ALTERNATIVE FAMILY PLANNING STRATEGIES FOR INDIA: A SIMULATION EXPERIMENT

by

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The present study examines the results of eight alternative family planning strategies on ten-year trends in fertility rates for India through the use of a demographic microsimulation model known as POPSIM. A number of parameters describing the characteristics of India's population were estimated in order to generate the population sample in the computer. To project the population into the future, the parameters required for generalizing vital events were also estimated.

Three factors were considered in the practice of family planning by couples: (i) Eligibility to accept a family planning method, (ii) adoption pattern of family planning, and (iii) switching pattern for specific methods of family planning. Two levels for each of these factors were specified and the necessary parameters were estimated. The eight combinations of the levels of the three factors were defined as eight alternative family planning strategies. The specific contraceptive methods considered in the present study were conventional contraceptive, IUD and sterilization.

An initial sample of 1500 women was considered and events were generated for 10 years under each of the eight family planning strategies. Events were also generated for 10 years without family planning (control). The experiment was replicated six times.

In the present study, analysis was conducted on five indices of fertility: (i) Crude birth rate, (ii) General fertility rate, (iii) Intrinsic rate of growth, (iv) Intrinsic birth rate, and (v) Net reproduction rate. For each of these five fertility indices, the response over the ten years of simulation was analyzed by means of the response curve technique. Under each strategy, the number of couples adopting each of the contraceptive methods (work-loads) was estimated.

The analysis of the results showed that the two levels of 'adoption' were highly significant in terms of their impact on the selected fertility indices. For the Crude birth rate, the two levels of 'switching' were also significant though not as highly as the 'adoption' levels, while the levels of 'eligibility' were not significant. The three-factor interaction was, however, significant for most of the fertility indices. A comparison of the eight family planning strategies with the control indicated that all the eight strategies yielded significant reductions in the fertility indices.

Implications of the results of the present study for India's family planning program were discussed. Some recommendations were made for the future simulation studies and the need for data for India on the contraceptive behavior of couples was expressed.

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CHAPTER I

SPECIFICATION OF THE PROBLEM

1.1 Introduction

The official family planning program in India was started during the First Five Year Plan[1] of India [32]. During this plan period, a number of demographic and attitude studies [10] and pilot family planning service programs were conducted. During the Second Five Year Plan period, emphasis shifted to attempting to raise the public awareness of family planning by the use of mass educational media such as posters, pamphlets and folders. Until the end of the second plan period, the national family planning program used mainly the clinic approach. Among the mechanical and chemical contraceptives, the diaphragm-jelly method was relatively popular until the IUD took its place in the early nineteen-sixties. With indigenous manufacture in India, the condom has been reported as one of the methods of family planning since the late nineteen-sixties. Use of the oral pill is still restricted mainly to clinical trials.

In the Third Five Year Plan period, attempts were made to involve local community leaders and thus take the family planning services into the community. Even during the second plan period, a few

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[1] The First, Second, Third and Fourth Five Year Plans are 1952-57, 1957-62, 1962-67, 1967-72 respectively.

states conducted 'sterilization camps'[2] which involved community leadership for motivational purposes. Sterilization camps have recently become popular in other states.

In India, sterilization is not offered to a person unless he or she is currently married and obtains the written approval of his or her spouse. In addition, the couple should usually satisfy certain eligibility criteria for sterilization. Criteria are usually based on the number, sex and ages of living children. Criteria adopted so far have differed from one state to another. A minimum of three or four children is usually a requirement. Sometimes it is further specified that one of the children should be a boy who is three or four years old. Such eligibility criteria are specified in the case of sterilization because it is essentially an irreversible method of fertility control. Usually, no such criteria are applied to eligibility for other methods of family planning.

In a country with the national program as the main or sole source of contraceptive methods, the impact of family planning on the birth rate depends mainly on three factors related to eligible couples.[3] First, the eligibility criteria set forth for different methods may be liberal or stringent. Second, among the eligible couples, the rate of adoption and the continuity of use of different methods will vary depending on their degree of motivation. Third, if there is a switch

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[2] A sterilization camp is one in which a touring team of medical and paramedical personnel conducts sterilizations, usually on males, during a period of two to five days in the physical premises of a community.

[3] It is assumed that the program delivers all the supplies and services requested by the couples.

from one method to another, the switching may be either to a more effective or to a less effective method. The pattern of switching may depend both on satisfaction with the method being used and on the purpose for which it is used, namely, spacing (short term or long term) or for permanent prevention of further births.

Different sets of assumptions with regard to the three factors mentioned above give rise to many ways of designing a family planning program.

Once a decision has been made, say, to reduce the birth rate to a specified level within a given time period, the program planner is faced with making decisions about many elements which make up a complete program. Ideally, for the various alternatives, the planner should have estimates of the course which the birth rate will follow and the costs of each alternative strategy in order to make informed decisions.

In the absence of adequate data on acceptance and continuation rates, as well as effectiveness of the various methods, estimation of the future course of fertility requires that a number of assumptions be made. With the necessary data, known or assumed, in hand, many methods can be applied to arrive at estimates of the possible impact of alternative family planning strategies on the future course of fertility.

The present study examined the results of eight alternative family planning strategies on ten year trends in fertility rates for India through the use of the POPSIM[4] computer simulation model. Ar-

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[4] Population Simulation

bitrary decisions were made about the necessary assumptions. The criterion used for judging whether one strategy was better than another was the decline in birth rates. The only indirect indication of costs developed were the estimates of the work-load, such as number of sterilizations to be performed, and these were also made for each strategy. Planners must, at a minimum, consider the relative costs of implementing various alternative strategies in order to decide which would be the best program.

1.2 Eligibility to Accept a Family Planning Method

In the present study, only married couples were considered eligible to practice any method of family planning. In addition, for sterilization, further restrictions were made based upon the number of living children, their ages and sexes. The two alternative criteria in the present study were:

(i) A couple should have at least two living children including a boy aged three years or more,

or

at least three living children irrespective of age and sex.

(ii) A couple should have at least three living children, including a boy aged three years or more,

or

at least four living children irrespective of age and sex.

1.3 Adoption Patterns of Family Planning

Among eligible couples, the proportion which accepts and practices family planning is of vital importance. Adoption probably results from a series of rather complex stages and/or interactions. It was assumed here that it differed only from one age-family size group to another. Adoption patterns are represented by sets of annual proportions adopting a method of family planning by family size and age of wife.

Two adoption patterns, High and Low, were considered in the present study. The manner in which they were derived is described in Chapter V.

1.4 Switching Pattern Between Specific Methods of Family Planning

Having accepted a specific family planning method, a couple, after some time, may change to another method or practice no method. Thus change may be either to a more effective or to a less effective method.

The contraceptive methods considered in this study were IUD, sterilization and 'conventional contraceptive'. The 'conventional contraceptive' was included to represent all the mechanical and chemical contraceptives. However, its use-effectiveness was taken as close to that of the condom.

Switching patterns may be related to the purpose for which couples practice family planning. When their ultimate goal is to limit family size, a proportion of couples may choose sterilization. If their goal is to space births, they may switch between conventional contraceptives, IUD and no method depending upon the time at which the next child is desired and/or satisfaction with the specific method.

In the present study, two switching patterns were considered. In one pattern, the proportions switching to sterilization were higher. than in the other pattern. These two patterns are discussed in Chapter V.

1.5 Definition of a Family Planning Strategy

The purpose of the present study was to evaluate the effect of alternative family planning strategies on India's birth rate. There were eight combinations of the three factors, each at two levels as discussed above. Each combination was a strategy, so that there were, in all, eight alternative strategies to be evaluated.

1.6 Study Design

Possible approaches that could have been adopted to conduct the present study are discussed in Chapter II. The method adopted in the present study and a description of the POPSIM microsimulation model which was used are also described in the same chapter.

To use the microsimulation model mentioned above, it was necessary to estimate a number of parameters describing the characteristics of India's population, in order to generate the initial population sample. To project the population into the future, it was also necessary to estimate the parameters for generating vital events. Such estimations are presented in Chapter III. Chapter IV is completely devoted to the estimation of monthly birth probabilities by age and parity of women.

A description of the proposed family planning strategies and estimation of the necessary parameters are covered in Chapter V.

Analysis of the results and conclusions are presented in Chapters VI and VII.

CHAPTER II

MODELS USED IN FERTILITY ANALYSIS AND APPROACH ADOPTED IN THE PRESENT STUDY

2.1 Models Used in Fertility Analysis

A model is defined by the assumptions made and the relationships hypothesized between factors. When the hypothesized relationships between factors and the underlying assumptions are repeatedly supported by real data, a model may serve as a reasonable substitute for experimentation in real life situations. Suppose one wants to know, for example, what the fertility level of a nation will be ten years from now if a family planning program is implemented in a specified way. Without considering possible outcomes, it would be unwise to implement programs in sample populations at a high cost and wait ten years to observe the impact on fertility in order to choose among several alternative strategies. Experimentation on a sample basis in real life situations would not only be expensive, but more important, it would be time-consuming. In fact, the usual course is to begin a program and modify it over time as evaluation results become available.

Models can be and often are used for such initial policy making and prospective planning decisions in many fields including family planning.

Uses of models have been discussed in detail by Sheps [35]. Sheps also categorized models from the point of view of complexity into three types--analytic, macrosimulation and microsimulation. Definitions of these types and distinctions between them have been discussed by Sheps [31]. In the same paper, a discussion of several studies based on analytical models was presented. Hence a review of the studies based on analytical models will not be presented here. Only a few studies, which used either macro or microsimulations will be discussed below.

Using a macrosimulation model for India, Immerwahr [17], studied the effectiveness of various family planning policies, such as delay in age at marriage, spacing between pregnancies and prevention of further conceptions after a certain age or certain parity. He used a quarter-year as the unit of time for grouping the ages of women, as well as for the surviving women through time. He considered thirteen parity states--from 0 to 12; three marital states--single, married and widowed; two fertility states--fertile or sterile; one death state and a number of pregnancy and post partum states associated with different pregnancy outcomes. The input probabilities were the quarterly conditional probabilities of death, marriage, widowhood, sterility, etc. One finding of this study was that a delay in marriage would have a significant effect on fertility, but would not, in the author's words, 'eliminate' the long-term population growth. Two and three year spacing after each live birth seemed to have significant effects on fertility, while one year spacing seemed to have little effect. Limiting the reproductive age span, by means of sterilization, to 40, 35 and 30 years, reduced the Total Fertility Rate to 5.77, 5.02 and 3.90, respectively, from the original level of 6.05.

A more elaborate macrosimulation model known as FERMOD was developed by Potter and Sakoda [29]. Their model, for a homogeneous marriage cohort of women, assumed (i) a constant length of reproductive period, (ii) a constant probability of miscarriage and a constant probability of still birth, (iii) a constant gestation period of three months for a miscarriage and nine months for a live or still birth, (iv) a constant length of amenorrhea of one month for a miscarriage, three months for still birth and an arbitrary distribution of specified range for live birth and (v) fecundability varying by parity and marriage duration. A cohort of ten million women were processed through time in steps of one month each. Contraception was represented by reduced fecundability. With different assumptions about contraceptive effectiveness, the authors studied the impact of contraception on completed family size.

The main limitation of the above studies, as the authors themselves pointed out, was that the possible states incorporated in the models were restricted in number.

Menken and Sheps [36] developed a macrosimulation model, BIOSIM, which allowed fecundability and probability of live birth to vary with parity and duration of marriage, while length of gestation and post partum non-susceptibility were consistent for each pregnancy outcome.

Among the few studies which used microsimulation models, there were two basic methods for generating births. Models in which births are generated by using the probability of a live birth per unit of time are said to have a 'demographic approach' to natality. Some models, on the other hand, used detailed probabilities for events such as conception, live birth, still birth, fetal loss and resumption of menstruation. Models dealing with natality in such biological detail are said to have a 'biologic approach' to natality. An example of a mathematical model with a biologic approach to natality is the one developed by Perrin and

and Sheps [28]. The computerized version of this model developed by Ridley and Sheps [34], is known as REPSIM.

There were also other studies, which used macro and/or microsimulation, which were undertaken to determine the effect on family size when couples want to be highly certain that at least one of their sons will survive the father's sixty-fifth birthday [22], or the effect on population growth if couples practice perfect contraception when survivorship of at least one of their sons is assured [15].

With parameters applicable to India, Mukerji and Venkatacharya studied the effects on the birth rate of increasing age at marriage [23] and of changing degree of induced abortion [24]. Another study [25] was done to observe the effect of changing patterns of post partum amenorrhea on completed family size, age-specific marital fertility schedule and birth intervals.

The microsimulation model known as POPSIM, developed jointly by the Research Triangle Institute and Department of Biostatistics, University of North Carolina, and used in this study, is discussed in some detail in the next section.

2.2 Approach Adopted in the Present Study

A general discussion of the problem was presented in Chapter I. The magnitude of the present problem ruled out an analytical model approach.

Macrosimulation could have been employed, but the scope of results derivable from such a model would have been somewhat more limited. It probably would have to have been restricted to cohort data since, with a large number of variables, the computer memory requirements are so large as to exceed even the largest computer available.

However, microsimulation has the advantage of being able to simulate a much more complex process and generate a variety of results. Furthermore, it is advantageous to use a microsimulation model which has already been developed. Prior familiarity with POPSIM [16] and its availability for use were the main reasons that led to its use in the present study.

2.3 Description of POPSIM

POPSIM is a microsimulation model of a human population which uses a demographic approach, in contrast to a biologic approach, to natality simulation. It can be used to simulate cohort as well as period populations.

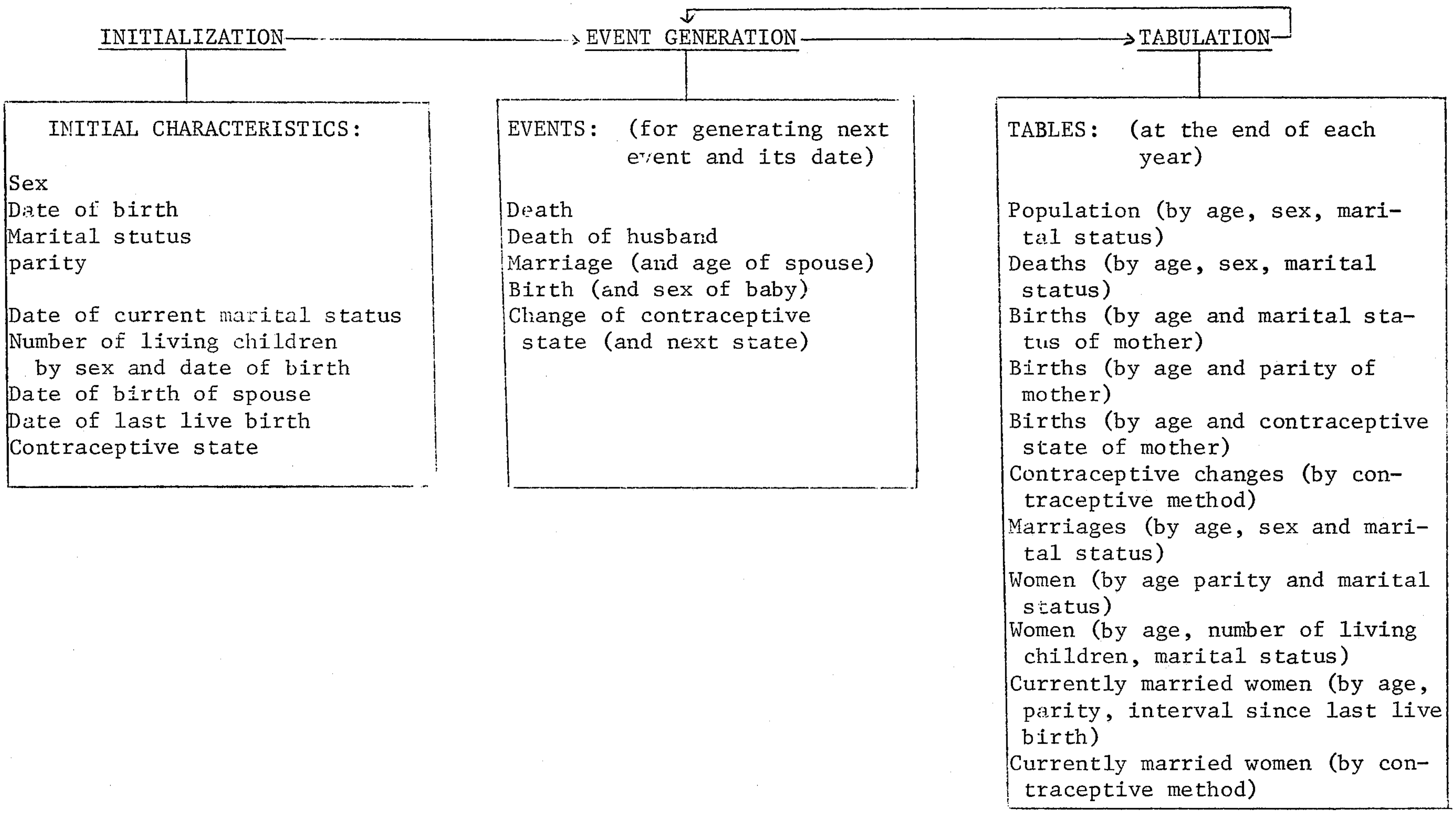
Operation of this model includes three stages--(i) Initialization of the population, (ii) Event generation and (iii) Tabulation of the population and vital events at specified intervals of time.

