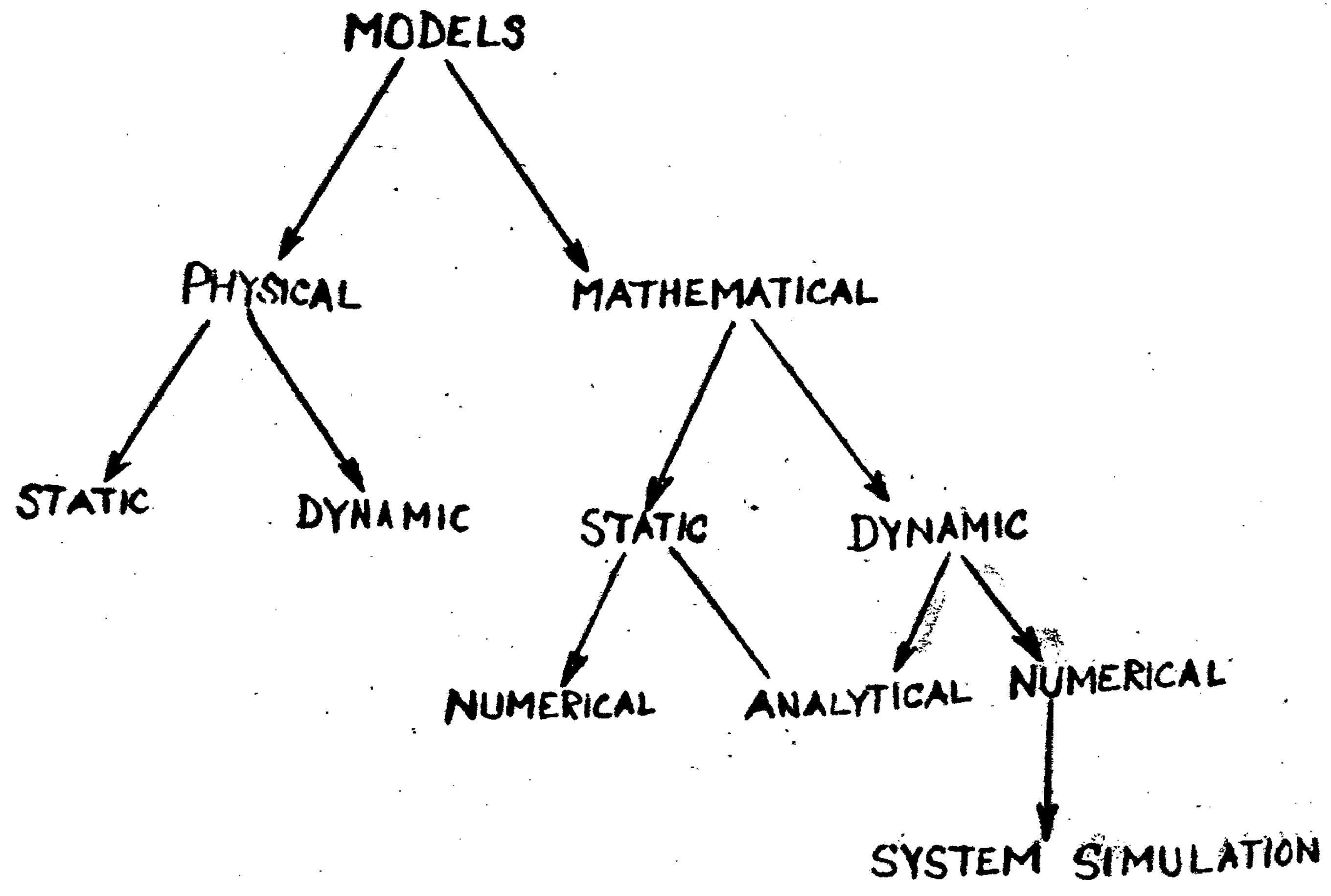

FIG 1. TYPES OF MODELS

by using computational techniques to optimize values.

2.3 Utility of Models

For an engineer the introduction of model provides a link between discriptive and experimental data. The existence of a mathematical model provides a mean for rapid experimentation and understanding of the system functions which may not be possible otherwise. For those involved in research work a mathematical model provides a method of summarizing what is known about a system and communicating the information to others.

One of the advantages of model concept is that it can be used as an aid in system studies that involve the interaction between components of the system. A perfect model can be built only if everything about the real system is known. Hence a systematic combination of the gross aspects and then more subtle properties of the system is necessary. This implies that a model can not be developed by analysis along. The process must consists of both the analysis and experimental work, each supplementary to each other. By examing the difference between the postulated model and real system, the understood portion of the real system is, in effect, subtracted out and attention then can be focused on more subtle properties of the system. Thus the models are used to provide a technique to gain more insight and understanding of system functions.

2.4 Simulation

Simulation is one of the most powerful analysis tools available to those responsible for the design and operation of complex systems. It allows the user to experiment with systems where it would be impossible otherwise. We define simulation as the technique of solving problems by the observation of the performance of a dynamic model of the system.

Simulation is heavily based upon computer science, mathematics & statistics. Like all powerful tools which depend heavily upon art in their application, Simulation is capable of giving either very good or very bad results, depending upon how it is used. It is therefore necessary that the decision maker should be aware of the implications of certain assumptions made (15).

In substance, every model or representation of a thing is a form of simulation. Therefore, simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behaviour of the system or of evaluating various strategies for the operation of the system (15). Thus the process of simulation includes both the construction of model and the analytical use of the model for studying a problem.

Simulation modelling is an experimental and applied methodology which seeks to:

1. Describe the behaviour of systems

2. Construct theories or hypotheses that account for the observed behaviour.

3. Use these theories to predict future behaviour i.e. the effect that will be produced by changes in the system or in its method of operation.

Unlike most technologies, which can be classified according to the discipline in which they have their roots, simulation is applicable in all discipline, Simulation received its original impetus from the aerospace programmes, but even a casual survey of the literature indicates the broad field of present applications. For example simulation is used in business, economics, marketing, education, social science, transportation and many others.

All simulation are so-called input-output models (4). Therefore, simulation models are 'run' rather than 'solved' in order to obtain the desired information or results. They are incapable of generating a solution on their own in the sense of analytical models, they can only serve as a tool for the analysis of the behaviour of the system under conditions specified. Thus simulation is not a theory but a methodology of problem solving. Furthermore, simulation is only one of the several valuable problem solving approaches available to the system analyst. Simulation is used when one or more of the following conditions exists.

(a) Analytical methods are available but the mathematical procedure ~~are~~ is so complex that simulation provides a simpler method of solution.

(b) A complete mathematical formulation of the problem does not exist or analytical methods to solve the model is not yet been developed.

(c) It is desired to observe a simulated history of the process over a period of in addition to estimate certain parameters.

The main drawback of simulation is that it gives specific solutions rather than general solutions. It may be more time consuming and more costly to obtain the same sample size. Many simulation runs have to be made to understand the relationships involved in the system, so the use of simulation in a study must be planned as a series of experiment.

The idea of simulation is appealing to system analyst because of its simplicity. Therefore one tends to adopt the simulation approach to almost every problem one encounters. Despite its lack of mathematical sophistication and elegance, simulation is one of the most widely used quantitative techniques employed in management problem solving.

<u>Computer Simulation of Dynamic Model (5)</u>

Simulation is a very general method of studying problems. Some of the steps involved in the progress of a simulation study are illustrated by flow-chart shown in Fig. 2.