(i) Initialization of population:

The initial characteristics, such as age, sex, marital status, etc., are assigned to each member of the sample population. In the context of a family planning program, non-use of contraception or use of a specific contraceptive method becomes one of the initial characteristics. The purpose of this stage of operation is to make the characteristics of the sample resemble closely those of the universe to be simulated. A list of the initial characteristics is given in chart 2.1. These characteristics are assigned to individuals by sampling the correspoiding conditional distributions which form a part of the input data [9].

CHART 2.1

STAGES IN THE OPERATION OF POPSIM



INITIALIZATION

INITIAL CHARACTERISTICS:

Sex
Date of birth
Marital stutus
parity

Date of current marital status
Number of living children by sex and date of birth
Date of birth of spouse
Date of last live birth
Contraceptive state

EVENT GENERATION

EVENTS: (for generating next event and its date)

Death
Death of husband
Marriage (and age of spouse)
Birth (and sex of baby)
Change of contraceptive state (and next state)

TABULATION

TABLES: (at the end of each year)

Population (by age, sex, marital status)
Deaths (by age, sex, marital status)
Births (by age and marital status of mother)
Births (by age and parity of mother)
Births (by age and contraceptive state of mother)
Contraceptive changes (by contraceptive method)
Marriages (by age, sex and marital status)
Women (by age parity and marital status)
Women (by age, number of living children, marital status)
Currently married women (by age, parity, interval since last live birth)
Currently married women (by contraceptive method)

Estimation of parameters of these various conditional distributions and methods of assigning initial characteristics in the present study will be discussed in Chapters III and IV.

Of the initial characteristics, assignment of age in POPSIM is noteworthy. Suppose, in a specified sex-marital status group, there are n individuals in an age group whose lower and upper limits are L and U, respectively. The ages of these n individuals are determined as follows.

A linear density function for this age group is set up as

$$f(t) = a+bt, \tag{1}$$

so that the distribution function is

$$F(t) = at+\tfrac{1}{2}bt^2. \tag{2}$$

If y is a uniform random number between 0 and 1, then

$$F^{-1}(y) = t = (-a + \sqrt{a^2+2by})\ /b. \tag{3}$$

With appropriate constraints, the values of a and b work out as

$$a = 2/(U-L)\ ,\quad b = -2/(U-L)^2\ .$$

Since there are n individuals between ages L and U to be assigned ages, the interval (0,1) is divided into n sub-intervals of length $\frac{1}{n}$ each and a random number is selected in each sub-interval. Using the inverse of the distribution function given by (3) and the random number selected, t is computed and age is assigned as (L+t).

(ii) Event generation:

After assigning the individual characteristics, the next stage is generation of events such as birth, death, marriage, etc. for individuals in the computer population. A list of the events is presented in chart 2.1. The total length of simulation and the length of the time-interval to be simulated each time are decided at the beginning of simulation. For example, one may decide to simulate for a total period of ten years at intervals of one year. This permits changes in the event generation parameters, if desired, from one year to the next.

For the generation of events, conditional monthly probabilities of occurence of different events are specified. Estimation of such parameters for the present study will be discussed in Chapters III and IV. The date of occurrence of a specified event to an individual is computed as follows.

Suppose p is the monthly probability of occurrence of an event appropriate to the characteristics of an individual. During the time period for which p is constant, the waiting time t has a geometric density function given by

$$f(t) = p(1-p)^{t-1} , \qquad (1)$$

so that the distribution function is

$$F(t) = 1-(1-p)^{t} \qquad (2)$$

A uniform number R between 0 and 1 is selected and set equal to (2), so that

$$t = \frac{\ell n(1-R)}{\ell n(1-p)} . \qquad (3)$$

If t is less than or equal to the time period T_o for which p is constant for that individual, then this particular event is understood to have a waiting time equal to t months.

If t is greater than the time period T_o for which p is constant for that individual, then a new probability p_1 and a new random number R_1 are used to compute t_1 with the help of relationship (3). If t_1 is less than or equal to the time period T_1 for which p_1 is constant, then the waiting time for the event to occur is taken as (T_o+t_1). If t_1 is greater than T_1, then the procedure is repeated until a value t_i is reached satisfying the required conditions, and the waiting time is computed as $(T_o+T_1+...t_i)$.

By this procedure, waiting times for all events for which the individual is eligible are computed and the event with the least waiting time is judged to be the next event for that person. The next event and the date of its occurrence, thus computed, are entered in the history of that individual. On the date of occurrence, changes in the characteristics caused by this event are made in the history and once again the next event and its time of occurrence are generated, and the process continues until the end of the specified simulation period or until the person dies.

This is essentially what happens in event generation. However, in the mechanics of computer operation, event generation is done in stages--one year at a time for all individuals in order to permit tabulation on a calendar year basis. Adjustment of the affected characteristics (updating) and generation of the next event are done only when the year of simulation coincides with the year in which the event occurs.

The event generation procedure described above applies to all events but with a restriction in the case of birth. A birth is not allowed to occur to a woman unless the interval since her last birth is at least nine months.

When family planning is included in simulation, an additional event, change of current contraceptive state, is computed. The method of computing this additional event and estimation of the necessary parameters are discussed in Chapter V.

(iii) Tabulation:

In POPSIM, tabulations of population and vital events are performed at specified intervals of time, say, at the end of every calendar year. A list of the usual tabulations in POPSIM are presented in chart 2.1.

2.4 Assumptions Made in the Present Study

In the present study, only the female population was considered. The age-marital status distributions of females as given by the 1961 census of India were used for the purpose of initialization.

During the simulation period of ten years, the birth, death, and marriage probabilities were kept constant.

Divorces and widow-remarriages were assumed to be nil during the period of simulation.

Only currently married women were assumed eligible for any method of family planning. It was further assumed that at the start of simulation (initialization), nobody was practicing contraception.

CHAPTER III

ESTIMATION OF PARAMETERS FOR INITIALIZATION OF POPULATION AND FOR GENERATION OF EVENTS

3.1 Introduction

As explained in Chapter II, the first step in simulating India's population consisted of generating a sample of specified size which possessed the characteristics of the population of India. Only a female sample was considered in the present study. The initial characteristics that were assigned to the sample women are age, marital status for all women, age at marriage, duration of marriage, and present age of husband for currently married women and parity of ever married women. The age-assignment technique for women in each marital status category was discussed in Chapter II, and the necessary parameters are estimated in Section 3.2. Procedures used in the present study for estimating the age at marriage and duration of marriage of currently married women and the necessary parameters are described in Section 3.5. The method of computing husband's present age for a given age of wife is detailed in Section 3.6.

For a currently married woman, the number of previous live births was assigned as follows. First, the duration of effective marriage as described in Section 3.5 was conputed and the number of live births that could occur during this period of reproductive life was generated with the help of the age-parity specific monthly birth probabilities estimated in Chapter IV. The number of live births thus estimated was assigned as her parity at the beginning of simulation. It may be noted that while generating the parity at the beginning of simulation as well as while generating births during the period of simulation, the sex ratio at birth was taken as 106 male births per 206 total births [33]. Since this method of estimating the live births to a woman provided the date of birth of each child born prior to the beginning of simulation, it was possible to estimate the number of male and female living children by age for a currently married woman by surviving these male and female births up to the beginning of simulation.

Since remarriages of widows were assumed nil in the present study, the initial parity of a woman who was already a widow at the beginning of simulation was of no importance. From this point of view the parity of a widow was generated using the functional form, namely, the negative binomial as shown in Chapter IV.

For the second step in the simulation, namely, the generation of events, birth, death, and marriage probabilities were needed. As already mentioned, Chapter IV is devoted to the estimation of birth probabilities. Death probabilities are discussed in Section 3.3 in this chapter. The probabilities of marriage for single women and the method of computing a groom's age are described in Section 3.7.

The assumptions involved and estimation of the necessary parameters for family planning are discussed in Chapter V.

3.2 Age-Marital Status of the Population of India

The census of India served as a good source for the age-sex-marital status distribution of the population of India. Errors such as misreporting of ages and preference for ages ending in certain digits, for example 0 and 5, were common.

The age-marital status distributions of females considered in the present study were from the 1961 census of India. Errors in age-reporting were adjusted (smoothed) in the male and female populations separately by the census actuary, and the adjusted distributions have been published [41] and are presented in Appendix Table 1. Unsmoothed distributions by quinquennial age groups for each marital status were available for females in the 1961 census of India [42] and are presented in Appendix Table 2.

Since only women were included in the present simulation, we were interested in computing the age-marital structure of the female population. For the purpose of estimating the age-marital status distribution, the following procedure was adopted. The number of women in a specified age group as given by the age-adjusted data in source [41] was taken and this number was broken down into the three categories - single, married, and widowed according to the marital status distribution indicated for that age group by source [42]. This procedure implicitly assumes that age-reporting errors are independent of marital status. Since there was no evidence either to support or refute such an assumption, the age-marital status distributions thus obtained were used for the purpose of initialization of the population.

The portions single, married and widowed in the total female population were 0.43, 0.47 and 0.10 and these are presented in the last row of table 3.1. The age distributions of women in the three marital status groups are presented in the same table. It may be

TABLE 3.1

AGE-MARITAL STATUS DISTRIBUTION OF WOMEN, INDIA, 1961

AGE GROUP	PROPORTION OF WOMEN		
	SINGLE	MARRIED	WIDOWED
0-1	.08770		
1-5	.28569		
5-10	.29687		
10-15	.25213		
15-16	.05604	.01689	.00395
16-17		.02194	
17-18		.02628	
18-19		.02990	
19-20		.03285	
20-21	.01270	.03513	.01079
21-22		.03679	
22-23		.03788	
23-24		.03841	
24-25		.03849	
25-30	.00379	.18075	.02272
30-35	.00171	.14442	.04151
35-40	.00097	.10974	.05752
40-45	.00074	.08897	.09684
45-50	.00046	.06171	.10441
50-55	.00042	.04518	.15783
55-60	.00022	.02351	.09942
60-65	.00026	.01729	.16756
65-70	.00011	.00688	.07436
70-75	.00009	.00313	.07302
75-80	.00005	.00201	.04689
80-85	.00003	.00116	.02699
85+	.00002	.00069	.01619
Total	1.00000	1.00000	1.00000
Proportion of women in marital status group	.42576	.46543	.10881

noted that for married women between ages 15 and 25, single year age grouping was used in accordance with the input specifications in POPSIM. These single year proportions were read off from a polynomial fitted to the cumulative proportions married up to ages 15, 20, 25, ...

Proportions beyond age 70 presented in Table 3.2 also deserve comment. In the age and marital status distributions, referred to in sources [41] and [42], the last age group was given as 70+. Under each marital status category, the age group 70+ was broken into four sub-groups 70-75, 75-80, 80-85 and 85+ in the same proportion as the female life table population of India 1951-61.

3.3 Monthly Probability of Death by Age and Marital Status for Males and Females

Probabilities of death by age and sex are usually available from a life table. The most recent life tables of India are those prepared by the census actuary after the 1961 census and are available for males and females separately [11]. The columns in these life tables are given by single year ages. There are also other life tables available for rural India [4], but only 10-year age grouping is available in the published form. For the computation of monthly death probabilities in the present study, the former source was used.

Life tables of India are not available by marital status, and the computations that follow refer to persons of all marital statuses. The monthly probabilities of death were computed in each of the age groups: 0-1 month, 1-12 months, 1-4 years, 5-9 years and quinquennial age groups thereafter, and for each sex separately.

(i) Age groups 5-9, 10-14 etc.:

In life table notation, the probability that a person in the age group (x, x+5) will survive for 5 years is given by

$$P_{x,x+5} = {}_5L_{x+5}/{}_5L_x, \qquad (1)$$

where

$P_{x,x+5}$ = probability that a person in the age group (x, x+5) will survive for 5 years,

${}_5L_{x+5}$ = life table population in the age group (x+5, x+10)

and

${}_5L_x$ = life table population in the age group (x, x+5).

Taking a month as a unit of time, the proportion belonging to age groups (x, x+5) dying during a period of 5 years is given by

$$Q_{x,x+5} = 1-P_{x,x+5}$$

It was assumed that the monthly probability $q_{x,x+5}$ of death of a person in age group (x,x+5) follows a geometric distribution, so that the proportion of persons in the age group (x,x+5) dying during a period of 60 months is given by

$$[1-(1-q_{x,x+5})^{60}]$$

which when equated to the value in (2) will yield

$$q_{x,x+5} = 1-(1-Q_{x,x+5})^{\frac{1}{60}} . \tag{3}$$

By this method, the monthly probability $q_{x,x+5}$ of death for a person in the age group (x,x+5) was computed for x=5, 10, ...

(ii) Age groups 0-1 month and 1-12 months:

In life table notation again, the number of infant deaths in the life table is given by

$$I = \ell_0-\ell_1 \tag{4}$$

where

ℓ_0 = original cohort of births (radix of the life table),

ℓ_1 = number attaining 1 year of age in the life table

and

I = number of infant deaths in the life table.

Of these I deaths during the first year of life, 45 percent were assumed to have occurred during the first month itself and the remaining 55 percent during the subsequent 11 months [43].

The monthly probability of death of children aged less than one month was computed as

$$q_{0-1 \text{ month}} = (.45)I/\ell_0. \tag{5}$$

Now, the number of babies attaining 1 month of age is given by

$$\ell_{1 \text{ month}} = \ell_0 - (.45)I \tag{6}$$

The number attaining 1 year of age is given in the life table.

Thus the proportion dying during 1-12 months of age was

$$Q_{1\text{-}12 \text{ months}} = [\ell_{1 \text{ month}} - \ell_{12 \text{ months}}]/\ell_{1 \text{ month}},$$

and the monthly probability of death of children aged 1-12 months was computed as

$$q_{1\text{-}12 \text{ months}} = 1-(1-Q_{1\text{-}12 \text{ months}})^{\frac{1}{11}} \tag{7}$$

It may be noted that the value given by equation (5) is actually the probability that a baby born will die before it reaches its first month of age. But what we ought to have computed is the monthly probability of death of a baby aged 0-1 month. In other words, we over-estimated the monthly probability of death in the age group 0-1 month.

Also the value given by equation (7) is actually the monthly probability of death of a baby aged 1 month. But we took this probability in the place of the monthly probability of death of a baby aged 1-12 months. Once again we over-estimated the monthly probability.

We have in essence considered, for infant ages, a mortality higher than that indicated by the life tables.

It is criticized that the official life tables of India, 1951-61, which we have used, were based on an infant mortality rate which was an under-estimate [7]. The over-estimation of monthly probabilities of death in the infant ages in the above computations, was believed to counteract, to some extent, the under-estimation inherent in the life tables.

(iii) <u>Age group 1-4 years</u>:

The monthly probability of death of a person aged 1-4 years is, by relationships (1), (2), (3), given by

$$q_{1\text{-}4 \text{ years}} = 1-({}_{10}L_6/{}_5L_1)^{\frac{1}{60}} \quad . \qquad (8)$$

The monthly probabilities of death in different age groups for males and females were computed from the male and female life tables, respectively. The monthly probabilities obtained by the above procedures were considered applicable to single and married persons.

In India, widows are believed to have higher mortality than married women of the same age. It is probably due to the fact that there is a taboo on widow-remarriage, and hence widows are subject to economic hardships. Accordingly, the monthly probability for widows in any age group was arbitrarily chosen in this study as ten percent higher than that of married women in the same age group.

Although males were not included in the initial sample population, death probabilities of men were still required for two reasons -- (i) male babies born during the period of simulation needed to be survived year after year and (ii) the date of widowhood for a married woman was decided by computing the date of death of her husband.

Husbands were treated as secondary individuals while wives were treated as primary individuals, and, when a married woman died, her husband no longer existed as a secondary individual. For this reason, the monthly probabilities of death for widowed men were not needed.

The monthly probabilities of death by age, sex and marital status are presented in Table 3.2.

3.4 Number of Marriages for Women

As was mentioned earlier, divorces are practically nil in India. Also remarriages of widows are uncommon. For the purpose of the present study it was assumed that each ever-married woman in the initial population had married only once. Also during the period of simulation remarriages were not permitted.

3.5 Age at Marriage and Duration of Marriage of Currently Married Women in the Initial Population

The date of marriage of a currently married woman of age x in the initial population was needed. Knowledge of the age at marriage of a woman enabled us to compute the age at marriage of her husband (Section 3.6). By adding the difference between the age at marriage and the present age of a woman to her husband's age at marriage, we obtained the present age of her husband.

In India, ceremonial marriage and effective marriage need not occur on the same date. For girls married very young, the consumation usually takes place later, around age 15. Thus, for reckoning the reproductive behaviour of a woman, effective marriage duration rather than ceremonial marriage duration should be considered. To obtain the duration of effective marriage, two values were computed, namely, the duration from ceremonial marriage to the present age and the duration from age 15 to the present age, and the minimum of these two values was taken as the duration of effective marriage. The parity of a married woman before the start of simulation was computed with the help

TABLE 3.2

MONTHLY PROBABILITY OF DEATH BY AGE, SEX AND MARITAL STATUS

INDIA, 1951-61

AGE GROUP	MALE	FEMALE	
	Single and Married	Single and Married	Widowed
0-1 months	.06895	.06222	
1-12 months	.00859	.00766	
1-4 years	.00086	.00105	
5-9	.00034	.00040	
10-14	.00038	.00040	.00044
15-19	.00045	.00047	.00051
20-24	.00052	.00056	.00062
25-29	.00066	.00099	.00109
30-34	.00100	.00154	.00170
35-39	.00146	.00188	.00207
40-44	.00191	.00212	.00233
45-49	.00241	.00248	.00273
50-54	.00317	.00304	.00334
55-59	.00412	.00380	.00418
60-64	.00534	.00474	.00522
65-69	.00691	.00591	.00650
70-74	.00894	.00735	.00808
75-79	.01156	.00916	.01008
80-84	.01583	.01249	.01374
85-89	.02602	.02218	.02440
90-94	.04990	.04654	.05119
95-99	.06622	.06901	.07591

of the duration of effective marriage and the age-parity specific birth probabilities estimated in Chapter IV.

In order to compute the age at ceremonial marriage of a currently married woman aged x, in the initial population, we needed the probabilities of ceremonial marriage between the ages x and x-1, and x-2, etc.

Marriage statistics, in any form, are not available for India. One way of obtaining probabilities of marriage for women is by estimating them from the age distributions of single women in two consecutive censuses. Since the effect of migration for India as a whole is negligible, the difference in the number of single women belonging to a specified age group x in one census and the number in the age group x+10 in the following census ten years hence, would account for the deaths and marriages during the intercensal period. The age distributions, of course, should be adjusted for errors. With the knowledge of the age-specific death probabilities for the intercensal period, one could compute age-specific marriage probabilities.

Such computations were done by Kumar [20] on the age distributions of single women in the 1951 and 1961 censuses of India. Kumar estimated, for various values of x, the probability of a single woman marrying between ages x and x+5.

These five-year probabilities of marriage were applied to a cohort of N single women at the lowest age of marriage. This procedure yielded cumulative numbers of marriages $c_x, c_{x+5}, \ldots$ at ages x,x+5,... . By means of a polymonial, the single year values c_x, $c_{x+1}, \ldots$ were obtained and the unconditional probability of marriage for a woman between ages x and x+1 were computed as $(c_{x+1}-c_x)/N$.

These probabilities are presented in Table 3.3.

The probability that a currently married woman aged x was married between ages (j-1) and j is given by

$$p_{j,x} = p_j / \sum_{i=0}^{x} p_i \ .$$

A uniform random number R_1 between 0 and 1 was selected and it was decided that she married between her ages y-1 and y if

$$\sum_{j=0}^{y-1} p_{j,x} < R_1 \leq \sum_{j=0}^{y} p_{j,x} \ .$$

Another uniform random number R_2 between 0 and 1 was selected and her age at ceremonial marriage was computed as $(y-1+R_2)$ years.

Thus for a currently married woman aged x in the initial population, her ceremonial marriage duration was $(x-y+1-R_2)$ years and her effective marriage duration was the minimum of the two values $(x-y+1-R_2)$ and (x-15) years.

3.6 Age of Husband for a Given Age of Wife in the Initial Population

The age for every currently married woman in the sample initial population was known. In order to compute her husband's age, knowledge of the distribution of couples by age of wife and age of husband would have sufficed, but such a bivariate distribution is not available for India. However, classification of couples by age at marriage of wife and husband is available for over 17000 couples in a National sample survey [12] and was used in the following estimation.

TABLE 3.3

PROBABILITY OF CEREMONIAL MARRIAGE FOR WOMEN BY AGE

INDIA, 1951-61

AGE x (YEARS)	PROBABILITY OF MARRIAGE BETWEEN AGES x-1 AND x	AGE	PROBABILITY
3	.004	21	.041
4	.009	22	.033
5	.014	23	.026
6	.019	25	.015
7	.024	26	.010
8	.029	27	.007
9	.035	28	.005
10	.041	29	.003
11	.047	30	.001
12	.053	31 & above	*
13	.060		
14	.067		
15	.073		
16	.081		
17	.087		
18	.073		
19	.061		
20	.050		

* Value less than 0.001

Note: These are unconditional probabilities and add to 1.0

For a given age at marriage of wife, the husband's age at marriage can be adequately described by a Log Normal Distribution. The fit of the Log Normal distribution for various given ages at marriage of wife are presented in Table 3.4.

The above fits were accomplished as follows. In each case, a normal distribution was fitted to the logarithmic values of husband's age. The method used in fitting was the method of moments. The two moments used were the mean and standard deviation of the logarithmic value of husband's age at marriage. These two moments were separately regressed on wife's age at marriage.

For a currently married woman aged x in the initial population, her age (w) at marriage was computed according to the procedure described in Section 3.5. Having computed the age at marriage w of wife, the mean and S.D. were estimated by the relationships

$$\hat{\mu}_w = A_1 + A_2 w + A_3 w^2 + \cdots$$
$$\hat{\sigma}_w = B_1 + B_2 w + B_3 w^2 + \cdots$$

The husband's age at marriage (in log. value) was known to be distributed as a normal distribution, viz., $N(\hat{\mu}_w, \hat{\sigma}_w)$. With the help of a normal random variable, the value of log H was decided where H was the age at marriage of the husband the estimated regression coefficients A_i and B_i are presented in Table 3.5.

It is possible that the age (H) at marriage of husband computed in the above manner could be lower than the age (w) at marriage of wife. In the context of India, such a situation is unlikely. It is believed that husband's age is always, except in the case of very late marriage for a woman, higher than the wife's age. In the case of a very late marriage for a woman, her husband's age may be equal to her age. In the observed data, as presented in Table 3.4, only a few cases were reported where the husband's age at marriage was slightly lower than that of his wife. The fact that the responses in the survey were obtained several years after marriage and that there may have been misreporting of ages on account of memory error and other reasons might explain the discrepancy.

In order to take care of the restriction, namely, the husband's age at marriage should not be lower than that of wife, the log-normal distribution discussed above was truncated at the wife's age at marriage. Having thus obtained the age (H) at marriage of husband, the duration (D) of ceremonial marriage was added to H in order to get the present age of her husband. The computation of duration of ceremonial marriage is discussed in Section 3.5. The above procedure was applied in the case of women in the initial population who were already married and were currently in the married state.

Up to this point, for a woman in the initial population already married, the functional form of the log-normal was used to compute her husband's age at marriage. For marriages to single women, occurring during the period of simulation, a slightly different form of input data was used, namely, a matrix of conditional probabilities describing husband's age at marriage for a given age at marriage of wife. The procedure is discussed in the next section.

3.7 Marriages to Single Women During the Period of Simulation

During the period of simulation, no distinction was made between a ceremonial and an effective marriage. All marriages were treated as

TABLE 3.4

FITS OF LOG-NORMAL DISTRIBUTIONS TO AGE AT MARRIAGE[1] OF HUSBAND IN EACH MARRIAGE-AGE-GROUP OF WIFE

Husband's age at marriage (Years)	Wife's age at marriage (years)														
	0-5		6-11		12-14		15-16		17-21		22-26		27+		
	OBS	EXP	OBS	EXP	OBS	EXP	OBS	EXP	OBS	EXP	OBS	EXP	OBS	EXP	
0-5	.31	.41	*	.01	.00	*	.00	*	.00	*	.00	.00	.00	*	
6-11	.55	.42	.27	.32	.01	.02	.00	*	.00	*	.00	.00	.00	*	
12-14	.07	.08	.28	.25	.09	.11	.01	.03	*	.01	.00	.00	.00	*	
15-16	.03	.03	.18	.14	.20	.14	.05	.07	.01	.03	.00	*	.00	*	
17-21	.03	.04	.19	.19	.45	.40	.51	.36	.26	.22	.07	.04	.02	*	
22-26	.01	.01	.05	.06	.17	.23	.28	.33	.42	.33	.21	.20	.07	.04	
27+	.00	.01	.02	.02	.08	.09	.15	.21	.31	.41	.71	.76	.91	.96	
All ages	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
Sample Size	742		4521		5140		3319		2705		575		410		17512
(Prop. of Total sample)	(.0427)		(.2597)		(.2951)		(.1906)		(.1553)		(.0331)		(.0237)		(1.0000)

*Negligible value

[1] Ceremonial marriage

TABLE 3.5

POLYNOMIAL REGRESSION COEFFICIENTS USED IN THE ESTIMATION OF AGE AT MARRIAGE OF HUSBAND [2]

Regression Coefficient	Parameter estimated	
	μ	σ
Intercept	1.48413	0.79412
Linear	0.16397	-0.07625
Quadratic	-0.00456	0.00331
Cubic	0.00004	-0.00004

---

[2] The independent variable in the regression equation is the age at marriage of wife. If H is the age at marriage of husband, $(\log_e H) \sim N(\hat{\mu},\hat{\sigma})$.

effective marriages and the date of marriage of a woman was considered to be the beginning of her reproductive life in the simulation.

If effective marriage alone were treated as the marriage, a large number of girls would have had their marriages between their 15th and 16th year of age for the following reasons. In India, the age at menarche is between 13 and 14 years of age and for girls married before that age, marriage is usually consummated within a year after their first menstruation. Thus it was assumed that all ceremonial marriages occuring before age 15 of the bride were consummated between 15 and 16 years of age. It was further assumed that marriages occuring beyond age 15 of bride were consummated at the time of marriage.

The total probability of marriage up to age 16 was thus taken as the conditional probability that a single girl aged 15 would be married before age 16. The conditional probabilities of marriage at different ages are presented in Table 3.6. Using these probabilities, the age at marriage of a woman getting married during the period of simulation was computed. Using the age of the bride, the groom's age was decided by the truncated log-normal distribution discussed in Section 3.6. the only difference in this case, as mentioned earlier, was in the form of the input data. The probabilities under the truncated log-normal corresponding to each age of bride were computed beforehand and were input in the form of a matrix.

TABLE 3.6

CONDITIONAL PROBABILITY OF MARRIAGE AT EACH AGE FOR SINGLE WOMEN

AGE OF SINGLE WOMAN x (YEARS)	PROBABILITY OF MARRIAGE BEFORE AGE x+1
15	.5531
16	.1952
17	.2048
18	.2152
19	.2265
20	.2385
21	.2510
22	.2638
23	.2757
24	.2852
25	.2890
26	.2822
27	.2580
28	.2110
29	.1447

Note: Probabilities at further ages are not presented in this table since only less than one percent of all marriages take place beyond age 30.

Each value in this table represents the probability that a woman will get married between ages x and x+1 given that she is single up to age x.

CHAPTER IV

ESTIMATION OF MONTHLY PROBABILITIES OF LIVE BIRTH FOR CURRENTLY MARRIED WOMEN BY AGE AND PARITY

4.1 Introduction

The monthly chance of conception, known as fecundability, has been estimated by several authors. Potter and Parker [30] considered the number of conceptions by susceptible month of occurrence for a group of women. They hypothesized that fecundability would be constant over time for the same woman, but would vary from one woman to another in the manner of a Pearson Type I distribution.

Mukerji and Venkatacharya [26] attempted to estimate fecundability from a different type of basic data. They considered age specific birth rates of currently married women and obtained monthly probabilities by age on the assumption that the monthly probability of a live birth in any age group follows a geometric distribution. By further assuming a constant proportion of fetal deaths and fixed lengths of amenorrhea following a fetal death and live birth, they arrived at estimates of fecundability.

James [18] estimated fecundability on the basis of completed family size by two methods: first, with no allowance made for variation in fecundability from one woman to another, and second, with allowance made for such variation.

The above studies attempted to estimate fecundability varying with age, but no attempt was made to estimate the fecundability for women of the same age but with different parities.

In the present study we needed the monthly probabilities of a live birth for women by age and order of live birth. In this chapter, a method of estimating such probabilities from a cross-sectional fertility table of ever-married women by age and order of live birth is described.

4.2 The Model

The model assumes that births to a woman, during a time interval of length t, are random events in time. It further assumes that the probability of a birth to a woman during a small interval of time dt is independent of the number of previous births to that woman, and that the probability of more than one birth during the interval dt is zero.

It follows that the probability of a birth during a small interval of time dt is given by ydt where y is a positive constant. In view of the above assumptions, the process is a Poisson process, and the probability of exactly x births during a time interval of length t is given by

$$p(x/vt) = \frac{e^{-yt} (yt)^x}{x!} \quad . \tag{1}$$

For a fixed value of t, we may write vt=y so that (1) becomes

$$p(x/y) = \frac{e^{-y} y^x}{x!} \quad . \tag{2}$$

This is the situation when the probability of birth during a small interval of time is the same for all women. However, when this probability varies from one woman to another, y has a probability density say $\phi(y)$ and the process becomes a mixed Poisson process with the unconditional distribution of x given by

$$p(x) = \int_y \phi(y) \frac{e^{-y} y^x}{x!} dy \quad . \tag{3}$$

Having hypothesized that, for fixed t, the conditional distribution of x given y is a Poisson distribution with mean y=vt, if we further specify that y follows a Gamma distribution given by

$$\phi(y) = \frac{\theta^\lambda}{\Gamma\lambda} e^{-\theta y} y^{\lambda-1} \tag{4}$$

where $\lambda > 0$, $\theta > 0$, $y \geq 0$,

then

$$p(x) = \frac{\lambda+x-1}{x} \left(\frac{\theta}{1+\theta}\right)^\lambda \left(\frac{1}{1+\theta}\right)^x \tag{5}$$

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

which is a negative binomial distribution.

It can be easily seen that

$$E(x) = \frac{\lambda}{\theta} \quad , \tag{6}$$

and

$$\mathrm{var}(x) = \frac{\lambda}{\theta} + \frac{\lambda}{\theta^2} \quad . \tag{7}$$

Ottestad [27] derived the negative binomial distribution from the assumption that a mixed Poisson distribution has the following property

$$E(y|x) = Ax+B \tag{8}$$

This can be exploited to obtain the monthly probability of a live birth for a woman with a specified order of live birth.

We have

$$E(y|x) = \frac{1}{p(x)} \int_y p(x,y)\ y\ dy \tag{9}$$

From equation (3) and (4) we know

$$p(x,y) = \frac{\theta^\lambda}{\Gamma\lambda} e^{-\theta y} y^{\lambda-1} \frac{e^{-y}y^x}{x!} \tag{10}$$

which, when substituted, equation (9) becomes

$$E(y|x) = \frac{1}{p(x)} \cdot \frac{1}{x!} \cdot \frac{\theta^\lambda}{\Gamma\lambda} \int_y e^{-y(\theta+1)} y^{\lambda+x} dy \tag{11}$$

By substituting the value of p(x) from equation (5) and simplifying, we get

$$E(y|x) = \frac{x+\lambda}{\theta+1} \tag{12}$$

so that

$$E(v|x) = \frac{x+\lambda}{\theta+1} \cdot \frac{1}{t} \tag{13}$$

If data are available in the form of a distribution of women by number of children ever born specified by duration of marriage, then the value of t in the above model will be the duration of marriage in months, while λ and θ are the parameters of the Negative Binomial distribution given by (5) under the hypothesized model. Knowledge of the values of t and of estimated values of λ and θ will enable us to use the relationship (13) to compute E(y) for specified values of x=0,1,2....