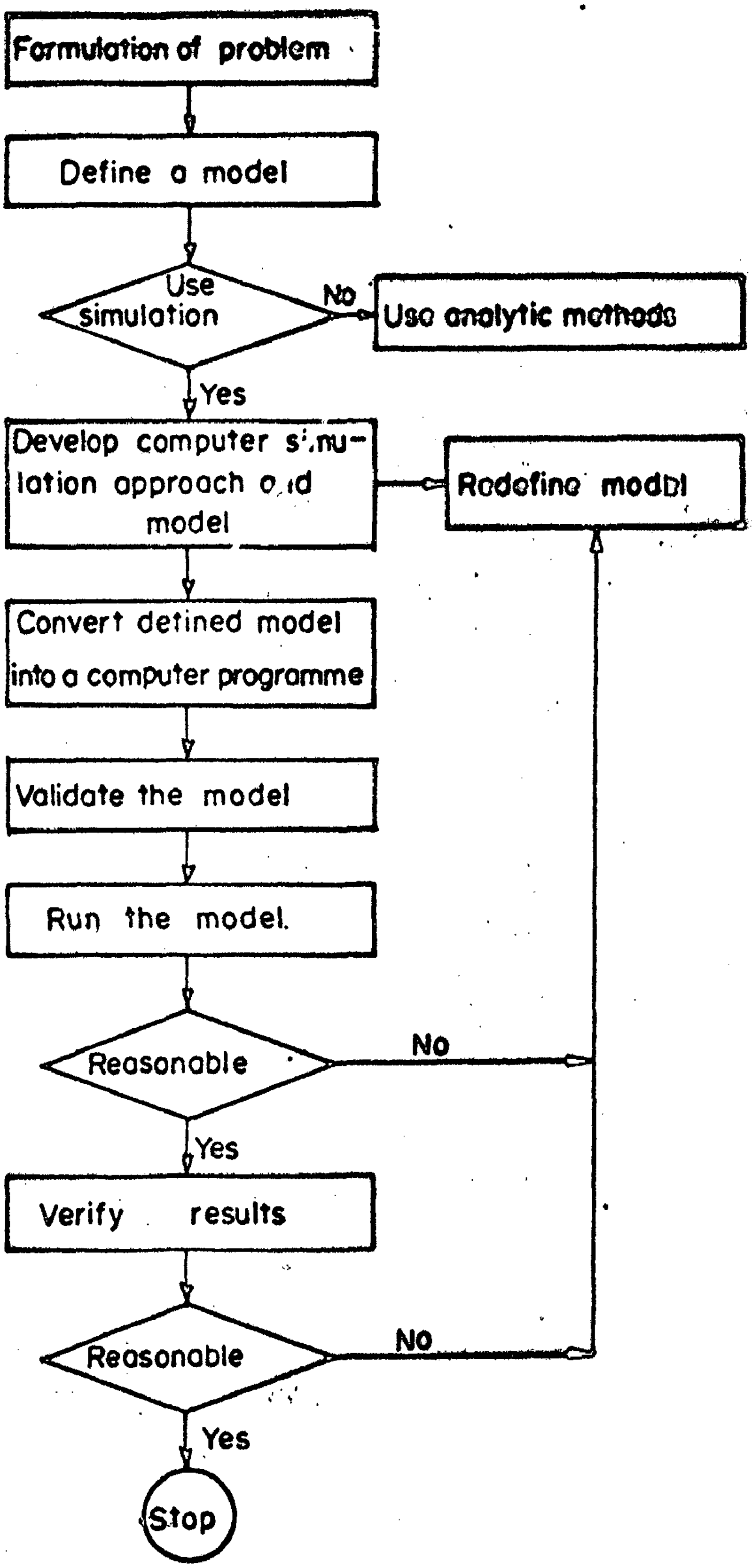

FIG.2 [ADAPTED FROM (5)]
SIMULATION STUDY

Initial step is to describe problem which is tobe solved. Based on the problem definition, a model must be defined when it is decided to simulate, the experimental nature of the simulation technique makes it essential to plan the study by deciding upon the major parameters to be varied, the number of laws to be conducted, and the order in which runs are to be made.

Given that a simulation is to be on a digital computer, a programme must be written. The validity of model must be established before begining the major set of runs. This is an important step which requires good judgement.

The study then moves into the stage of executing a series of runs according to the study plan the study is not likely to proceed in the orderly steps implied by flow chart. As results are obtained, it is quite likely that there will be many changes in the model and the study plan. In the construction of a model certain parameters of the system are clearly going to be important. There may also be some parameters where importance is not so clear. The early runs may make their significance clear and so lead to a reassessment of the model.

In simulation more data and understanding of the problem are gained, the validity of using simulation should be re-evaluated. As large computers and large sample sizes are so often involved, the cost of simulation is nearly always high compared with solving a analytical model.

CHAPTER - 3

DEMOGRAPHIC MODELS

Having discussed the topics of modelling & simulation in general in previous chapter, this chapter is devoted to study of demographic model, specially selected for study of population dynamics in Indian context.

3.1 Demographic Model

To analyze the population characteristics for a certain span of time a discrete time age model has been developed on following facts and assumptions.

1. It has been assumed that population system is a closed system i.e. no person is migrate to other countries and no foreigner is allowed to remain in India as its citizen.

2. If the whole populationis devided into different age groups say as 0-5, 5-9 etc. (0-4 means children who have not completed 5 years & so on), then it is obvious that after a given span of 5 years, the population of any particular age group will be the population of its previous age group minus deaths in that group.

3. In first age group i.e. 0-4 years, the population will be the children born during last 5 years. The population of this group will depend on survival of children, female population in different age groups and their fertility.

4. Mortality rates had decreased considerably in earlier decades after independence. However, in recent years these have become some what constant. While, it is expected that there would be further reduction in mortality rates in future also, specially in infant mortality ratio, it is difficult to estimate the values of mortality coefficients in different years. So the mortality coefficients which are mentioned in the census 1981 has been assumed to remain constant throughout the duration of our study.

5. Only female population is being considered in the model.

As the data available for population study are in a aroup of 5 years. So it is not possible to study the population pattern by a continuous model to simulate the population pattern discrete model is more appropriate. In this work a discrete time model is used to simulate the pattern.

The basic demographic model (3) in discrete time age horizon can be described as

$$P(i+1,\ j+1) = P(i,\ j) - \mu(i\ j)\ P(i\ j) \qquad (3.1)$$

Where,

$P(i,j)$ = No. of persons in the age group $(i - 1)$ to its at the instant to $+jh$.

Where,

$i = 1, 2, 3 \ldots\ldots$

$j = 0, 1, 2 \ldots\ldots$

$\mu(i, j)$ = Mortality co-efficient, death perunit of person of age i, at the time interval j, in the interval $(i - 1)h$ to ih during h years.

For simplicity we assume that mortality coefficients do not depend on time j.

$$\mu(i\ j) = \mu(i)$$

The eqn 3.1 has an initial condition

as $P(1, j+1) = U(j)$ (3.2)

for j = 0, 1, 2 ....

Here $U(j)$ is the number of persons born during the period to +jh to + (j+1)h and surviving up to the end of this period. The number of children born and surviving during interval h, is given by.

$$(j) = \sum_{i=1}^{N} s.\delta . h. m.(i,j)\ P_f(i,j) \qquad (3.3)$$

Where

$P_f\ (i,j)$ is the female population of age i during time interval j.

m(i, j) is fertility of a woman of age i and at time interval j.

S = survival ratio during to +jh to to + (j+1)h

δ = female or male population to total birth.

A computer programme to calculate population of different age groups for popul next years has been developed on the basis of flow diagramme shown is fig. 3.