4.3 Data Available

A fertility table is usually published in the form of a cross-classification of ever-married women by age and number of live births at the time of survey. Such a classification was available for parts of India, but not for the country as a whole. Some of the sources of such data were: the Gujarat Post Censal Fertility Survey [40], the Fertility Survey of Athur Block in Gandhigram [37], Differential Fertility of Central India [5], and the Fertility Survey of Kanpur [21]. In all of these sources, except the first, either the sample size was very small or the entire reproductive age-span was grouped into two or three broad age groups. Data from the Gujarat Survey were available in quinquennial age groups 13-17, 18-22,..., 43-47 and 48 and over, and were based on a sample of over 44000 women. In addition, these were the most recent data, having been collected in 1962.

To estimate the monthly probability of a live birth for a currently married woman, by means of the model discussed in Section 4.2, the data from the Gujarat Survey were used.

4.4 Estimation of Negative Binomial Parameters λ and θ

The functional form of the Negative Binomial distribution is given by equation (5). As explained in Section 4.3, the distribution of ever-married women by number of children ever born was available separately for each of the quinquennial age groups, 13-17,19-22,...43-47.

In each age group, the Negative Binomial Distribution was fitted by the Method of Maximum Likelihood; this method has been discussed by R. A. Fisher in a note on the efficient fitting of the Negative Binomial Distribution [2]. The maximum likelihood estimates of the parameters λ and θ are presented in Table 4.1.

The fit of the Negative Binomial Distribution in each age group is shown in Table 4.2. The fits were not acceptable according to the chi-square goodness of fit test criterion. This is understandable in view of the large sample size. However, the fits were considered adequate for modelling purposes in the present study.

4.5 Estimation of Average Duration (t) of Marriage per Ever-Married Woman

Since the required monthly probabilities of live birth were for currently married women, an ideal form of data would have been a cross-classification of currently married women by duration of marriage and order of live birth. But the data at hand represented a tabulation of ever-married women by age.

The age of an ever-married woman does not provide information on the period of susceptibility to birth. The duration of marriage may be used as the period of susceptibility. Thus is was necessary to estimate the average duration of marriage per ever-married woman in each age group. Such an estimation was attempted by subjecting a cohort of women to a set of specified marriage and widowhood probabilities, as follows.

Conditional probabilities of marriage for women between ages x and x+1 were estimated earlier in Chapter 3. The probability that a woman will become widowed between ages x and x+1, given that she is currently married at age x, is given by the formula

$$P_x^w = P_x^f \; (1-P_{x+d}^m) \quad ,$$

where

P_x^f = probability of female surviving from age x to x+1,

P_x^m = probability of male surviving from age x to x+1 and

d = age difference between wife and husband.

The survival probabilities between ages x and x+1 for men and women were taken from the Official Life Tables of India.

A cohort of 1,000,000 single women was taken at the lowest marriageable age, advanced to later ages with the help of appropriate survival probabilities, and married according to the appropriate probabilities of marriage. Similarly, the currently married women at each age were survived to later ages and subjected also to the risk of widowhood with the help of specified widowhood probabilities. Thus the original cohort of single women was depleted, as it was aged, due to death and marriage, while the married group was depleted due to death and widowhood.

TABLE 4.1

ESTIMATED VALUES OF λ AND θ IN EACH AGE GROUP

AGE GROUP	VALUE OF $\hat{\lambda}$	 $\hat{\theta}$
13-17	.9332	8.5302
18-22	13.6166	15.0526
23-27	8300.9038	3604.2307
28-32	7008.9932	1925.2302
33-37	163.0303	34.8877
38-42	28.8372	5.6214
43-47	17.2233	3.3125

TABLE 4.2

FIT OF NEGATIVE BINOMIAL DISTRIBUTION TO EVER MARRIED WOMEN BY ORDER OF LIVE BIRTH, IN EACH AGE GROUP

AGE GROUP		ORDER OF LIVE BIRTH									TOTAL	SAMPLE SIZE
		0	1	2	3	4	5	6	7	8+		
13-17	OBS	.9021	.0863	.0115	.0						1.0	1216
	EXP	.9017	.0883	.0090	.0						1.0	
18-22	OBS	.4269	.3278	.1755	.0558	.0118	.0023	.0			1.0	7904
	EXP	.4165	.3533	.1609	.0522	.0135	.0030	.0001			1.0	
23-27	OBS	.1180	.1775	.2597	.2468	.1377	.0487	.0101	.0014	.0	1.0	7882
	EXP	.1000	.2302	.2650	.2035	.1172	.0540	.0207	.0068	.0026	1.0	
28-32	OBS	.0573	.0667	.1254	.1985	.2333	.1784	.0940	.0336	.0119	1.0	8462
	EXP	.0263	.0956	.1739	.2110	.1920	.1398	.0848	.0441	.0326	1.0	
33-37	OBS	.0452	.0434	.0726	.1123	.1621	.2009	.1656	.1174	.0804	1.0	4862
	EXP	.0100	.0453	.1036	.1588	.1837	.1710	.1334	.0898	.1045	1.0	
37-42	OBS	.0430	.0417	.0622	.1015	.1262	.1592	.1705	.1411	.1548	1.0	5303
	EXP	.0089	.0388	.0874	.1356	.1630	.1617	.1377	.1035	.1634	1.0	
43-47	OBS	.0449	.0433	.0718	.0856	.1348	.1476	.1584	.1250	.1886	1.0	3049
	EXP	.0106	.0425	.0897	.1333	.1563	.1538	.1321	.1016	.1799	1.0	

The model assumes that consummation of marriage does not take place before age 15 even though the ceremonial marriage does take place before that age. For women in the married state in age group 15-16, an average duration of (effective) marriage equal to 0.5 years was assigned. Thus the average age at (effective) marriage for women still married at age x was computed. The difference between the average age at marriage and x was thus the average duration of marriage D_x^m for a currently married woman aged x.

The model assumes that marriage and widowhood do not take place in the same year. Thus for a woman who becomes widowed in the age group 16-17, it assumes that her marriage had taken place while she was in the age group 15-16, and accordingly a marriage duration of 0.5 years was assigned. The average duration of (effective) marriage for a widow at age x is specified by D_x^w.

If K_x^m and K_x^w are the observed number of married and widowed women at age x in the population under consideration, then the average duration of marriage per ever-married woman in the age group x to x+n is given by

$$D^E_{x,x+n} = \sum_{i=0}^{n-1} \left[K^m_{x+i}\ D^m_{x+i} + K^w_{x+i}\ D^w_{x+i}\right] \Big/ \sum_{i=0}^{n-1} \left[K^m_{x+i} + K^w_{x+i}\right] .$$

The average duration (t), in months, of marriage per ever-married woman by current age is presented in Table 4.3.

It may be noted that in the computations, it was assumed that the pattern of first marriage and of widowhood had remained constant over the past 30 years and widow remarriages were nil.

TABLE 4.3

AVERAGE DURATION OF MARRIAGE PER EVER-MARRIED WOMAN IN EACH AGE GROUP

AGE GROUP	AVERAGE DURATION OF MARRIAGE (MONTHS) PER EVER-MARRIED WOMAN
13-17	11.38
17-22	43.37
23-27	88.98
28-32	140.56
33-37	194.43
38-42	245.65
43-47	285.09

The value of d, the age difference between wife and husband, was varied from 5 to 8 years, and the effect of such variation on the average duration of marriage per ever-married woman was negligible.

It may be pointed out that the value of t corresponding to each age group is the estimated average duration of marriage, in months, per ever-married woman in that age group. Substitution of average marriage duration for t in the above model, however, may not be justified. In the present situation, where women had differing lengths of exposure to marriage, the average value, rather than the maximum possible value of t, was considered appropriate.

It may be noted that the monthly probabilities estimated in this chapter are those of live births and not of conceptions. In other words, we have been dealing with only the effective fecundability. From this point of view, in the simulation, a birth was not permitted to occur to a woman within nine months from the date of her marriage or from the date of her last live birth.

4.6 Monthly Probabilities of Birth for Currently Married Women by Parity and by Original Age Groups

Estimates of λ, θ and t were obtained for each age group according to the procedures discussed in Sections 4.4 and 4.5. The monthly probability of live birth for a currently married woman belonging to a specified age group, given that she had already had x live births, x=0,1,2..., was estimated with the help of relationship (13) using the corresponding estimates of λ, θ and t. Monthly probabilities of live birth by parity are presented in the first half of Table 4.4 for each of the original age groups.

These probabilities, known as the unadjusted probabilities, need some comment. As an example, for a currently married woman of zero parity, the monthly probability of a live birth is 0.0086 if she is in the age group 13-17 and it is 0.0196 if she is in the age group 18-22. These are the average monthly probabilities based on the entire marriage duration starting from the date of marriage.

The monthly probability averaged over marriage duration (say d_1) corresponding to age group 13-17 is smaller in magnitude than the monthly probability averaged over the duration (say d_2) corresponding to the age group 18-22. Obviously the average monthly probability during (d_2-d_1) months must be greater in magnitude than 0.0196. In other words, the monthly probability of a further birth operating on the woman while she is in the age group 18-22, given that she had zero births thus far, should be greater than 0.0196.

By the same logic it may be seen that, for example, for a woman of zero parity, the probability of a birth occurring during the time she is in the age group 43-47 should be lower than 0.0140.

Thus an adjustment was needed in the monthly probabilities presented in the first half of Table 4.4, in order to make them applicable for the period a woman was in the specified group.

4.7 Adjusted Monthly Probabilities of Birth

We know from the first half of Table 4.4 that a woman of parity n who is in the age group (x,x+5) has monthly birth probability, averaged over her entire marriage duration, equal to, say, $p_{x,x+5}(n)$. We do not know her age when she had her nth birth or (n-1)th birth. Nor do we know her duration of marriage at the time of her nth and (n-1)th births.

In the absence of such knowledge, only a crude adjustment could be effected in the birth probabilities and is described below.

A woman who had already had n births and who was in the age group (x,x+5) was assumed to have had her nth birth either in the age group (x,x+5) or in the age group (x-5,x). Also it was assumed that she had her (n-1)th birth either in the age group (x-5,x) or in the age group (x-10,x-5). In other words, it was assumed she had had her nth birth in either of the two quinquennial age groups centering at age x, and the (n-1)th birth in either of the two quinquennial age groups centering at age (x-5). Let us denote the probability (unadjusted) of a birth for a woman in age group (x,x+5), given that she has already had her nth birth, by $p_{x,x+5}(n)$ and the probability (unadjusted) of a birth for a woman in the age group (x-5,x), given that she has already had her (n-1)th birth, by $p_{x-5,x}(n-1)$. Then the adjusted probability of birth for a woman who has already had n births so far and who is in the age group (x,x+5) is taken as

$$p^*_{x,x+5}(n) = \frac{d_x \cdot p_{x,x+5}(n) - d_{x-5} \cdot p_{x-5,x}(n-1)}{d_x - d_{x-5}}$$

where

d_x = duration of marriage of a currently married woman aged x years,

and

d_{x-5} = duration of marriage of a currently married woman aged x-5 years.

TABLE 4.4

PROBABILITY OF LIVE BIRTH FOR CURRENTLY MARRIED WOMEN BY PARITY AND BY ORIGINAL AGE GROUPS

PARITY	AGE GROUP 13-17	18-22	23-27	28-32	33-37	38-42	43-47
			UNADJUSTED PROBABILITIES				
0	.0086	.0196	.0259	.0259	.0233	.0177	.0140
1	.0178	.0210	.0259	.0259	.0235	.0183	.0148
2	.0270	.0224	.0259	.0259	.0237	.0190	.0156
3	.0363	.0239	.0259	.0259	.0238	.0196	.0164
4	.0455	.0253	.0259	.0259	.0239	.0202	.0173
5 & over	.0547	.0267	.0259	.0259	.0241	.0202	.0181
			ADJUSTED PROBABILITIES				
0	.0086	.0289	.0293	.0259	.0181	.0007	.0000
1	.0178	.0315	.0293	.0259	.0185	.0031	.0031
2	.0270	.0263	.0286	.0259	.0190	.0052	.0047
3	.0363	.0212	.0278	.0259	.0194	.0072	.0063
4	.0455	.0160	.0270	.0259	.0198	.0093	.0080
5 & over	.0547	.0108	.0262	.0259	.0203	.0013	.0096

Note: The values in the table are reduced to 4 decimal places for convenience in presentation.

As mentioned earlier, the purpose of the adjustment was to convert the monthly probability, which is an average over the entire duration of marriage, into a probability operating during the period a woman is in the specified age group. No adjustment was effected in the probabilities in the first age group 13-17 since the date of effective marriage of a currently married woman in this age group was presumably within that age group.

The adjusted monthly probabilities of birth for currently married women of different parities are presented in the second half of Table 4.4, in the original age groups.

Adjustment in the original probabilities could probably be effected by assumptions different from those formulated here, but such an adjustment would still be crude because we do not know the exact age of a woman at her n<u>th</u> birth and at her (n-1)<u>th</u> birth. For the purpose of simulation in the present study, the adjustment described above was considered adequate.

4.8 Monthly Birth Probabilities by Parity in the Conventional Age Groups

For all estimation thus far, the original age groups 13-17,..., 43-47 were retained. To obtain birth probabilities by parity in the conventional age groups 15-19,...,40-44, the following procedure was used.

Birth probabilities were regressed on age by means of an appropriate polynomial for each parity separately, and the birth probabilities corresponding to the mid-points of the age groups 15-19,..., 40-44 were estimated. They are shown in Table 4.5.

The birth probabilities specified by parity and age groups as given in Table 4.5 were used in the simulation.

4.9 Simulation Results Related to the Estimated Birth Probabilities

Using the monthly birth probabilities given in Table 4.5, a simulation was carried out on a sample of 3000 women, as a test run.

Only two of the simulation results will be discussed here--(i) Average number of children ever-born per currently married woman in each age group at the beginning of the simulation and (ii) Nuptial Fertility Rate (number of births in a year per 1000 married women aged 15-44) for the ten years of simulation.

(i) For currently married women at the beginning of simulation, the average parity in each group was computed and is compared in Table 4.6 with the average parity computed from acutal data from a survey [12] of the North-West Region of India. The state of Gujarat, the data of which were used in the estimation of birth probabilities, is a part of the North-West Region of India. The age groups used in the National Sample Survey were not the conventional five year age groups. In order to make the comparison easy, the values corresponding to the conventional age groups were read off from a free hand curve. The average parity in each age group thus obtained for the North-West Region of India are presented in Table 4.6.

(ii) Nuptial Fertility Rate[1] was computed for each of the ten

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[1] Nuptial Fertility Rate is defined as annual number of live births per 1000 currently married women aged 15-44 at the mid-year.

TABLE 4.5

MONTHLY PROBABILITY (ADJUSTED) OF LIVE BIRTH FOR CURRENTLY MARRIED WOMEN BY PARITY AND CONVENTIONAL AGE GROUPS

PARITY	AGE GROUP					
	15-19	20-24	25-29	30-34	35-39	40-44
0	.0185	.0308	.0301	.0215	.0101	.0011
1	.0246	.0321	.0298	.0215	.0116	.0039
2	.0253	.0272	.0288	.0238	.0127	.0034
3	.0267	.0230	.0273	.0252	.0142	.0039
4	.0282	.0188	.0258	.0267	.0158	.0044
5 & over	.0297	.0146	.0243	.0281	.0173	.0050

TABLE 4.6

AVERAGE PARITY OF CURRENTLY MARRIED WOMEN BY AGE: DATA ON NORTH-WEST REGION OF INDIA AND SIMULATION RESULTS

AGE GROUP	AVERAGE NUMBER OF CHILDREN EVER BORN PER CURRENTLY MARRIED WOMAN	
	INDIA[1] (N.W. REGION)	SIMULATED POPULATION[2]
15-19	0.5	0.53
0-24	1.9	1.93
25-29	3.1	3.26
30-34	4.1	4.49
35-39	5.0	5.88
40-44	5.5	6.31

[1] These averages are based on data from a National Sample Survey. The reporting of the number of live births is subject to memory error. Since the memory error usually increases with age, the degree of under estimation of the average parity increases as age increases. Memory error as a factor may explain at least a part of the difference between the average parities of India and those based on simulation results.

[2] Simulation is for 3000 women.

years of simulation and is shown in Table 4.7: Crude Birth Rates[2], which correspond to the above Nuptial Fertility Rates, are also given in the same table.