Population model was simulated for different methods of fertility control. For starting time instant, the data were taken from Prelim census estimates of India 1981. The distribution of population by age-group, percentage of married, divorced, widowed of separated population and fertility pattern were necessary input data for simulation. Distribution of popln population by age group is shown in table 1. In this

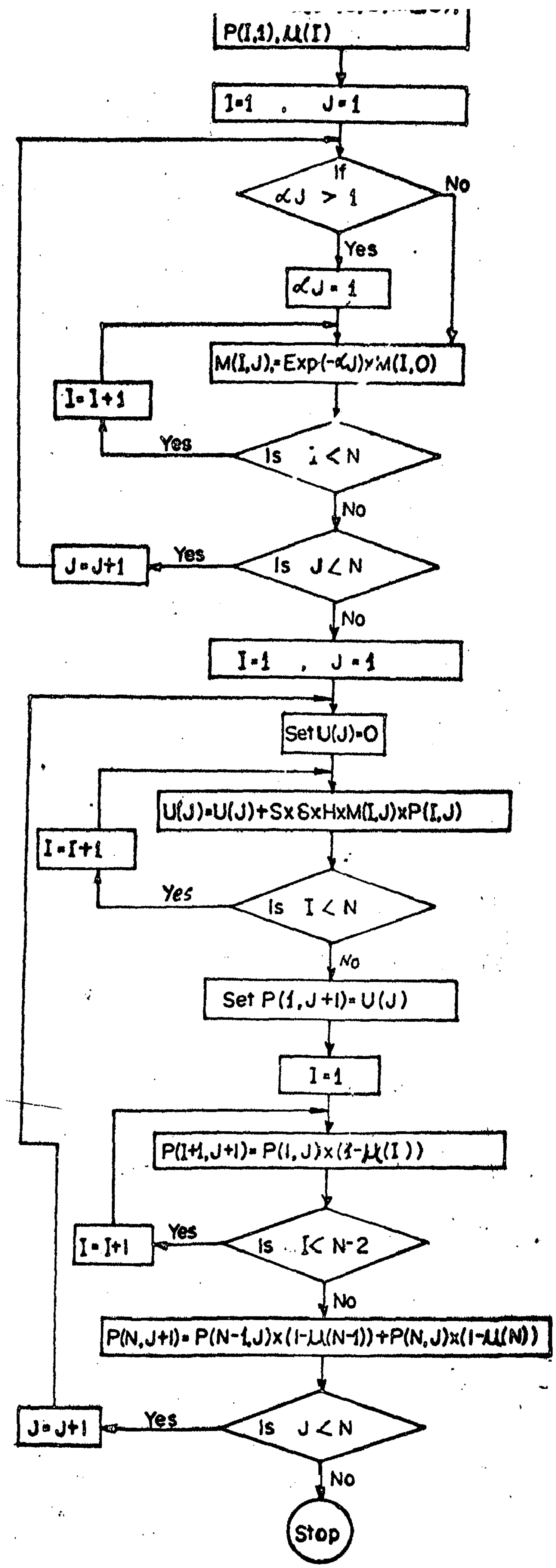

FIG.3 FLOW CHART

Table - 1

CENSUS DATA 1981

Distribution of Population by Age Groups

AGE GROUP	POPULATION (in thousands)
0-4	83,751*
5-9	93,839
10-14	85,675
15-19	64,087
20-24	57,308
25-29	50,747
30-34	42,442*
35-39	38,895
40-44	34,212
45-49	29,250
50-54	25,440
55-59	16,441
60+	43,172

*Data suspect.

table the population from 0-4 is suspected because it is tess than the population of age group 5-9, also there is a sharp decline in population level after 10-14 years age group, which seems to be incorrect. This pattern does not match with the previous censuses.

It's reason may be that the children who have not attained the age of 5 years but are older than 4 years not have been included in the 0-4 years age group. If the population of this group is increased by a suitable amount the pattern would be in conformity with previous data of expected values.

In table 2 approximate female population in different age groups is mentioned. These data are derived from table 1 by considering female population as 48% of the total population. In this work only female population has been taken into account instead of whole population. This is not unreasonable as only error on this account would be because of a slightly different male to female ratios in different fertile age groups for which average value have been used, based on over-all population.

Age specific mortality is tabulated in table 3. Mortality co-efficients of only female population are mentioned. These coefficients are taken from Indian statistical department and are assumed to remain constant for coming years. Census data for percentage of married, widowed or separated women are tabulated in table 4. The percentage of unmarried women in

Approximate Female Population Distribution (Derived from Table 1)

AGE GROUP	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49
POPULATION (in thousands)	40200	45134	41006	30866	27622	24460	20457	18747	16490	14098

AGE GROUP	50-54	55-59	60+
POPULATION (in thousands)	12262	7891	20808

Table - 3

Age Specific Mortality 1981

AGE GROUP	FEMALE POPULATION
0-4	0.0222800
5-9	0.0020000
10-14	0.0008500
15-19	0.0012200
20-24	0.0017500
25-29	0.0017500
30-34	0.0021200
35-39	0.0024400
40-44	0.0024400
45-49	0.0034600
50-54	0.0058100
55-59	0.0071200
60+	0.0260000

Mortality coefficients are taken from Indian Statistical Department.

Table - 4

(Census Data 1981)

(Percentage of Married, Widowed and divorced Females Population)

Age Group	Married	Widowed	Divorced	Unmarried
15-19	43.47	0.21	0.42	55.9
20-24	86.44	0.69	0.82	12.05
25-29	94.33	1.50	0.88	3.29
30-34	94.81	3.12	0.87	1.2
35-39	93.17	5.42	0.77	0.64
40-44	87.81	10.86	0.78	0.55

Table - 5

Fertility Rate (1981 Census)

AGE GROUP	15-19	20-24	25-29	30-34	35-39	40-44	45-49
BIRTH/ 1000 women	34	192	256	208	162	90	56

different age groups has been derived from these available data. Smooth curves are shown in fig. 4 for ever married and married excluding widowed and divorced women.

3.2 Choice of Fertility Control

The important factor which effects the population growth is the fertility pattern. Fertility pattern describes the age specific fertility of women. To check the population in coming years, it is necessary to control the fertility by different control efforts. Following different fertility controls have been considered for five years age group.

(i) Exponential Decay: In this model fertility decays from an initial value at a rate proportional to the current values. The change in level of pattern may be expressed by (3.4).

$$m\,(j,\ j) = e^{-\alpha j}\, m\,(i,\ 0) \qquad (3.4)$$

Here we will assume the pattern of fertility will not vary with time but the level may be increased or decreased as a whole. In above relationship m(i,j) is the fertility of age group i at time interval j and m(i,0) is initial fertility of that group, α is arbitrary control factor. The characteristics of the model is that the level m(i,0) is divided by a constant factor for a given interval of time. Since e is approx. 2.72 the level is reduced by a factor 0.37. Each successive interval of time reduces the level by the same factor, so there is nothing significant about the value e, but comparing

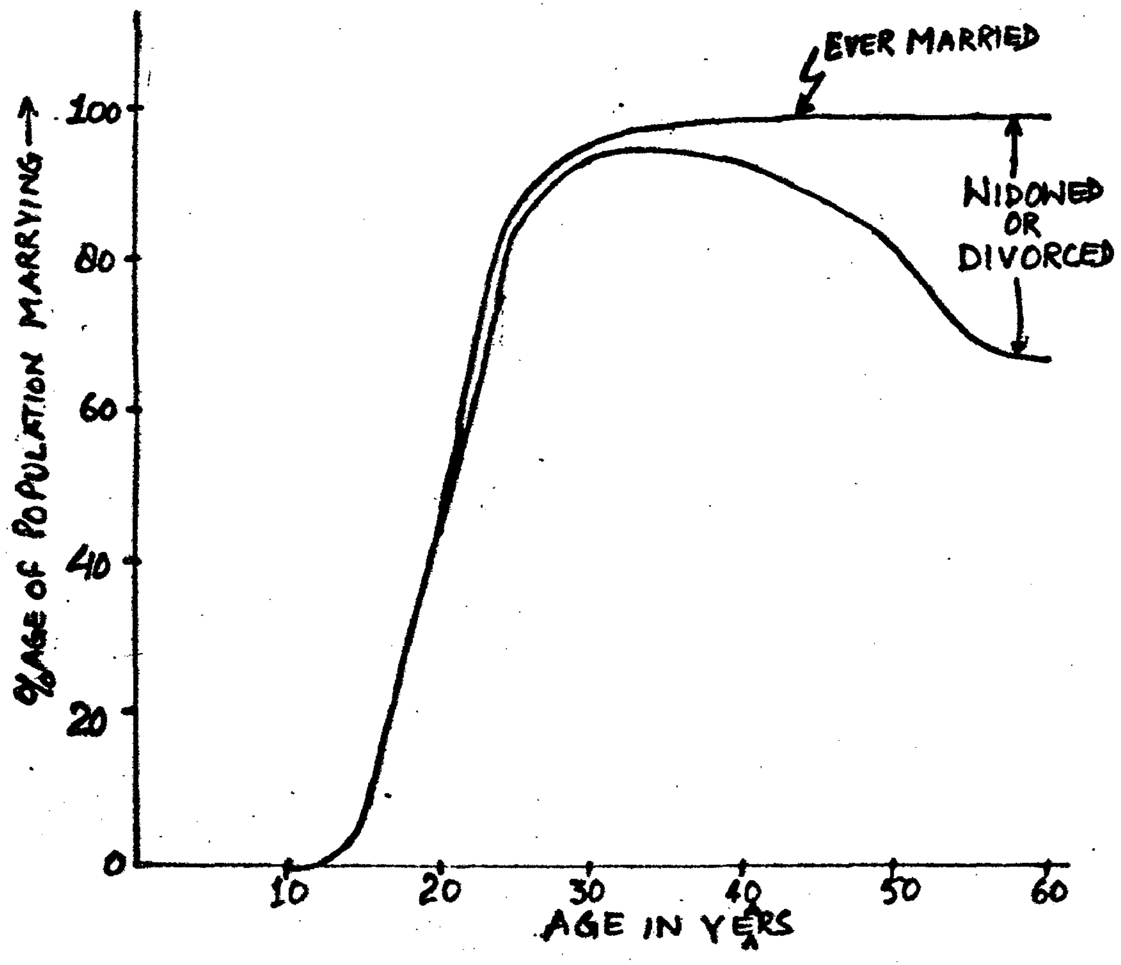
EVER MARRIED
WIDOWED OR DIVORCED
%AGE OF POPULATION MARRYING
100
80
60
40
20
0
10
20
30
40
50
60
AGE IN YEARS

FIG. 4

values of j for different models measures the relative times they will take to decay by a given fraction. As the value of α goes on increasing the value of m (i,j) will decrease fastly in future time interval.

In practice a lower bond on fertility levels will also have to be used. Further the rate of decrease cannot exceed an upper limit which depends on the efforts as well as the social norms. The maximum rate of decay of fertility should be chosen properly with lower minimum bounds on fertility to obtain results of practical use.

Table - 5 deals with the fertility pattern in different age groups. These data have been taken from census of Indian-1981. This pattern is represented by a histogram in fig. 5. Based on the age fertility, Marital fertility has been derived in table 6 for different age groups.

(ii) Minimum Age of Marriage: The minimum age of marriage plays an important role in fertility control specially in the initial fertile age group. If the minimum age of marriage is increased, the fertility in that age group will certainly be decreased. To find out the effect of minimum age of marriage on fertility the model (4) [illegible] is used. The expression for age specific marriage rate as proposed by M.C.Nail (3) is

$$g(a) = \frac{C}{K} e^{-0.\frac{174}{K}(a-a_0-6.06K) - 0.\frac{288}{K}(a-a_0-6.06K)} \quad (3.5)$$

This relation gives rate of marriage in different age group. In this relation a_0 is the minimum age of marriage, a is the age at which marriage takes place, K is the moment at which marriage takes place, e & c is proportionality constant.

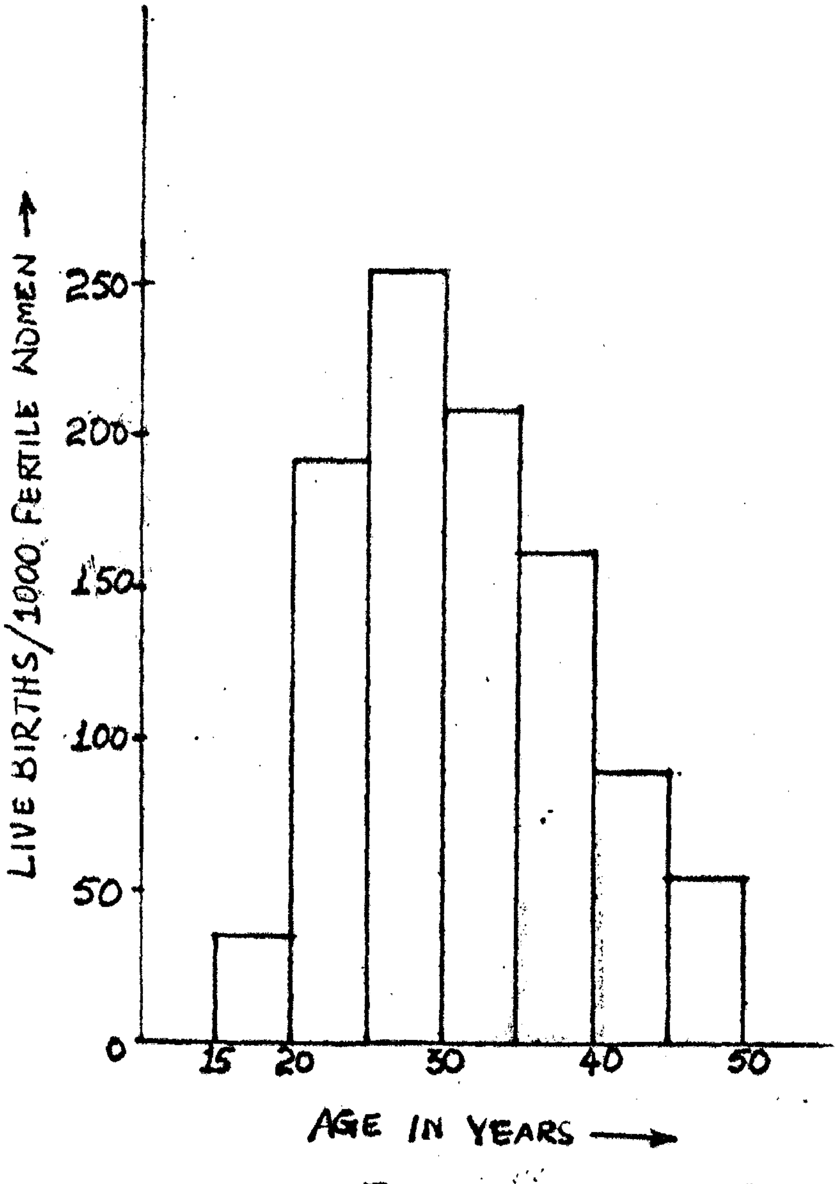

FIG. 5 FERTILITY PATTERN

Proportion of population marrying up to age a is given by

$$G(a) = \int_{a_0}^{a} g(x)\ dx \qquad (3.6)$$

To match the percentage of married women in different age group, with the preliminary census estimation 1981, it was necessary to find a suitable value of K. It was found that at K = 0.44, the marriage pattern would be in conformity with that of census data. The age specific fertility f(a) of a particular age group is given by

$$f(a) = G(a) \times \gamma(a) \qquad (3.7)$$

Where $\gamma(a)$ is a marital fertility of female of age a.