Various estimates of the crude birth rate of India are available, and these rates mostly range from 40 to 45 per 1000 population. A look at the crude birth rates in Table 4.7 and the comparison of the average parity by age in Table 4.6 indicates that the birth probabilities estimated in this chapter (Table 4.5) provide plausibe fertility indices.

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[2] According to the 1961 census of India, the proportion of currently married women aged 15-44 is 0.18 of the total population. The crude birth rates were obtained by multiplying the corresponding Nuptial Fertility Rates by 0.18.

TABLE 4.7

NUPTIAL FERTILITY RATES AND CRUDE BIRTH RATES

BASED ON A SIMULATION OF 3000 WOMEN

SIMULATION YEAR	NUPTIAL FERTILITY RATE (ANNUAL NUMBER OF BIRTHS PER 1000 CURRENTLY MARRIED WOMEN AGED 15-44)	CRUDE BIRTH RATE[1]
1	225.6	40.62
2	235.9	42.47
3	242.9	43.73
4	244.0	43.92
5	236.8	42.63
6	233.1	41.96
7	238.2	42.88
8	238.7	42.96
9	238.1	42.86
10	232.3	41.82

[1] Obtained by multiplying the corresponding N.F.R. by 0.18.

CHAPTER V

ESTIMATION OF PARAMETERS FOR THE FAMILY PLANNING MODULE

5.1 Operation of Family Planning Module

In this section a description of the operation of the Family Planning Module in POPSIM is presented. Change of present contraceptive state is one option among the list of competing events in POPSIM.

The Family Planning Module operates in three steps. In the first step, each currently married woman in the age range 15-44 years is assigned to a contraceptive state depending on her use-status at the beginning of simulation. Non-use of any form of family planning is one of the possible states and is called Null state. The second step of the operation consists of computing the date of change of her present contraceptive state. As described earlier, in generating the 'next event,' waiting times for the occurrence of all possible events such as birth, death, widowhood, etc. to which a person is eligible are computed and the event with the least waiting time is chosen as the 'next event' for that person. The third step determines which one of the other states the woman will enter. The first step corresponds to Initialization and the second and the third steps correspond to Event-generation in the general operation of POPSIM.

In using the family planning module, birth probabilities are modified in accordance with the contraceptive method each woman is currently using. If a woman is currently using contraceptive method j, then her monthly birth probability p_j is obtained as

$$P_j = P(1-E_j) \quad , \tag{1}$$

where

P = monthly birth probability with no contraceptive in use, and

E_j = use-effectiveness of contraceptive method j.

It should be noted that the use-effectiveness value of any contraceptive in the present study was assumed to remain constant with respect to and and/or family size of women.

It was further assumed that a woman did not practice any method of family planning immediately after a birth and she was therefore automatically placed in the Null state.

The three steps in the operation of the family planning module, namely, specification of initial contraceptive state, computation of date of change of current state and the switching from one contraceptive state to another were accomplished in the present study as discussed below.

5.2 Specification of Initial Contraceptive State

In the present study, the following four contraceptive states were considered:

(i) Null state or non-use of family planning (N)
(ii) Conventional contraceptive state (C)
(iii) IUD state (I)
(iv) Sterilization state (S)

Since there was not enough evidence that the family planning program in India has produced a noticeable reduction in the national birth rate, it was assumed at the beginning of simulation that the proportion practicing any method of family planning was nil. Thus every woman was initially placed in the Null state.

5.3 Change of Present State

As mentioned earlier, change of present contraceptive state is an event, and computation of the date of change is necessary in order to decide the 'next event' for a woman. In the computation of the date of change of present contraceptive state, the inverse of the cumulative exponential distribution was used for the following reasons.

It was assumed that when a woman in the Null state decides to adopt some method of family planning, she usually will do so very soon, as a delay may result in another birth. It was considered to be as the same case with a woman who decides to practice contraception after a certain child birth. According to a Taiwan study, the more recent the last live birth, the higher was the acceptance rate of some method of family planning [6].

Also, among women who accept an IUD or a conventional contraceptive, the discontinuation rate is usually very high in the months following acceptance. This rate becomes smaller as time passes. In other words, the probability that a woman using IUD or conventional contraceptive will change her current state becomes smaller as time increases and the rate of decline in this probability decreases with increasing time. Thus the probability of changing the current state, whether it be Null, IUD or conventional contraceptive, may be assumed to decline exponentially with time.

The probability that a woman of age (a) and family size (f) will change her current state at time t is given by the density function

$$f(a,f,t) = g(a,f)\ e^{-g(a,f)\cdot t} \tag{2}$$

where

t = time since last change.

The distribution function is

$$F(a,f,t) = 1-e^{-g(a,f)\cdot t}\quad . \tag{3}$$

In the usual manner a uniform random number R between 0 and 1 may be selected for that woman and equated to the right hand side of equation (3), in order to compute the waiting time t for change of present state. Thus we have

$$t = \frac{\ell n(1-R)}{-g(a,f)}\ . \tag{4}$$

In order to compute the value of t in (4), the value of g(a,f) is needed. Estimation of g(a,f) values for different values of age (a) and family size (f) is discussed separately for each of the states N, C, I and S in the following sections.

(i) Null State:

The data that would have been ideal for computing g(a,f) values for the Null state would have been proportions adopting some method of family planning in a specified period of time among women who had never used a method. These proportions were needed in each age-family size group. Such data were not available for India. For Taiwan, however, data on the proportion of women adopting family planning during a period of 2.5 years specified separately by age and by family size were available [6]. These proportions are presented in Table 5.1. The average annual proportions by age and family size were computed and are presented in the same table. These average annual proportions correspond to the experience of the Taiwan program during the first 2.5 years of its operation. If these proportions (acceptance rates) are assumed to increase in a linear fashion, the levels in the tenth year will be about three or four times the present level, because the program presumably becomes more efficient as time passes. In the present study, proportions twice as high as the average annual proportions observed so far in Taiwan were assumed to hold true for the tenth year of the program in the case of India. The assumed levels for the tenth year of simulation are also presented in Table 5.1. Based on these assumed levels (proportions) of the tenth year, the following computations were made.

The annual proportion of women of age (a) and family size (f) leaving the Null state was assumed to be of the following form

$$P(a,f) = A + B(a) + C(f) + D(a)f \quad .$$

If N(a,f) is the number of women with age (a) and family size (f) in the population, then

$$\frac{\sum_f N(a,f)\cdot P(a,f)}{\sum_f N(a,f)} = \text{annual proportion leaving the null state among women aged a.}$$

Similarly

$$\frac{\sum_a N(a,f)\cdot P(a,f)}{\sum_a N(a,f)} = \text{annual proportion leaving the null state among women of family size f.}$$

Thus the annual proportion leaving the Null state specified by age and by family size given in Table 5.1, can be used to obtain Least Squares estimators of A, B, C, and D. The values of N(a,f) were obtained from the initial distribution of women by age and number of living children resulting from the simulation of 3000 women.

Using the Least Squares Method of estimation of parameters, the regression equation[1] was obtained as

$$p(a,f) = .001304-.000156(a^*)+.124224(f)-.018678(a^*)\cdot f, \quad (5)$$

where

$p(a,f)$ = annual proportion leaving the Null state in the tenth year of simulation among women of age (a) and family size (f), and,

$a^* = (\text{age}-15)/5$.

The annual proportions leaving the Null state during the tenth year, among women belonging to different age-family size groups result-

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[1] Regression equations incorporating higher powers of a and f were tried and it was found that equation (5) was adequate.

TABLE 5.1

CUMULATIVE RATES OF ACCEPTANCE OF SOME METHOD OF FAMILY PLANNING OVER A PERIOD OF 2.5 YEARS, TAIWAN

	CUMULATIVE RATES FOR 2.5 YEARS	AVERAGE ANNUAL RATE	ASSUMED PROPORTION OF WOMEN LEAVING NULL STATE IN 12 MONTHS (ASSUMED TO HOLD FOR THE 10TH YEAR OF SIMULATION)
AGE GROUP			
15-19	N.A.	(.012)	.024
20-24	.20	.08	.16
25-29	.26	.10	.20
30-24	.26	.10	.20
35-39	.21	.08	.16
40-44	N.A.	(.03)	.06
FAMILY SIZE			
0	.03	.012	.024
1	.11	.04	.08
2	.19	.08	.16
3	.28	.11	.22
4	.27	.11	.22
5 & over	.30	.12	.24

Note: N.A.: Not available. Values in parentheses were assumed.

Source: Freedman and Takeshita, "Family Planning in Taiwan," page 164.

ing from the regression relationship (5), are presented in Table 5.2.

The p(a,f) values for the earlier years of simulation then remained to be decided. When a family planning program operates for ten years, it usually is expected to start moderately and gain momentum year after year. In other words, annual proportions adopting family planning (leaving the Null state) should increase from one year to the next. But it is difficult to say whether the proportions would increase at the same rate in all the age-family size groups. Consideration of a differential rate of increase on these proportions was not plausible due to the absence of such data. For simplicity in the present study, it was assumed that these proportions increased from one year to another at the same rate in all the age-family size groups.

One could assume a linear increase and obtain the proportions in any year K of simulation to be equal to $\frac{K}{10}$ P(a,p). It might also be argued that the adoption rate of family planning increases rapidly in the earlier years of program operation but later becomes stationary. In the present study the latter view was taken. From Table 5.2, it may be seen that the proportion of all women in the reproductive ages who adopted family planning in the tenth year of the program is 0.152. It was assumed that the overall proportion in year K is given by $[1-e^{-\alpha K}]$. Based on the tenth year proportion of 0.152, we have

$$\hat{\alpha} = \ell n(1-.152)/-10 = .016487 \quad (6)$$

The proportion $P_K(a,f)$ adopting family planning in year K among women of age (a) and family size (f) was obtained as

TABLE 5.2

PROPORTION[1] OF WOMEN LEAVING NULL STATE DURING A PERIOD OF 12 MONTHS IN TENTH YEAR OF SIMULATION BY AGE AND FAMILY SIZE

FAMILY SIZE	AGE GROUP					
	15-19	20-24	25-29	30-34	35-39	40-44
0	.0012	.0011	.0009	.0008	.0006	.0004
1	.1161	.0973	.0784	.0596	.0408	.0219
2	.2310	.1935	.1560	.1185	.0809	.0434
3	.3459	.2897	.2335	.1773	.1211	.0649
4		.3859	.3110	.2362	.1613	.0864
5 & over			.3886	.2950	.2015	.1079

overall proportion = 0.1520

---

[1] These proportions are obtained from regression relationship given by equation (5).

[*] Initial distribution of women by age and number of living children resulting from the simulation of 3000 women was used to obtain the weighted proportion.

$$P_K(a,f) = P(a,f) \quad \frac{1-e^{-\hat{\alpha}K}}{1-e^{-10\hat{\alpha}}} \tag{7}$$

where P(a,f) corresponds to the tenth year.

The corresponding g(a,f) value for the Kth year is given by

$$g_K(a,f) = \ell n[1-P_K(a,f)]/-12 \quad . \tag{8}$$

(ii) IUD State:

In order to compute g(a,f) values for different values of a and f, we once again needed data on the proportions of women, by age and family size, who left the IUD state during a specified period of time. On the basis of some studies conducted in India, such data were reported in the literature. Agarwala [1] gave cumulative net termination rates at the end of 24 months of observation of IUD use; these rates are presented in Table 5.3. For Taiwan, Potter and others [31] reported cumulative termination rates of IUD use during a period of 24 months of observation. It may be noted from Table 5.3 that the termination rates by age were lower in the case of India than those for Taiwan. This may have been either due to the fact that the Indian data were based on controlled clinical trails while the Taiwan data were from a mass program, or due to differences in study design.

If we had the distribution of IUD users by age and number of living children we could estimate the proportion P(a,f) of women leaving the IUD state by age and family size. In the absence of such data,

TABLE 5.3

CUMULATIVE TERMINATION RATES (PER 100 WOMEN) OF IUD DURING 24 MONTHS OF OBSERVATION, INDIA AND TAIWAN

	CUMULATIVE TERMINATION RATE	
	INDIA	TAIWAN
AGE GROUP		
24 & below	53.1	76.8
25-29	34.9	68.7
30-34	32.6	58.3
35-39	34.2	44.1
FAMILY SIZE		
1-3	45.3	N.A.
4-5	34.5	
6-7	30.9	
8+	29.3	

N.A.: Not available.

Sources: 1. Agarwala, S. N., "A follow-up study of intra-uterine devices: An Indian experience," Institute of Economic Growth, New Delhi, Mimeographed.

2. Potter, R. G., et al., "Taiwan's family planning program," Science, 24, Volume 160, May, 1968.

TABLE 5.4

PROPORTIONS (ASSUMED) OF WOMEN LEAVING IUCD STATE, FOR SELECTED VALUES OF AGE AND FAMILY SIZE, FROM WHICH REGRESSION PARAMETERS ARE ESTIMATED

FAMILY SIZE	AGE GROUP					
	15-19	20-24	25-29	30-34	35-39	40-44
0	.80	.85	.90	.95	.99	.99
1						
2		.70				
3			.60			
4				.50		
5					.40	
6	.15	.20	.25	.30	.35	.30

P(a,f) values for selected values of age and family size were arbitrarily chosen as shown in Table 5.4. Using the method of Least Squares estimation, the following relationship was obtained.

$$P(a,f) = .764133+.075735(a^*)-.096913(f)-.000913(a^*)(f) -.006343(a^{*2})-.001767(f^2) \quad (9)$$

where

$P(a,f)$ = proportion of women of age (a) and family size (f) leaving IUD state in 24 months and

$a^* = (\text{age}-15)/5$.

Since P(a,f) values are the proportions leaving the IUD state in a 24 month period, the corresponding g(a,f) values are given by

$$g(a,f) = \ell n[1-P(a,f)]/-24 \quad . \quad (10)$$

The proportions of women, by age and family size, leaving the IUD state during the 24 months after acceptance, as given by the regression equations (9), are presented in Table 5.5. It may be seen from this table that the proportions for a given family size increased with age. Also, the proportions in any given age group decreased by family size. This is the pattern one would usually expect.

(iii) Conventional Contraceptive State:

In India, at present, only three methods of family planning are offered on a large scale. These are sterilization, IUD and condom. In the present study the conventional contraceptive state was essentially equivalent to use of the condom. Though few data are avail-

TABLE 5.5

PROPORTION[1] OF WOMEN LEAVING IUD STATE OVER A PERIOD OF 24 MONTHS, BY AGE AND FAMILY SIZE

FAMILY SIZE	AGE GROUP					
	15-19	20-24	25-29	30-34	35-39	40-44
0	.8004	.8635	.9138	.9515	.9765	.9888
1	.7013	.7634	.8129	.8496	.8737	.8851
2	.5986	.6598	.7084	.7442	.7674	.7778
3	.4924	.5527	.6003	.6353	.6575	.6671
4		.4421	.4888	.5228	.5441	.5528
5 & over			.3737	.4068	.4272	.4349

---

[1] These proportions are obtained from regression relationship given by equation (9).

able on the length of continuous use of condoms by couples, it is often conjectured that the duration of continuous use is usually less than a year. In the present study, it was assumed that the proportion terminating continuous use of condoms by the end of 12 months after acceptance was 0.75. This proportion was further assumed to be constant with respect to age and family size. Thus the values of g(a,f) are given by

$$g(a,f) = \ell n(1-.75)/-12 \quad . \tag{11}$$

(iv) Sterilization State:

Though techniques have been developed to reverse sterilization, such reversals are very rare in India and clients are informed beforehand that the sterilization operation is an irreversible method of birth control. Failures in sterilization operations are assumed to be neglibible.

From this point of view, it appeared reasonable to assume for the present study that the proportion ever-leaving the sterilization state was zero. In view of this assumption, we have

$$g(a,f) = 0 \quad . \tag{12}$$

5.4 Levels of Adoption of Family Planning

In the design of the present experiment, as described in Chapter I, two levels of adoption patterns for family planning were included. Adoption of family planning is characterized by a change of state for women in the Null state. In order to describe the two levels of adoption patterns, we have specified two alternative sets of parameters corresponding to a change of Null state. The parameters for changing from the C, I and S states, however, were assumed to remain unchanged. The regression relationship given by equation (5) may be taken as corresponding to a Low Level of adoption pattern. For the second or High Level, P(a,f) values twice as large as those given by equation (5) were assumed.