Using this relationship marital fertility has been calculated for different age groups from census data 1981. Which has been shown in table 6. Then using these values of marital fertility and the calculated percentage of ever married women have been used to find the age specific fertility for different age groups. Using these values of age-specific fertility effect of minimum age of marriage on population pattern has been simulated.

The effect of change in minimum age of marriage can be studies in two ways.

1. Step change in the minimum age of marriage and then compute the proportion of population marrying in different age groups. In this work step change of 17.0 yrs. and 19.0 yrs. has been made and the percentage of population marrying in different age groups is computed.

2. Change in minimum age of marriage taking place over a period of time. Here change in minimum age of marriage has

Table - 6

(Marital and Age Specific Fertility of Female of different age group)

Age Group	Age specific F(a)	G(a)	Marital Fertility $\gamma(a)$
15-19	0.17	43.47	0.391
20-24	0.96	86.44	1.11
25-29	1.28	94.33	1.35
30-34	1.04	94.81	1.09
35-39	0.81	93.17	0.86
40-44	0.45	87.81	0.51
45-49	0.28	82.93	0.33

been taken into consideration during the period 1981 to 1991 from 15.5 yrs. to 19.0 years into two steps.i.e. in 1981 it is 15.5 yrs. in 1986 it is 17.0 yrs. and in 1991 it is 19.0 yrs. After 1991 the minimum age of marriage has been assumed to remain at 19.0 years for the rest of the period.

In this thesis work the population changes in different age groups and different time interval are computed for above two conditions.

(iii) Family Planning Efforts: India is the first developing country which recognized population control as one of the gradients to accelerate development, set out to reduce the birth rate through an official family planning programme. Inspite of encouragement given by the government the control efforts have to be increased considerably to attain the desired reduction in birth rate.

Earlier a very simple model with uniform decay in fertility level has been discussed. In real situation uniform decay of fertility in all age groups are not realistic. The change in minimum age of marriage has effect in initial age groups where as the family planning in later age groups.

The pattern which determines the effect of family family planning on fertility pattern can be given by (4)

for $i = 4 \quad 10 \quad m(i,j+1) = m(i,j)\, e^{am(j).(1-e^{5-ak(i-4)})}$ (3.8)

& $j = 0, 1, 2 \ldots N$

Earlier work reported has suggest the value of parameter ak to be approx. 0.32649 for Indian case (4). The same value has been adopted here. The initial value of am i.e. am(0) is taken as 0.1. The value of am(0) are chosen to match the family planning. The value of m(i,j) for j=0 has been taken from the census of 1981.

Family planning has been studied into two ways.

1. Step change in family planning efforts as 0.1, 0.2, 0.4 and then compute the population in different age groups.

2. Change in family planning efforts for different time interval. In this case the efforts has been increased from 0.1 to 0.5 in 25 yrs. and then its value remains 0.5 for the rest period.

CHAPTER - 4

SIMULATION RESULTS

In previous chapter, demographic model and choice of fertility control has been discussed and all the input data are tabulated. Based on these data in different tabulated form, the effect of various control efforts on the population distribution upto year 2041, have been simulated. To use the input data with the modification, the time interval of each period has been selected as 5 years.

In table 7 age distribution of female population has been shown for the year 2001 and 2041 for the situation in which no change in birth rate have been assume. The age distribution clearly shows that in later years ~~the older population.~~ (Also in year 1981 and 2001) the older population has a handsome contribution in total population. The population levels are exceedingly high.

The pattern of population upto 2041 is simulated under the different ways of controlling fertility pattern. Results have been obtained for the different situations outlines in the previous chapter.

4.1 Exponential Decay (Arbitrary Control)

Effect of different values of arbitrary control efforts is tabulated in table 8 and the trajectories have been shown in fig. 7. It is clear from the trajectories and tables that by increasing the value of control efforts, the population

Table - 7

(Age distribution of female population)

with no control

Age Group	% of total female population 1981	2001	2041
0 - 4	14.7	14.7	13.48
5- 9	13.7	11.3	10.9
10-14	12.5	9.5	9.6
15-19	9.4	8.3	8.6
20-24	8.4	8.0	7.6
25-29	7.4	8.4	6.9
30-34	6.2	7.6	6.35
35-39	5.7	5.7	5.8
40-44	5.0	5.0	5.2
45-49	4.3	4.5	4.5
50-54	3.75	3.7	3.8
55-59	2.4	3.3	3.25
60+	6.34	9.9	13.85

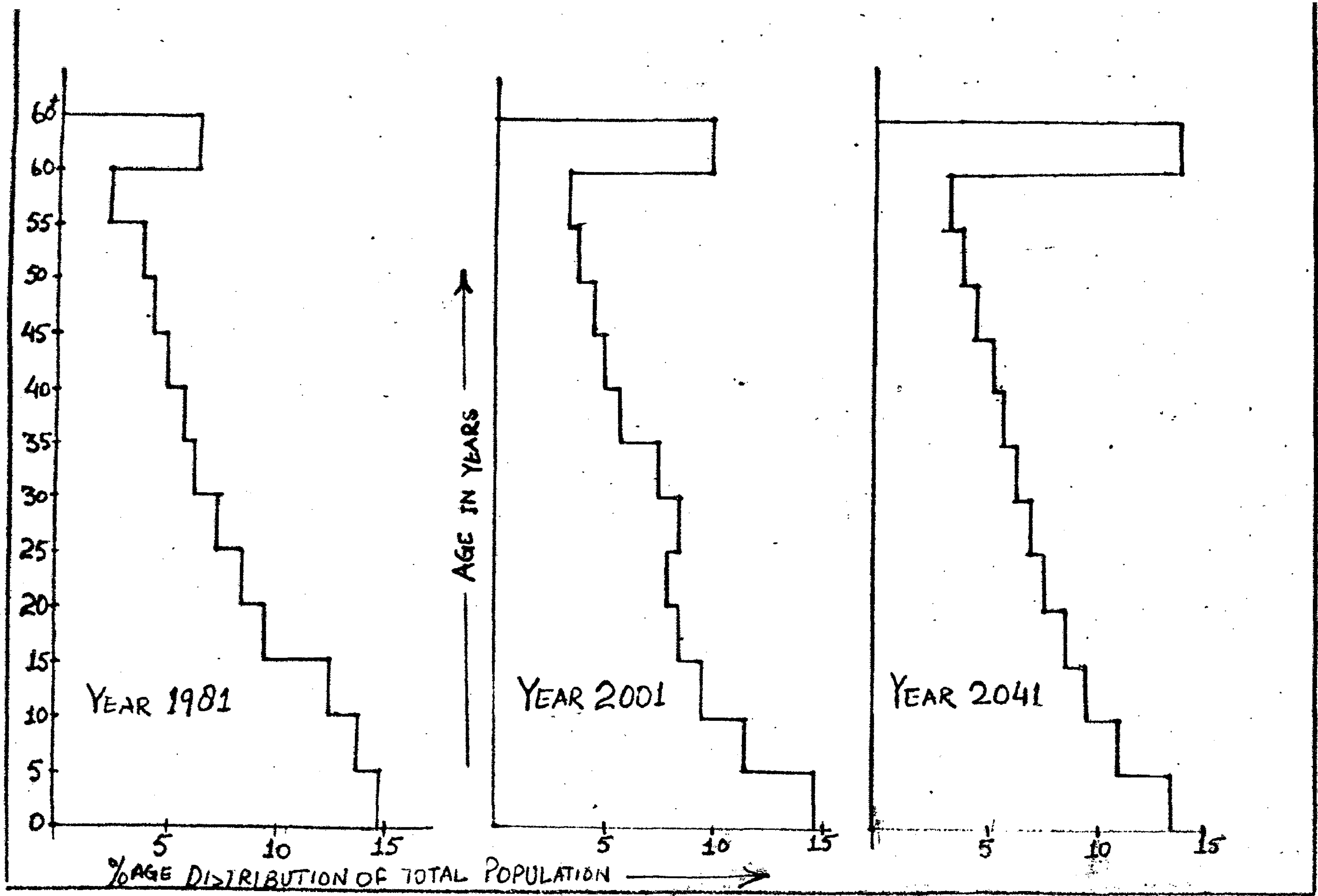
YEAR 1981
YEAR 2001
YEAR 2041
AGE IN YEARS
60+
60
55
50
45
40
35
30
25
20
15
10
5
0
5
10
15
%AGE DISTRIBUTION OF TOTAL POPULATION