In summary, the parameters corresponding to change of states C, I and S were unchanged for both levels of adoption patterns while in the case of the N state, the P(a,f) values are given by

$$P(a,f) = .001304-.000156(a^*)+.124224(f)-.018678(a^*)\cdot(f) \tag{13}$$

for the Low Level adoption pattern and

$$P(a,f) = .002608-.000312(a^*)+.248448(f)-.037356(a^*)\cdot(f) \tag{14}$$

for the High Level, where

$P(a,f)$ = proportion of women of age (a) and family size (f) leaving the Null state in 12 months during the tenth year of simulation and

$a^* = (\text{age}-15)/5$

From equation (7) of section 3(i), it may be seen that an adjustment factor $[1-e^{-\hat{\alpha}K})/(1-e^{-10\hat{\alpha}})]$ was necessary in order to compute P(a,f) values for the K<u>th</u> year of simulation. The values of $\hat{\alpha}$ corresponding to the two levels of adoption pattern are

$$\hat{\alpha} = .016487 \tag{15}$$

for the Low Level adoption pattern and

$$\hat{\alpha} = .036241 \qquad (16)$$

for the High Level.

5.5 Switching Patterns Between Contraceptive States

After the date of change of present state is computed, the next stage is to assign a new state to that woman. Given that a change from state i has occurred, what is required is the conditional probability of moving to state j. It may be recalled that this is the third step of operation of the family planning module.

Since there are four states in all, a 4x4 matrix of conditional probabilities is required. In the present study, it was assumed that these probabilities depended only on family size and not on age, so that the input consisted of one transition matrix for each family size. The assignment of a new state was determined as follows.

A woman of family size f, given that she had left state i, was assigned a new state K if

$$\sum_{j=1}^{K-1} v(p,i,j) < R \leq \sum_{j=1}^{K} v(p,i,j)$$

where

R = uniform random number between 0 and 1 selected for the woman and

v(p,i,j) = probability that a woman with family size p will move to state j given that she has left state i.

A switching pattern was thus characterized by a set of six transition matrices, one corresponding to each of the family sizes, 0,1,2,3,4 and 5 & over.

5.6 Levels of Switching Patterns

In accordance with the two switching patterns required in the design, two sets of matrices were prepared as input data. One set had higher probabilities of transition to the sterilization state from the remaining states, while in the other set the probabilities of transition to the IUD state were higher. The two switching patterns may therefore be named Sterilization oriented and IUD oriented switching patterns, respectively.

There was no actual data available from which these probabilities could have been computed. The matrices of transitional probabilities were arbitrarily specified based on the following considerations:

(i) Couples leaving the Null state switch to C, I or S. The higher the family size, the higher will be the probability of switching to a more effective method such as I or S.

(ii) Couples leaving the C state switch to the N state or to I or S. The higher the family size, the lower will be the probability of switching to the N state.

(iii) Couples leaving the I state switch to the S state more often (or at least as often) than couples leaving the N or C states. However, there is an upper limit to the proportion changing from the I state to any other contraceptive state. This maximum proportion, based on Taiwan data [6], was set at 0.6, while the remaining proportion, namely 0.4, were allowed to switch to the Null state.

The transition matrices in the case of the IUD and Sterilization oriented switching patterns are presented in Table 5.6.

TABLE 5.6

CONDITIONAL PROBABILITIES OF CHANGING FROM ONE STATE TO ANOTHER UNDER THE TWO LEVELS OF SWITCHING PATTERN

FAMILY SIZE		STERILIZATION ORIENTED PATTERN					IUD ORIENTED PATTERN			
		TO STATE					TO STATE			
	FROM STATE	N	C	I	S	FROM STATE	N	C	I	S
0	N	-	.50	.50	.0		SAME AS IN STERILIZATION ORIENTED PATTERN			
	C	.90	-	.10	.0					
	I	.90	.10	-	.0					
	S	*	*	*	*					
1	N	-	.25	.75	.0					
	C	.80	-	.20	.0					
	I	.80	.20	-	.0					
	S	*	*	*	*					
2	N	-	.10	.85	.05					
	C	.70	-	.25	.05					
	I	.70	.25	-	.05					
	S	*	*	*	*					
3	N	-	.05	.80	.15	N	-	.05	.85	.10
	C	.30	-	.50	.20	C	.30	-	.55	.15
	I	.50	.25	-	.25	I	.50	.25	-	.20
	S	*	*	*	*	S	*	*	*	*
4	N	-	.05	.70	.25	N	-	.05	.80	.15
	C	.25	-	.45	.30	C	.25	-	.55	.20
	I	.45	.20	-	.35	I	.50	.20	-	.30
	S	*	*	*	*	S	*	*	*	*
5	N	-	.05	.65	.30	N	-	.05	.75	.20
	C	.20	-	.40	.40	C	.20	-	.55	.25
	I	.40	.20	-	.40	I	.40	.20	-	.40
	S	*	*	*	*	S	*	*	*	*

---

* Change from sterilization state does not occur.

5.7 Use-Effectiveness Values for Contraceptive States

For each contraceptive method a use-effectiveness value was needed to adjust the birth probability correspondingly in the manner specified by equation (1) in section 5.1. If Ej is the use-effectiveness value for contraceptive method j, then (1-Ej) may be taken as follows.

$$1\text{-}Ej = \frac{\text{pregnancy rate with method j in use}}{\text{pregnancy rate with no method in use}} \cdot$$

Based on a sample of women attending family planning clinics in Bombay, Chandrasekaran and Kuder [3] estimated that the pregnancy rate (per 100 years of exposure), when the women were not using any form of contraception, was 64. This could have been slightly underestimated for the reason that it was based on a retrospective survey of clinic clientele. The authors did, in fact, mention that the true natural pregnancy rate would be slightly higher than their estimate.

Tietze and Lewit [38] reported pregnancy rates ranging from 2 to 10 for IUD on the basis of data collected in various countries.

From a study conducted by Poti and others on a residential sample of couples in Calcutta, Tietze [39] quoted a failure rate (pregnancy rate) of 23 for condoms. In the same study, a further breakdown of the sample into three social classes--upper, middle and laboring--yielded pregnancy rates of 12, 25 and 32, respectively. The value for the laboring class would be closer to what might be assumed for a mass program for India.

On the basis of the above discussion, it seemed reasonable to assume values of $(1-E_m)$ as 1.0 for the Null state, 0.5 for the conventional contraceptive state, 0.15 for the IUD state and 0.0 for the sterilization state.

5.8 Limitations of the Proposed Family Planning Program

The main limitation in the proposed family planning program is that the future contraceptive practice of a woman is not based on the entire past contraceptive experience. In a real life situation, the use-effectiveness, the continuity rates and the choice of method for switching may depend on the specific contraceptives previously used, and on the number of times, as well as the length of time, each contraceptive was used.

As a result of this limitation, no distinction was made between women who had never used a family planning method and women, having ever practiced family planning, who are presently in the Null state.

(ii) general fertility rate[2]

(iii) intrinsic rate of growth[3]

(iv) intrinsic birth rate[4]

(v) net reproduction rate[5]

The methods employed in computing the Intrinsic growth rate, the Intrinsic birth rate and the Net reproduction rate are given by Keytitz [19].

Using the six independent estimates given by the six sample populations, the annual means (arithmetic) and standard errors were computed for the five selected indices of fertility for each of the nine family planning strategies. The means and standard errors of the crude birth rate are presented in Table 6.2. The means and standard errors of the other four indices are given in Tables 6.3-6.6.

In all the Tables in this Chapter, the eight strategies are identified by code numbers which specify the levels of the three factors in the experiment. For convenience in reading these tables, a description of these codes is given in Table 6.1.

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by a factor equal to 0.49 which is the proportion of females in the total population, according to the 1961 census of India.

[2] General fertility rate is the annual number of births per 1000 mid-year female population between the ages of 15 and 45.

[3,4] A population closed to migration when subjected to a constant set of age-specific fertility and age-specific mortality rates for a long time, will attain a stable age-structure. The birth and death rates of a stable population are called Intrinsic or Stable birth and death rates. The difference between the Intrinsic birth and death rates is called Intrinsic rate of Growth

[5] The expected number of female children to which a female child now born will give birth, based on the present fertility and mortality

CHART 6.1

SUMMARY DESCRIPTION OF FACTORS AND THEIR LEVELS IN THE 2^3 FACTORIAL DESIGN

FACTOR					
1		2		3	
ELIGIBILITY FOR STERILIZATION		ADOPTION OF FAMILY PLANNING		SWITCHING BETWEEN CONTRACEPTIVE METHODS	
LEVEL 1	LEVEL 2	LEVEL 1	LEVEL 2	LEVEL 1	LEVEL 2
Minimum 2 children, at least 1 boy aged 3 years or more or Minimum 3 children and no restriction on age and sex	Minimum 3 children, at least 1 boy aged 3 years or more or Minimum 4 children and no restriction on age and sex	High level adoption pattern detailed in Section 5.4 Chapter V	Low level adoption pattern detailed in Section 5.4 Chapter V	Sterilization oriented switching pattern detailed in Section 5.6 Chapter V	IUD oriented switching pattern detailed in Section 5.6 Chapter V

TABLE 6.1

CODES USED FOR DIFFERENT FAMILY PLANNING STRATEGIES AND THEIR DESCRIPTION

F.P. STRATEGY	CODE	DESCRIPTION OF F.P. STRATEGY ELIGIBILITY FOR STERILIZATION	ADOPTION PATTERN	SWITCHING PATTERN
1	111	Minimum 2 children, 1 boy, age 3 years...	High level	Sterilization oriented
2	112	Minimum 2 children, 1 boy, age 3 years...	High level	IUD oriented
3	121	Minimum 2 children, 1 boy, age 3 years...	Low level	Sterilization oriented
4	122	Minimum 2 children, 1 boy, age 3 years...	Low level	IUD oriented
5	211	Minimum 3 children, 1 boy, age 3 years...	High level	Sterilization oriented
6	212	Minimum 3 children, 1 boy, age 3 years...	High level	IUD oriented
7	221	Minimum 3 children, 1 boy, age 3 years...	Low level	Sterilization oriented
8	222	Minimum 3 children, 1 boy, age 3 years...	Low level	IUD oriented
9	CONTROL	none	none	none

TABLE 6.2

MEAN AND STANDARD ERROR OF CRUDE BIRTH RATE FOR TEN YEARS OF SIMULATION UNDER SPECIFIED FAMILY PLANNING STRATEGIES AND CONTROL

YEAR	FAMILY PLANNING STRATEGY CODE									
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	45.3	1.6	43.7	1.5	47.1	1.0	46.6	1.3	46.4	0.7
2	40.8	1.4	42.3	1.6	41.2	1.2	44.8	0.6	44.0	2.1
3	39.1	0.8	38.3	1.2	42.1	1.4	43.2	1.7	41.8	1.2
4	35.5	0.7	35.8	1.8	39.6	1.0	37.9	1.1	36.1	0.9
5	31.8	0.5	35.2	1.4	39.6	0.5	33.8	1.2	34.3	1.1
6	30.3	0.9	32.7	1.5	35.2	1.3	34.6	2.0	30.9	1.0
7	27.1	1.9	31.2	1.0	33.2	0.6	31.9	0.9	31.1	0.8
8	26.9	1.3	29.2	0.5	30.0	0.9	34.3	0.8	29.0	0.7
9	25.6	1.6	29.3	0.7	32.2	1.0	32.5	1.2	26.0	1.4
10	26.5	1.2	25.8	0.3	30.8	1.6	32.5	0.6	27.6	1.7

TABLE 6.2

CONTINUED

YEAR			FAMILY PLANNING STRATEGY CODE					
	212		221		222		CONTROL	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	46.8	0.7	45.2	1.9	49.3	1.3	45.8	0.9
2	43.3	1.0	44.2	1.5	42.7	0.8	46.4	1.9
3	41.7	2.0	39.7	0.8	41.9	1.4	45.6	0.8
4	35.6	0.8	37.9	1.3	38.4	0.6	43.5	1.4
5	35.5	0.9	35.0	0.8	35.4	0.9	42.6	1.2
6	31.2	1.5	35.5	0.9	36.0	0.6	42.3	1.3
7	29.5	1.0	35.5	1.2	34.2	1.2	40.4	1.1
8	27.9	1.0	30.3	1.0	32.2	1.0	39.6	1.5
9	27.0	1.2	30.0	0.9	32.4	0.5	40.7	0.7
10	27.7	1.3	32.6	1.0	30.3	1.3	41.6	1.2

Note: Mean and S.E. were computed from the estimates of the six independent sample populations.

TABLE 6.3

MEAN AND STANDARD ERROR OF GENERAL FERTILITY RATE FOR TEN YEARS OF SIMULATION UNDER SPECIFIED FAMILY PLANNING STRATEGIES AND CONTROL

YEAR			FAMILY PLANNING STRATEGY CODE							
	111		112		121		122		221	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	203.7	7.60	197.4	7.10	213.2	4.80	210.4	6.60	209.2	3.40
2	185.5	6.70	191.7	7.60	188.6	6.00	205.0	3.20	200.7	10.00
3	178.2	3.70	174.3	5.80	194.0	6.70	199.5	7.80	192.0	5.50
4	161.6	3.80	163.2	8.30	183.4	4.80	175.6	4.90	166.4	4.10
5	144.3	2.50	159.7	6.70	184.9	2.40	156.3	6.30	157.3	5.60
6	137.0	4.70	148.1	7.30	164.5	6.30	158.9	9.10	141.5	5.40
7	121.6	8.60	140.8	4.50	153.5	3.50	146.0	4.00	141.4	3.90
8	119.8	6.40	130.8	2.10	138.3	4.30	156.1	3.70	130.7	4.10
9	112.1	7.00	129.7	3.70	146.7	4.80	147.3	6.30	115.9	6.20
10	114.6	5.40	112.5	1.40	140.1	7.80	146.4	2.50	122.0	8.00

Note: Mean and S.E. were computed from the estimates of the six independent sample populations

TABLE 6.3

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE						CONTROL	
	212		221		222			
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	211.1	3.30	203.4	8.80	222.9	5.90	206.7	4.20
2	197.0	4.80	202.1	7.60	194.4	4.20	211.5	8.80
3	191.1	9.80	182.9	4.10	192.3	6.80	208.7	3.70
4	162.8	3.60	175.8	6.30	176.9	3.30	200.0	6.50
5	142.8	3.80	161.9	3.60	162.2	4.50	197.6	6.20
6	162.3	7.20	163.9	4.30	165.5	2.30	197.6	6.20
7	133.3	4.50	164.0	5.80	156.8	6.20	188.0	5.80
8	124.8	4.60	138.6	4.80	146.7	4.80	184.9	7.50
9	119.6	5.10	136.0	4.10	146.5	3.20	190.3	4.00
10	121.2	6.50	146.0	4.60	135.1	5.60	194.6	5.40

TABLE 6.4

MEAN AND STANDARD ERROR OF INTRINSIC RATE OF GROWTH FOR TEN YEARS OF SIMULATION UNDER SPECIFIED FAMILY PLANNING STRATEGIES AND CONTROL

YEAR	FAMILY PLANNING STRATEGY CODE									
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	2.5	0.17	2.5	0.14	2.6	0.10	2.7	0.16	2.5	0.18
2	2.0	0.12	2.0	0.21	2.1	0.18	2.5	0.16	2.2	o.15
3	2.0	0.14	1.8	0.16	2.2	0.15	2.4	0.11	2.3	0.12
4	1.5	0.14	1.6	0.10	2.2	0.10	1.9	0.15	1.7	0.15
5	1.1	0.13	1.5	0.16	2.1	0.14	1.6	0.19	1.4	0.27
6	1.1	0.19	1.3	0.12	1.6	0.17	1.4	0.31	1.1	0.17
7	0.6	0.40	1.2	0.14	1.3	0.23	1.4	0.15	1.2	0.19
8	0.6	0.21	1.0	0.02	1.0	0.12	1.5	0.21	0.9	0.07
9	0.4	0.39	0.9	0.13	1.5	0.22	1.3	0.31	0.6	0.24
10	0.7	0.23	0.2	0.20	1.2	0.33	1.5	0.18	0.6	0.32

TABLE 6.4

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE							
	212		221		222		CONTROL	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	2.6	0.11	2.4	0.30	2.7	0.22	2.3	0.12
2	2.3	0.19	2.7	0.17	2.1	0.10	2.5	0.14
3	2.3	0.23	2.1	0.06	2.2	0.15	2.4	0.09
4	1.6	0.12	1.9	0.22	2.1	0.14	2.2	0.12
5	1.6	0.22	1.8	0.13	1.5	0.16	2.4	0.12
6	1.0	0.24	1.7	0.15	1.9	0.05	2.3	0.15
7	1.1	0.19	1.9	0.21	1.9	0.20	2.3	0.19
8	0.8	0.19	0.7	0.20	1.3	0.21	2.3	0.19
9	0.5	0.14	1.1	0.06	1.5	0.16	2.3	0.21
10	0.7	0.25	1.2	0.09	1.1	0.18	2.2	0.11

Note: Mean and S.E. were computed from the estimates of the six independent sample populations.