FIG. 6

Table - 8

Effects of Arbitrary Control Efferts on Population

Control Effort	POPULATION (IN MILLIONS) 1981	1991	2001	2011	2021	2031	2041
0.00	320	405	517	645	793	978	1200
0.01	320	398	488	578	662	741	809
0.016	320	393	473	545	602	644	667
0.020	320	391	464	525	568	593	605
0.025	320	387	452	502	531	550	555

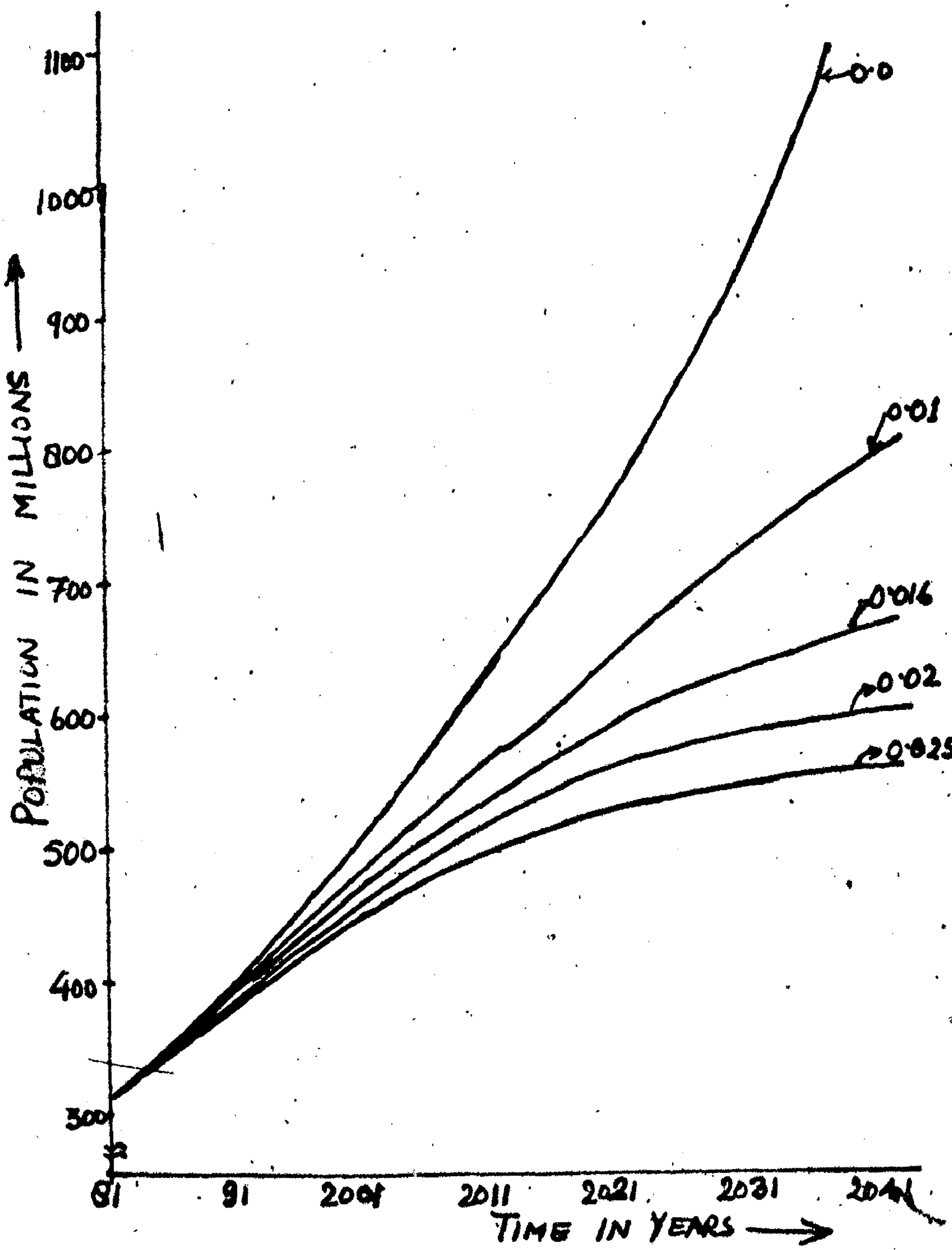

FIG. 7 ARBITRARY CONTROL

decreases more rapidely. Trajectory without any kind of control has been considered as a reference trajectory.

In this type of fertility control, if we assume the arbitrary control factor as 0.01, then after every decade the fertility would be reduced by 9.5% of its present value. If we want to further decrease the value of fertility pattern then the value of α should be increased. For example if we consider the value of α as 0.02 then the fertility pattern would be reduced by 18.2% after every decade.

4.2 Minimum Age of Marriage

This factor plays an important role in controlling fertility. Percentage of married women in different age groups for different minimum age of marriage are shown in table 9. By increasing the minimum age of marriage the percentage of female population in initial fecund group goes on decreasing. Which naturally effects the population in coming years.

In table 10 this effect is clearly shown upto year 2041. The another effect of varying the minimum age of marriage from 15.5 to 19 years upto year 1991 and after that it will remain constant at 19 years for the rest duration is also mentioned in the same table.

4.3 Family Planning Efforts

Increasing minimum marriage age has considerable initial impact on population control but family planning efforts only

[illegible]

(Percentage of married women in different age group for different min age of marriage)

AGE GROUP	MINIMUM AGE OF MARRIAGE 15.5 I	15.5 II	17.0 I	17.0 II	19.0 I	19.0 II	Remark
15-19	43.53	42.9	13.0	12.39	0.16	.032	I Total married women
20-24	91.10	89.61	83.32	81.84	68.25	66.96	II Married women excluding widowed, divorced & separated
25-29	98.59	96.26	96.97	94.65	95.21	92.88	
30-34	99.62	95.77	98.88	95.03	99.12	95.28	
35-39	99.74	93.91	99.74	93.31	99.66	93.81	
40-44	99.76	89.34	99.74	88.72	99.66	89.22	
45-49	99.76	85.32	99.74	84.70	99.66	85.57	

(Effect of Minimum Age of Marriage on Female Population)

MIN AGE			FE. POP (In million)				
	1981	1991	2001	2011	2021	2031	2041
15.5	320	406	519	647	796	984	1209
17.0	320	399	505	623	755	917	1109
19.0	320	393	491	602	717	856	1022
Min Age change from 15.5 to 19.0 in 15 yrs	320	402	500	612	734	878	1047