TABLE 6.5

MEAN AND STANDARD ERROR OF INTRINSIC BIRTH RATE FOR TEN YEARS OF SIMULATION UNDER SPECIFIED FAMILY PLANNING STRATEGIES AND CONTROL

YEAR			FAMILY PLANNING STRATEGY CODE							
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	43.4	1.20	42.7	1.20	44.6	0.60	44.7	1.20	43.7	0.50
2	40.5	1.70	41.3	1.80	40.4	0.90	43.4	0.40	43.1	1.50
3	39.7	0.60	38.3	1.20	41.6	1.50	41.9	1.30	41.9	0.90
4	36.2	1.10	35.7	1.50	39.6	1.00	39.1	0.90	37.9	1.10
5	33.8	1.00	37.0	1.70	40.4	0.80	35.8	1.30	35.7	1.20
6	31.5	1.20	34.3	1.10	37.6	1.40	36.4	1.60	32.7	1.40
7	27.2	2.00	33.0	1.20	35.6	0.60	34.2	0.90	32.5	0.90
8	28.2	1.60	30.8	1.00	32.8	1.20	36.13	1.10	36.1	1.00
9	26.8	2.00	30.2	1.00	34.5	1.60	34.4	1.30	25.9	1.80
10	26.7	1.50	25.9	0.30	32.5	1.50	34.3	1.00	28.8	1.90

TABLE 6.5

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE							
	212		221		222		CONTROL	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	45.3	0.70	43.3	1.70	46.2	1.00	43.1	0.70
2	43.0	0.90	42.8	1.30	42.2	1.00	44.8	1.30
3	41.9	1.80	39.3	0.80	42.1	1.30	45.4	0.60
4	35.0	1.10	38.4	1.20	39.1	0.50	42.4	1.30
5	36.7	0.70	37.3	1.00	37.8	0.70	43.1	1.10
6	33.1	1.60	37.4	1.00	38.1	0.70	42.8	1.00
7	31.0	0.90	37.0	1.10	36.3	1.30	42.3	1.30
8	29.9	0.90	32.8	1.00	33.6	1.30	40.9	1.50
9	27.7	1.30	32.2	1.10	34.0	0.90	42.5	0.80
10	28.9	1.50	34.7	0.90	32.8	1.20	43.8	0.90

NOTE: Mean and S.E. were computed from the estimates of the six independent sample populations.

TABLE 6.6

MEAN AND STANDARD ERROR OF NET REPRODUCTION RATE FOR TEN YEARS OF SIMULATION UNDER SPECIFIED FAMILY PLANNING STRATEGIES AND CONTROL

YEAR	FAMILY PLANNING STRATEGY CODE									
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	2.0	0.08	1.9	0.08	2.0	0.05	2.0	0.09	1.9	0.09
2	1.7	0.05	1.7	0.10	1.7	0.09	1.9	0.07	1.8	0.06
3	1.7	0.06	1.6	0.07	1.8	0.07	1.9	0.05	1.8	0.06
4	1.5	0.05	1.5	0.05	1.8	0.04	1.7	0.07	1.6	0.07
5	1.3	0.05	1.5	0.06	1.7	0.07	1.5	0.08	1.4	0.10
6	1.3	0.07	1.4	0.04	1.5	0.08	1.4	0.12	1.3	0.06
7	1.2	0.11	1.3	0.05	1.4	0.08	1.4	0.05	1.3	0.06
8	1.1	0.07	1.3	0.01	1.3	0.04	1.5	0.08	1.2	0.02
9	1.1	0.12	1.2	0.04	1.5	0.08	1.4	0.12	1.1	0.07
10	1.2	0.07	1.1	0.05	1.3	0.12	1.5	0.07	1.1	0.10

TABLE 6.6

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE							
	212		221		222		CONTROL	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	2.0	0.06	1.9	0.15	2.0	0.12	1.8	0.05
2	1.8	0.08	2.1	0.10	1.7	0.04	1.9	0.08
3	1.8	0.11	1.7	0.03	1.8	0.07	1.9	0.05
4	1.5	0.05	1.6	0.10	1.7	0.07	1.8	0.06
5	1.5	0.08	1.6	0.05	1.4	0.06	1.9	0.06
6	1.3	0.07	1.6	0.07	1.6	0.02	1.9	0.07
7	1.3	0.06	1.6	0.10	1.6	0.08	1.8	0.09
8	1.2	0.06	1.2	0.06	1.4	0.08	1.8	0.11
9	1.1	0.04	1.3	0.02	1.4	0.06	1.8	0.10
10	1.2	0.07	1.3	0.03	1.3	0.06	1.8	0.06

Note: Mean and S.E. were computed from the estimates of the six independent sample populations.

In this chapter, first, an analysis of the eight family planning strategies is presented using a fixed effects model for a three-factor completely randomized design. This analysis is done for each of the five fertility indices separately. Next a comparison of the eight family planning strategies is made with the control on the five selected indices of fertility. Comparisons between strategies are also made on certain functions of the annual birth rates of ten years.

Lastly, estimates of the family planning work-load are presented.

6.2 Factorial Analysis

In a univariate situation, the structured model of a 2^3 factorial design may be written as

$$Y_{ijk\ell} = \mu... + \alpha_i + \beta_j + \gamma_K + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + \xi_{ijk\ell} \qquad (1)$$

$$i,j,k=1,2$$
$$\ell=1,2,...,6 \ ,$$

where

$Y_{ijk\ell}$ = response of the ℓth sample in the (ijk) cell

$\mu...$ = constant for all samples

α_i, β_j, γ_k, $(\alpha\beta)_{ij}$, $(\alpha\gamma)_{ik}$, $(\beta\gamma)_{jk}$, and $(\alpha\beta\gamma)_{ijk}$ are the factorial effects and are constants for all responses in cell (ijk)

and

$\xi_{ijk\ell}$ = experimental error on the ℓth response in cell(ijk).

The $\xi_{ijk\ell}$ are assumed to be independently distributed as $N(0,\sigma^2)$.

---

rates is called the net reproduction rate.

By setting

$$
\begin{aligned}
\alpha_i &= 1 \quad \text{if } i=1 \\
&= -1 \text{ otherwise} \\
\beta_j &= 1 \quad \text{if } j=1 \\
&= -1 \text{ otherwise} \\
\gamma_k &= 1 \quad \text{if } k=1 \\
&= -1 \text{ otherwise}
\end{aligned}
$$

and

$$(\alpha\beta)_{ij} = (\alpha_i)(\beta_j),\ (\alpha\gamma)_{ik} = (\alpha_i)(\gamma_k),\ (\beta\gamma)_{jk} = (\beta_j)(\gamma_k),$$

$$(\alpha\beta\gamma)_{ijk} = (\alpha_i)(\beta_j)(\gamma_k).$$

We have the design matrix across samples given by

$$\underset{48\times 8}{A} = \left[\begin{array}{cccccccc}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
\multicolumn{8}{c}{\cdots\cdots\cdots\cdots\cdots} \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \\
\multicolumn{8}{c}{\cdots\cdots\cdots\cdots\cdots} \\
1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \\
1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \\
\multicolumn{8}{c}{\cdots\cdots\cdots\cdots\cdots} \\
1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
\multicolumn{8}{c}{\cdots\cdots\cdots\cdots\cdots} \\
1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\
1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 \\
\multicolumn{8}{c}{\cdots\cdots\cdots\cdots\cdots} \\
1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
\multicolumn{8}{c}{\cdots\cdots\cdots\cdots\cdots} \\
1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
\multicolumn{8}{c}{\cdots\cdots\cdots\cdots\cdots} \\
1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\
1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 \\
\multicolumn{8}{c}{\cdots\cdots\cdots\cdots\cdots} \\
1 & -1 & -1 & -1 & 1 & 1 & 1 & -1
\end{array}\right]
\begin{array}{l}
\\ \text{6 rows} \\ \\
\\ \text{6 rows} \\ \\
\\ \text{6 rows} \\ \\
\\ \text{6 rows} \\ \\
\\ \text{6 rows} \\ \\
\\ \text{6 rows} \\ \\
\\ \text{6 rows} \\ \\
\\ \text{6 rows} \\ \\
\end{array} \qquad (2)$$

The relationship (1) may, for convenience, be written as

$$E(Y_t) = a_{t1}\ \xi_1 + a_{t2}\ \xi_2 + \ldots + a_{t8}\ \xi_8 \qquad (3)$$

$$t = 1,2,\ldots,48$$

where

$\xi_1, \xi_2 \ldots \xi_8$ denote $\mu\ldots, \alpha_i, \ldots (\alpha\beta\gamma)_{ijk}$, respectively

and

α_{ij} = (ij)th element in matrix A.

Instead of a single response, we have a response vector corresponding to the ten years of simulation. Extending the univariate structural model given by (3) to the multivariate case, we have

$$E(Y_{tp}) = a_{t1}\ \xi_{1p} + a_{t2}\ \xi_{2p} + \ldots + a_{t8}\ \xi_{8p} \qquad (4)$$

$$p = 1,2,\ldots,10$$

The relationship (4) may be written in the matrix form as

$$\underset{48\times 10}{E(Y)} = \underset{48\times 8}{A}\ \underset{8\times 10}{\xi} \qquad (5)$$

It may be seen that the ith row of matrix Y has 10 responses corresponding to the 10 years of simulation on the ith sample of the female population. The analysis will be that of growth curves and the theoretical framework for such an analysis has been given by Grizzle and Allen [13].

Post-multiplication of (5) by U, where U is a 10×10 matrix of orthogonal polynomial coefficients, will yield

$$\underset{48\times 10}{E(YU)} = \underset{48\times 8}{A}\ \underset{8\times 10}{\xi}\ \underset{10\times 10}{U} \qquad (6)$$

$$E(Z) = A\xi^* \qquad (7)$$

where

$$Z + YU \quad \text{and } \xi^* = \xi U$$

A is called the design matrix across samples given by (2) and U is called the design matrix within samples. On the left side of equation (7), the ten columns represent 10 linear compounds of these 10 responses. The first, second, third ... columns are the intercept, linear, quadratic, ... components, respectively, of the 10 responses.

(i) <u>Describing within sample responses by a polynomial</u>

It may be of interest to know whether the within sample responses are adequately described by a polynomial of order q. Such a test is accomplished by the contrast

$$\underset{8\times8}{C} \quad \underset{8\times10}{\xi^*} \quad \underset{10\times(10-q)}{V} = \underset{8\times10}{0} \tag{8}$$

where

$$\underset{8\times8}{C} = I$$

and

$$\underset{10\times(10-q)}{V} = \left[\begin{array}{cccc} 0 & 0 & \cdots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \cdots & 0 \\ 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \cdots & 1 \end{array}\right] \begin{array}{l} \left.\vphantom{\begin{array}{c} 0 \\ \cdot \\ 0 \end{array}}\right\} q \text{ rows} \\ \left.\vphantom{\begin{array}{c} 1 \\ 0 \\ \cdot \\ 0 \end{array}}\right\} (10-q) \text{ rows} \end{array}$$

The matrix of sum of products due to the hypothesis contrast (8) is given by

$$\underset{(10-q)\times(10-q)}{S_H} = \underset{(10-q)\times 10}{V'} \ \underset{10\times 8}{\hat{\xi}^{*\prime}} \ \underset{8\times 8}{C'} \ \underset{8\times 8}{[C(A'A)^{-1}C']^{-1}} \ \underset{8\times 8}{C} \ \underset{8\times 10}{\hat{\xi}^{*}} \ \underset{10\times(10-q)}{V} \tag{9}$$

and the sum of products matrix due to error is given by

$$\underset{(10-q)\times(10-q)}{S_E} = \underset{(10-q)\times 10}{V'} \ \underset{10\times 10}{[Z'Z - Z'A\,\hat{\xi}^{*}]} \ \underset{10\times(10-q)}{V} \tag{10}$$

The classical univariate F statistics can be computed from the matrices (9) and (10). If the rank (C) = c, rank (V) = v and rank (A) = m, then

$$F_i = \frac{S_{Hii/C}}{S_{Eii/n-m}} \tag{11}$$

where $i=1,2,\ldots,v$; n = total number of samples; and S_{Hii} and S_{Eii} are the diagonal elements of the matrices S_H and S_E.

The (10-q) values of the F-statistic with (c,n-m) degrees of freedom will be used to test whether the polynomial describing the within sample response should be of order q+1, q+2, ..., 10.

The values of the F-statistic along with the significance levels are presented in Table 6.7 for the five response variables (fertility indices) in the present study. If we use the five percent level of significance as the criterion to decide on the degree of polynomial, a quadratic seems to describe adequately the ten-year growth of any of the response variables.

When we compare the significance levels of various polynomial components with .05, some higher degree components may be significant. For example, for Net Reproduction Rate, linear and quadratic components are significant; cubic and quartic are non-significant and quintic is again significant.

In the present study for further analysis of the response variables, it has been assumed that a cubic is adequate for describing the ten-year growth.

(ii) Tests for main effects and interactions

In relationship (4), ξ_{2p}, ξ_{3p}, and ξ_{4p} represent the three main effects, ξ_{5p}, ξ_{6p}, and ξ_{7p} represent the two-factor interactions and ξ_{8p} represents the three-factor interaction.

The first of the three main effects can be tested by the contrast

$$C \; \xi^* \; V = 0$$

where

$$\underset{1\times 8}{C} = [0 \;\; 1 \;\; 0 \;\; 0 \;\; 0 \;\; 0 \;\; 0 \;\; 0]$$

and

$$\underset{10\times q}{V} = \left[\begin{array}{l} \left.\begin{matrix} 1 & 0 & ..0 \\ 0 & 1 & ..0 \\ . & . & . \; . \\ 0 & 0 & ..1 \end{matrix}\right\} \text{q rows} \\ \\ \begin{matrix} 0 & 0 & ..0 \\ . & . & . \; . \\ 0 & 0 & ..0 \end{matrix} \end{array}\right]$$

TABLE 6.7

SIGNIFICANCE[1] OF DIFFERENT COMPONENTS OF THE POLYNOMIALS DESCRIBING THE GROWTH OVER TEN YEARS OF SELECTED RESPONSE VARIABLES COMPUTED FROM SIMULATION RESULTS

POLYNOMIAL COMPONENT	CRUDE BIRTH RATE	GENERAL FERTILITY RATE	INTRINSIC RATE OF GROWTH	INTRINSIC BIRTH RATE	NET REPRODUCTION RATE
Linear	162.1 (.0001)	176.8 (.0001)	96.7 (.0001)	119.0 (.0001)	106.7 (.0001)
Quadratic	12.5 (.0001)	7.6 (.0001)	2.7 (.0160)	4.1 (.0014)	4.3 (.0011)
Cubic	0.8 (.5351)	1.0 (.3977)	1.3 (.2519)	1.0 (.4240)	1.0 (.4283)
Quartic	1.0 (.4357)	1.1 (.3626)	0.3 (.9415)	0.6 (.7693)	0.3 (.9258)
Quintic	2.0 (.0630)	1.9 (.0730)	1.7 (.1222)	1.6 (.1315)	2.3 (.0364)
Sixth degree	0.8 (.5711)	0.8 (.5820)	1.1 (.3685)	1.1 (.3765)	1.1 (.3311)
Seventh degree	0.9 (.5309)	0.9 (.5401)	1.8 (.0938)	0.8 (.5989)	1.9 (.0833)
Eighth degree	0.9 (.5041)	1.0 (.4428)	1.3 (.2622)	1.0 (.3841)	1.4 (.1914)
Ninth degree	1.2 (.3076)	1.1 (.3515)	0.7 (.6488)	0.9 (.5200)	0.8 (.5369)

---

[1] The table contains the values of the univariate F statistic with (8,40) degrees of freedom. The values in parentheses are the corresponding significance levels. For convenience in presentation, F-values are reduced to one decimal place.

The matrix of sum of products S_H due to the hypothesis and the matrix of sum of products S_E due to error are computed according to the formulae given in (9) and (10). Since q linear compounds of the within sample responses are used in the computations, the matrices S_H and S_E will be of the order q×q. The following multivariate test statistics can be used.