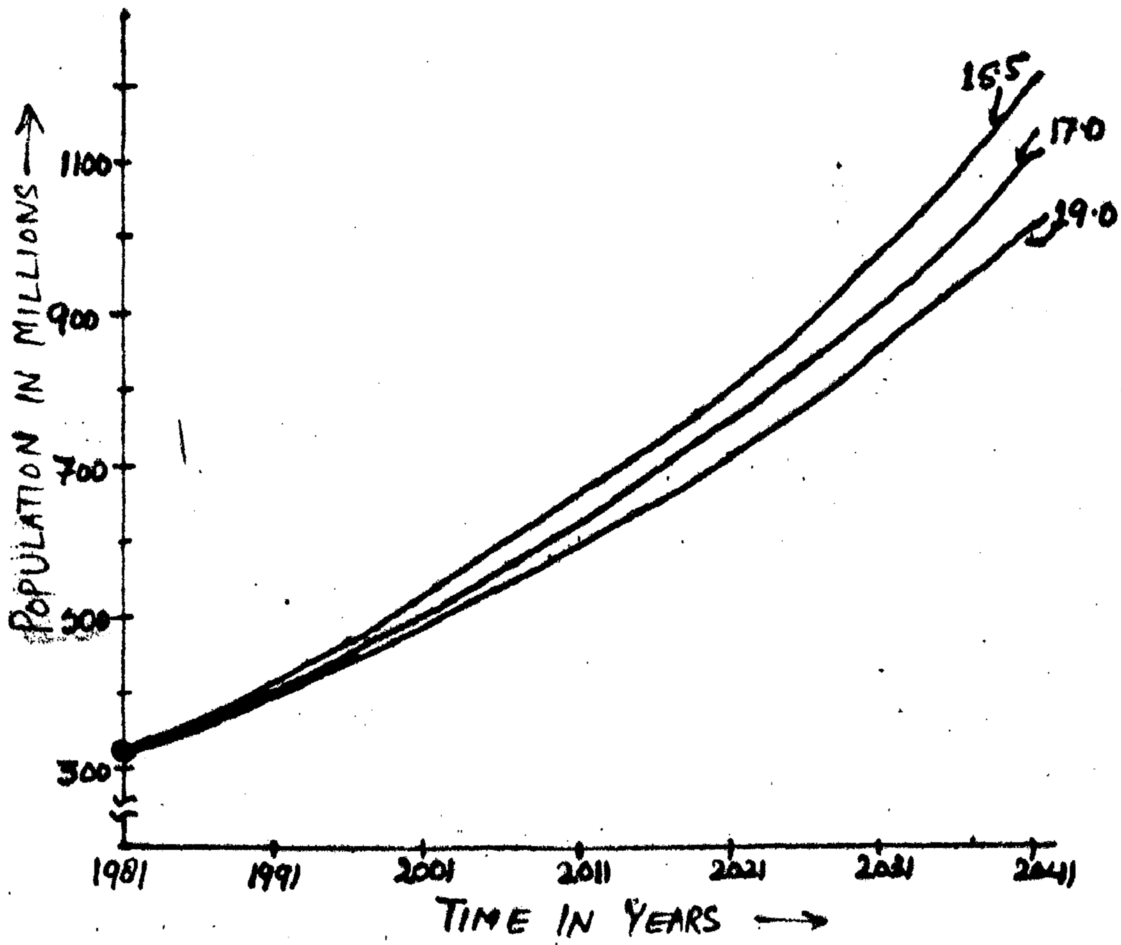

FIG. 8. MIN MARRIAGE AGE

are able to keep the population in the desirable limits in long term. Population upto 2041 has been shown for different values of family planning efforts in table 11. The table clearly shows the effect of increasing the control efforts on the population upto 2041 in a desirable limit. The effect of increasing the family planning efforts from 0.1 to 0.5 in 25 years is also shown in the table.

A complete table [12] showing the population level under above various cheices of fertility control, for the year 2001, 2021 & terminal year 2041 has been drawn. Which shows the comparative effect of different choice on population.

4.4 Birth Rate

Population of initial age group i.e. 0-4 years has been simulated for different types of fertility controls. Fig.10 represents the birth rate for arbitrary control. The curves are not smooth in nature, the reason for this is the data available for age group 0-4 is suspect and also there is a sharp difference in population of age group 10-14 & 15-19 which also seems erroneous. There is, thus, a need for proper modification of this data. However, these errors are not having significant effect on over all rates of population growth for a long period of time.

<u>Table - 11</u>

FAM PLAN EFFORTS

Fam Plan Efforts	Female Population (MILLION)						
	1981	1991	2001	2011	2021	2031	2041
0.10	320	402	498	592	683	774	850
0.15	320	401	490	571	643	705	745
0.20	320	400	482	552	609	650	666
0.25	320	398	475	536	580	602	605
0.30	320	397	469	522	556	569	557
0.35	320	396	463	509	535	538	519
0.40	320	395	457	497	516	513	487
0.45	320	394	452	487	500	490	461
0.50	320	393	447	478	486	472	439
Encreased from 0.1 to 0.5 in 25 yrs.	320	402	487	543	575	582	560

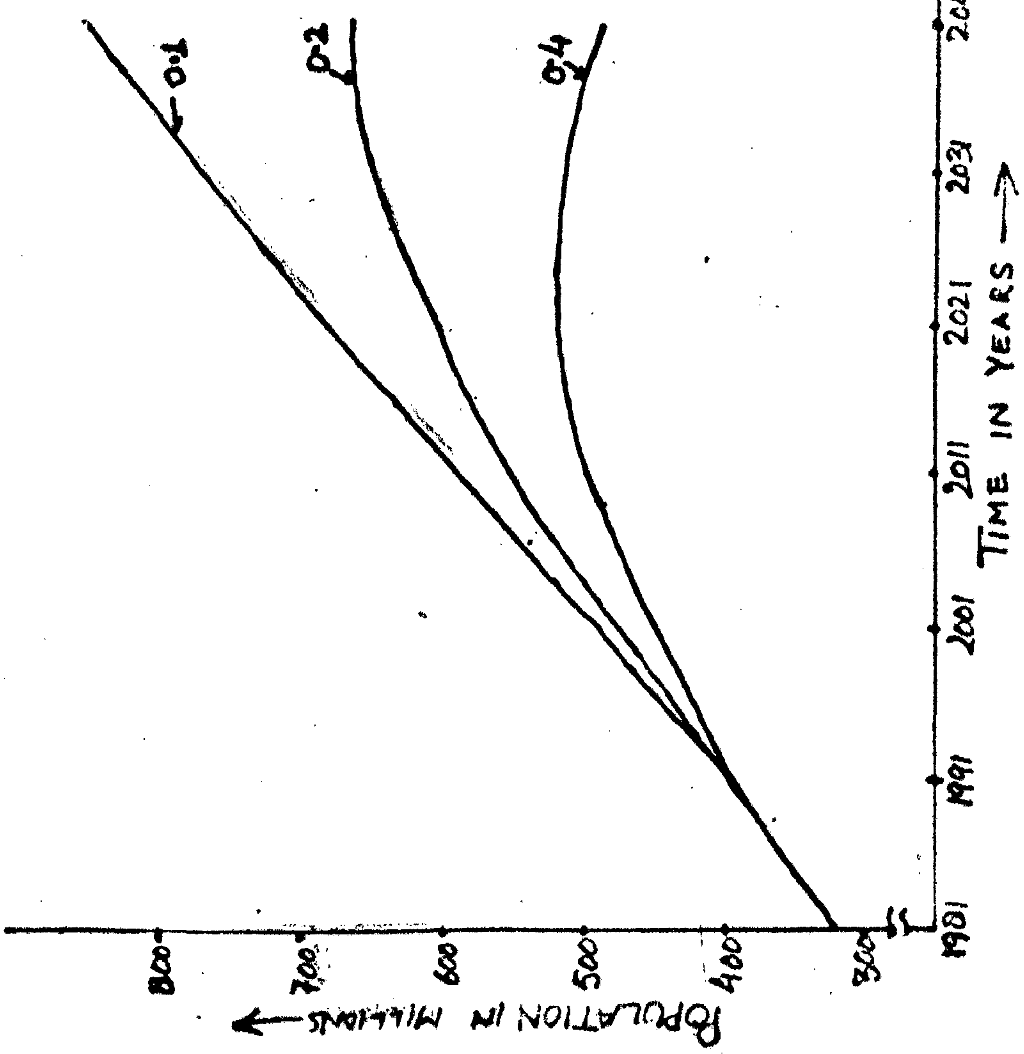

FIG. 9 FAM PLAN EFFORTS

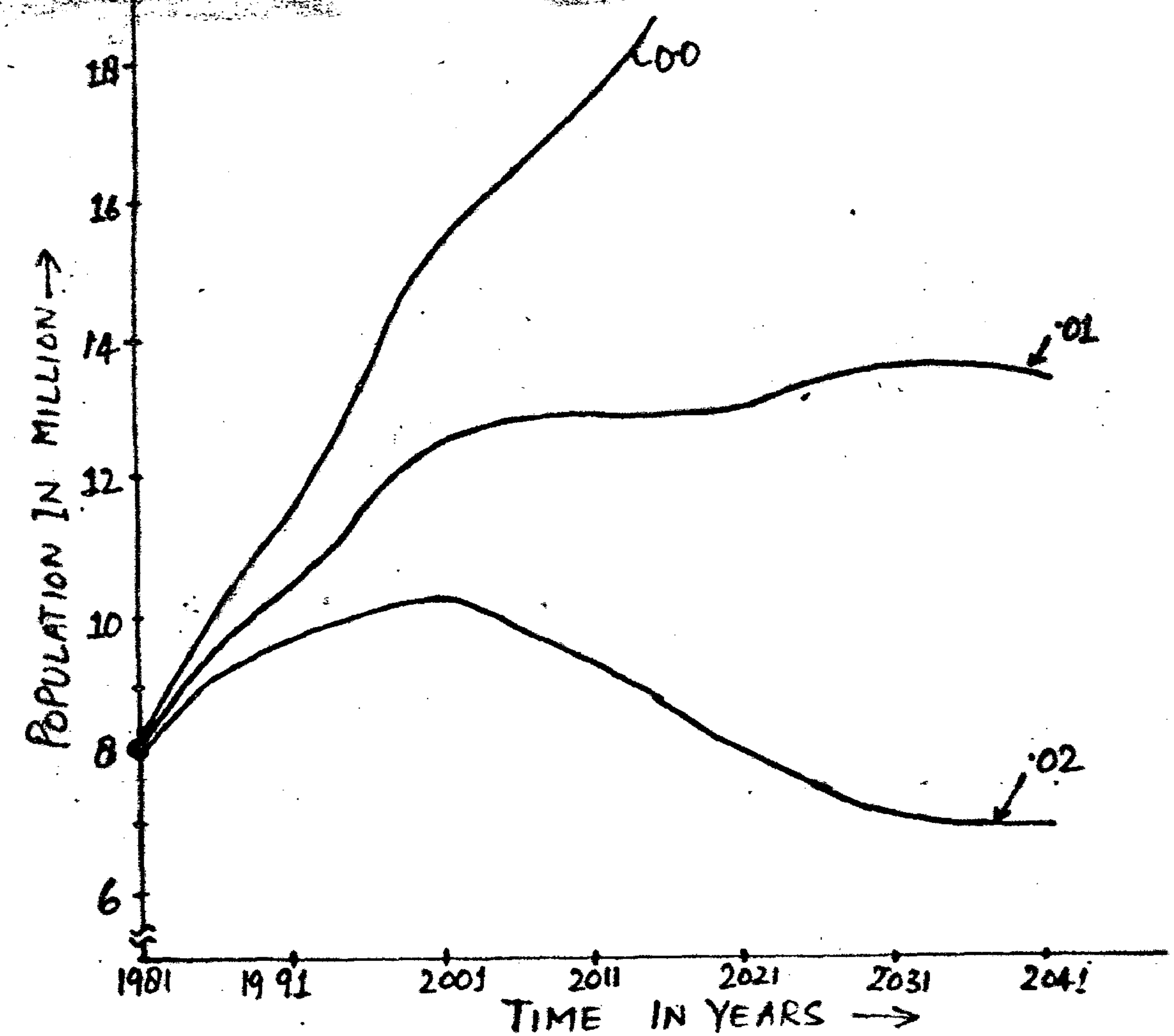

FIG. 10. BIRTH RATE

Table - 12

CONTROL STRATEGY	CONTROL EFFORT	POPULATION LEVEL (MILLION) 2001	2021	2041
Arbitrary	0.00	1078.2	1651.7	2500
Control	0.01	1017.5	1378.3	1685.8
	0.02	965.8	1183.3	1259.8
	0.025	942.5	1106.6	1156.9
Minimum	15.5	1079.2	1658.3	2518.8
Age of	17.0	1050	1571.9	2310.4
Marriage	19.0	1022.9	1494.4	2129.2
Min Age Increasing from 15.5 to 19 in 10 years		1041.7	1530	2181.3
Family	0.1	1037.5	1423	1770
Planning	0.2	1044.2	1268.8	1387.5
Efforts	0.4	952.1	1075	1014.6
	0.5	931.3	1012.5	914.6
Family Planning Efforts Increased for 0.1 to 0.5 in 25 years		1014.6	1198	1166.7

CHAPTER - 5

C O N C L U S I O N

On the basis of discussion and simulation of results for different methods of fertility control, in previous chapters, it is clear that a general conscience is necessary to reduce the population level. If we consider the bearing capacity of land to be about 1250 - 1300 million, then our aim would be to keep the population level with in this level in coming years.

From the results of simulation some conclusion can be drawn, about the effect of different population control measures and their levels required, so not to exceed the bearing capacity of the land.

1. In case of arbitrary control of fertility pattern, if the value of α is 0.01 then pattern will decrease by 9.5% per decade. For acquiring a level of 1250 - 1300 million the table shows that the value of α should be 0.02 i.e. the rate of decrease of pattern would be 18.5% per decade.

2. By varying the minimum age of marriage, on the basis of results mentioned in table 10, it can be concluded that this factor effects the population pattern only in initial stage of study. It is clear from table 10 that by raising minimum age of marriage 15.5 to 19.0 years, initially the reduction in population growth rate is quite high but the effect over a long time span is not that significant.

3. Family planning efforts really have condiderable effect on population growth in long duration. It's effect in initial time interval is not much. A observation of table 11 confirms this conclusion. It can be concluded, also that to control the population level, emphasize must be given on family planning efforts. To obtain the desired level of population upto bearing capacity of land, the table shows that the family planning efforts with a intensity of 0.2 should be used.

Suggestions & Farther Scope of Work

In this thesis due to lack of data available the mortality coefficients have been assumed to remain constant throughout the period of study but in actual case, the mortality coefficients would be decreased with time. So these coefficients must be estimated for different years to find out the actual population level.

In this work the famale population has been derived from total population by assuming the women rationas 48% of the total population for all age groups. In actual case the women ratio would be different for different age-groups. So if the actual age distribution of female population could be available then results can be more accurate.

A study can be very aggregated by considering zone wise population. A zone must have almost same geographic conditions and same level of living. Then results obtained can be more accurate.

One interesting study could be to consider the population of the status with very different level of education as in Bihar & Kerala (in India) then certainly some interesting results would be obtained to show the utility of education in keeping the population level to a certain limit.

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