(a) Hotelling's Trace = Trace $(S_H S_E^{-1})$

(b) Roy's Largest Root Criterion $\Theta = \frac{\lambda \max}{1+\lambda \max}$

where

$$\lambda \max = \text{largest root of } |S_H S_E^{-1} - \lambda I| = 0$$

(c) Wilk's Likelihood Ratio $\Lambda = \frac{|S_E|}{|S_H + S_E|}$

when s=1, Λ can be transformed into an exact F variate given by

$$F = \frac{1-\Lambda}{\Lambda} \quad \frac{n+1}{m+1}$$

with (2m+2,2n+2) d.f. when the null hypothesis is true.

where $m = (|v-c|-1)/2$

$n = (N-r-v-1)/2$

$s = \min(c,v)$

$v = \text{rank } (V)$

$c = \text{rank } (C)$

$r = \text{rank } (A)$

and

N = total number of samples.

For other values of s, Hick's Tables [14] may be consulted.

Under the null hypothesis, it is also known that N trace $(S_H S_E^{-1})$ is asymptotically distributed as a χ^2 with cv degrees of freedom.

The results of the tests on factorial effects are summarized in Table 6.8. The significance levels corresponding to the exact F value and the asymptotic χ^2 value, discussed above are given in this table.

One striking feature of Table 6.8 is that the main effect 'adoption' is highly significant for all the response variables. At the five percent level of significance, the three factor interaction is also significant for the crude birth rate, the general fertility rate and the intrinsic birth rate.

If the interactions are not present, then there is a significantly different effect of 'adoption level' which is the same regardless of the combined level of the other two factors. Taking the five percent level of significance as the criterion, we can conclude that the effects of the two levels of 'adoption' are different for each of the combined levels of the other two factors.

The levels of 'eligibility,' though not significantly different (at the five percent level), did show a significant interaction with the levels of 'adoption,' especially for the crude birth rate.

The level of significance for the main effect 'switching' is between five and ten percent for the crude birth rate.

It may be seen from Table 6.8 that all the five indices of fertility are not equally sensitive to changes in the three factors. A discussion on the sensitivity of these indices will be presented in Section 6.2 (iii).

TABLE 6.8

SIGNIFICANCE LEVELS IN THE MULTIVARIATE TESTS ON FACTORIAL EFFECTS FOR SELECTED RESPONSE VARIABLES[1] COMPUTED FROM SIMULATION RESULTS

FACTORIAL EFFECT TESTED	RESPONSE VARIABLE									
	CRUDE BIRTH RATE		GENERAL FERTILITY RATE		INTRINSIC RATE OF GROWTH		INTRINSIC BIRTH RATE		NET REPRODUCTION RATE	
	Test statistic used[2]									
	F	χ^2	F	χ^2	F	χ^2	F	χ^2	F	χ^2
Main effects:										
Eligibility (E)	.5314	.5850	.5018	.5531	.5403	.5077	.3041	.2455	.5602	.3844
Adoption (A)	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Switching (S)	.0904	.0518	.2648	.2069	.3029	.2443	.1014	.0603	.5675	.3767
Two-factor interactions:										
E×A	.0684	.0357	.0198	.0067	.1215	.0765	.0951	.0554	.1070	.0648
E×S	.3775	.3196	.3120	.2533	.9687	.9654	.3264	.2677	.9758	.9733
A×S	.2290	.1726	.1427	.0943	.5945	.5506	.2827	.2244	.5530	.5058
Three-factor interaction:										
E×A×S	.0286	.0110	.2077	.0105	.0891	.0508	.0287	.0111	.1354	.0881

[1] The growth curve over the ten years in each case is represented by a third degree polynomial.

[2] Two test statistics, exact F and asymptotic χ^2 (Section 6.2 ii) are considered. The degrees of freedom for these two test statistics are (4,37) and 4, respectively.

TABLE 6.9

SIGNIFICANCE[1] OF POLYNOMIAL COEFFICIENTS OF THE FACTORIAL EFFECTS

(SIMULATION RESULTS)

FACTORIAL EFFECT	CRUDE BIRTH RATE			GENERAL FERTILITY RATE			INTRINSIC RATE OF GROWTH		
	I	L	Q	I	L	Q	I	L	Q
Eligibility (E)	3.20 (.0773)	1.17 (.2847)	0.38 (.5474)	3.23 (.0763)	1.22 (.2738)	0.23 (.6367)	1.76 (.1884)	0.61 (.5573)	0.59 (.5504)
Adoption (A)	161.53 (.0001)	17.01 (.0004)	0.01 (.9385)	181.66 (.0001)	22.29 (.0001)	0.06 (.7962)	89.16 (.0001)	26.10 (.0001)	0.05 (.8122)
Switching (S)	5.76 (.0199)	0.20 (.6581)	0.14 (.7033)	2.88 (.0936)	0.10 (.7415)	0.35 (.5588)	1.46 (.2315)	1.15 (.2890)	0.01 (.9867)
E×A	7.77 (.0080)	1.17 (.2842)	0.37 (.5487)	11.07 (.0022)	0.93 (.6577)	0.31 (.5819)	3.55 (.0635)	0.34 (.5683)	0.99 (.6752)
E×S	1.20 (.2793)	2.13 (.1486)	0.07 (.7849)	1.23 (.2726)	2.24 (.1386)	0.04 (.8271)	0.30 (.5882)	0.05 (.8170)	0.11 (.7388)
A×S	0.35 (.5595)	0.88 (.6465)	5.03 (.0287)	0.77 (.6123)	1.14 (.2921)	5.41 (.0236)	0.01 (.8852)	.2927 (.5979)	2.79 (.0984)
E×A×S	5.45 (.0232)	0.01 (.9263)	4.54 (.0369)	6.02 (.0176)	0.01 (.9473)	4.08 (.0473)	0.98 (.6717)	1.08 (.3046)	4.92 (.0303)

---

[1] The entrees are the univariate F-values with (1,40) degrees of freedom and the values in parentheses are the corresponding significance levels.

Note: I, L, and Q represent intercept, linear, and quadratic component, respectively.

TABLE 6.9

CONTINUED

FACTORIAL EFFECT	INTRINSIC BIRTH RATE			NET REPRODUCTION RATE		
	I	L	Q	I	L	Q
E	4.23 (.0436)	0.58 (.5444)	0.35 (.5609)	1.60 (.2101)	1.62 (.2075)	0.61 (.5548)
A	165.42 (.0001)	40.32 (.0001)	0.01 (.9356)	84.25 (.0001)	13.06 (.0012)	0.73 (.5992)
S	4.74 (.0333)	0.08 (.7736)	0.36 (.5536)	0.68 (.5838)	0.91 (.6525)	0.05 (.8083)
E×A	6.99 (.0112)	0.27 (.6066)	0.46 (.5040)	3.42 (.0682)	0.60 (.5522)	0.79 (.6184)
E×S	1.16 (.2876)	2.54 (.1144)	0.33 (.5705)	0.34 (.5649)	0.01 (.9721)	0.07 (.7843)
A×S	0.42 (.5268)	1.45 (.2332)	2.81 (.0976)	0.02 (.8611)	0.63 (.5651)	2.15 (.1466)
E×A×S	5.25 (.0256)	0.02 (.8692)	8.11 (.0069)	0.28 (.6042)	1.44 (.2352)	4.02 (.0487)

Hotelling's Trace were computed for each of the fertility indices. These values are 344.5, 410.2, 238.5, 367.6, and 246.5 for the Crude birth rate, General fertility rate, Intrinsic rate of growth, Intrinsic birth rate, and the Net reproduction rate, respectively. Based on these values it appears the Intrinsic rate of growth and the Net Reproduction rate are less sensitive than the others. Among the five indices considered, the General fertility rate is the most sensitive index of the impact of family planning. This finding, namely, that the General fertility rate is more sensitive than the Crude iirth rate can be explained by the fact that the former has women of reproductive ages in the denominator while the latter has women of all ages.

6.3 Comparison of Family Planning Strategies with Control

From the factorial analysis in Section 6.2, it was clear that the three-factor interaction was significant at the five percent level for crude birth rate, General fertility rate, Intrinsic growth rate, and Intrinsic birth rate. The significance level of this interaction for Net reproduction rate is somewhat higher than five percent. In the presence of the three-factor interaction, the best treatment combinations rather than the best levels of factors are of interest. It is also of interest to compare the eight alternative family planning strategies with the control.

For analysis of this section, the nine strategies (including the control) are treated as nine groups in a completely randomized design. For comparison of the eight family planning strategies with the control, the average over the ten years of each fertility index is considered. The differences between the control and each of the strategies using the ten-year averages of the fertility indices are presented in Table 6.10. These differences were tested by Tukey's method of multiple comparisons and all the differences in Table 6.10 were found to be significant at the one percent level.

Of the five fertility indices considered in the present study the crude birth rate is the most commonly known index and is also the index on which the family planning program planners base their decisions. For this reason, the crude birth rate has been selected for further analysis. In the remainder of this section comparisons are made between the eight family planning strategies and the control on (i) Mean of the ten-year birth rates, (ii) Mean birth rate of years 6-10 and (iii) Mean birth rate of years 9 and 10.

(i) Mean of ten-year birth rates

The mean birth rate over the ten years of the family planning program was computed for each of the alternative strategies and for the control. The differences in the mean birth rates among pairs of groups are presented in Table 6.11. At the one percent level, all eight strategies differ significantly from the control group. Also all the strategies with high level adoption are significantly different from the strategies with low level adoption. Also, the first strategy is different from the fifth and sixth strategies at the five percent level of significance.

(ii) Mean birth rate of sixth through tenth year

The differences among pairs of strategies in the average birth rate of the sixth through the tenth year are presented in Table 6.12.

TABLE 6.10

REDUCTION IN THE TEN YEAR AVERAGE OF FERTILITY INDICES FOR ALTERNATIVE FAMILY PLANNING STRATEGIES

(SIMULATION RESULTS)

Strategy Code	Difference between control and alternative strategies in the ten-year average				
	Crude Birth Rate	General Fertility Rate	Intrinsic Rate of Growth	Intrinsic Birth Rate	Net Reproduction Rate
111	9.95	50.15	1.06	9.71	0.45
112	8.48	43.17	0.93	8.17	0.42
121	5.74	27.28	0.53	5.12	0.25
122	5.61	27.87	0.51	5.04	0.24
211	8.12	40.28	0.86	7.70	0.38
212	8.22	41.40	0.86	7.84	0.38
221	6.25	30.54	0.57	5.57	0.26
222	5.56	28.09	0.51	4.89	0.25

Note: All the strategies have ten-year averages of the five fertility indices lower than those of the control and these differences were significant at 1% level according to the Tukey method of multiple comparisons.

TABLE 6.11

DIFFERENCES AMONG ALTERNATIVE STRATEGIES AND CONTROL IN THE TEN YEAR AVERAGE BIRTH RATE

COMPUTED FROM SIMULATION RESULTS

Serial No. i	Strategy Code	Mean Birth Rate of Ten Years X_i	X_i-X_2	X_i-X_3	X_i-X_4	X_i-X_5	X_i-X_6	X_i-X_7	X_i-X_8	X_i-X_9
1	111	32.8	-1.46	-4.20 **	-4.33 **	-1.82 *	-1.73 *	-3.69 **	-4.39 **	-9.95 **
2	112	34.3		-2.73 **	-2.86 **	-0.36	-0.26	-2.22 **	-2.92 **	-8.48 **
3	121	37.0			-0.12	2.37 **	2.47 **	0.51	-0.18	-5.74 **
4	122	37.2				2.50 **	2.60 **	0.63	-0.05	-5.61 **
5	211	34.7					0.09	-1.86 **	-2.56 **	-8.12 **
6	212	34.6						-1.96 **	-2.66 **	-8.22 **
7	221	36.5							-0.69	-6.25 **
8	222	37.2								-5.56 **
9	Control	42.8								

** Significant at 1% level by Tukey's method of multiple comparisons

* Significant at 5% level

TABLE 6.12

DIFFERENCES AMONG ALTERNATIVE STRATEGIES AND CONTROL IN THE AVERAGE BIRTH RATE OF SIXTH THROUGH TENTH YEAR COMPUTED FROM SIMULATION RESULTS

Serial No. i	Strategy Code	Mean Birth Rate of 6th-10th Year X_i	$X_i - X_2$	$X_i - X_3$	$X_i - X_4$	$X_i - X_5$	$X_i - X_6$	$X_i - X_7$	$\lambda_i - X_8$	$X_i - X_9$
1	111	27.2	-2.36 *	-4.99 **	-5.89 **	-1.63	-1.37	-5.51 **	-5.77 **	-13.65 **
2	112	29.6		-2.63 **	-3.52 **	0.72	0.98	-3.14 **	-3.40 **	-11.65 **
3	121	32.2			-0.89	3.35 **	3.61 **	-0.51	-0.77	-8.65 **
4	122	33.1				4.25 **	4.51 **	0.37	0.12	-7.76 **
5	211	28.9					0.26	-3.87 **	-4.13 **	-12.01 **
6	212	28.6						-4.13 **	-4.39 **	-12.27 **
7	221	32.7							-0.25	-8.14 **
8	222	33.0								-7.88 **
9	Control	40.9								

** Significant at 1% level by Tukey's method of multiple comparisons.

* Significant at 5% level

Once again the mean birth rate is significantly different, at the one percent level, from that of control for all strategies. Also all the strategies with high level adoption are significantly different from the strategies with low level adoption. The first strategy in Table 6.12 is significantly different from the second strategy at the five percent level.

(iii) Mean birth rate of ninth and tenth years

As can be seen from Table 6.13, all strategies are different from the control at the one percent level of significance.

In this case, though, the second and sixth strategies having high level adoption, are different form the seventh and eigth strategies having low level adoption at the five percent level. All other strategies having high level adoption are different from those having low level adoption at the one percent level.

6.4 Family Planning Work-Load

The proportion of couples adopting contraception during the years following the initiation of a family planning program may be assumed as an indirect indicator of program service requirements and their costs. The amount and kind of services required vary from one contraceptive method to another.

The proportions of couples adopting the 'conventional contraceptive,' IUD, and sterilization in the simulated experiment are presented in Tables 6.14, 6.15, and 6.16, respectively. The values given in these tables are the means of the six samples with the corresponding standard errors.

TABLE 6.13

DIFFERENCES AMONG ALTERNATIVE STRATEGIES AND CONTROL IN THE AVERAGE BIRTH RATE

OF NINTH AND TENTH YEARS COMPUTED FROM SIMULATION RESULTS

Serial No. i	Strategy Code	Mean Birth Rate of 9th and 10th Years X_i	$X_i - X_2$	$X_i - X_3$	$X_i - X_4$	$X_i - X_5$	$X_i - X_6$	$X_i - X_7$	$X_i - X_8$	$X_i - X_9$
1	111	26.0	-1.49	-5.42 **	-6.46 **	-0.71	-1.30	-5.24 **	-5.29 **	-15.07 **
2	112	27.5		-3.93 *	-4.97 **	0.77	0.18	-3.74 *	-3.80 *	-13.57 **
3	121	31.4			-1.04	4.70 **	4.11 **	0.18	0.12	- 9.64 **
4	122	32.5				5.75 **	5.16 **	1.22	1.16	- 8.60 **
5	211	26.7					-0.58	-4.52 **	-4.58 **	-14.35 **
6	212	27.3						-3.93 *	-3.99 *	-13.76 **
7	221	31.3							-0.05	- 9.83 **
8	222	31.3								- 9.77 **
9	Control	41.1								

** Significant at 1% level by Tukey's method of multiple comparisons

* Significant at 5% level

TABLE 6.14

MEAN AND STANDARD ERROR OF PERCENT CURRENTLY MARRIED WOMEN AGED 15-44 ADOPTING CONVENTIONAL CONTRACEPTIVE, BY YEAR AND FAMILY PLANNING STRATEGY (SIMULATION RESULTS)

YEAR	FAMILY PLANNING STRATEGY CODE									
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	0.4	0.08	0.3	0.12	0.1	0.05	0.2	0.07	0.2	0.12
2	0.9	0.21	0.9	0.15	0.5	0.16	0.4	0.08	1.1	0.11
3	1.4	0.27	1.3	0.08	0.7	0.13	0.5	0.11	1.4	0.13
4	1.9	0.21	1.6	0.15	1.1	0.16	1.1	0.21	1.7	0.20
5	2.0	0.18	2.3	0.31	1.3	0.18	1.1	0.17	2.0	0.35
6	2.7	0.14	2.6	0.11	1.6	0.36	1.5	0.29	2.8	0.44
7	2.3	0.20	2.6	0.28	1.7	0.20	1.5	0.23	3.0	0.19
8	3.3	0.24	2.7	0.39	2.0	0.26	1.9	0.23	3.9	0.19
9	2.7	0.18	3.3	0.21	1.9	0.21	2.2	0.19	3.0	0.34
10	3.3	0.43	3.3	0.19	2.0	0.21	1.6	0.18	4.0	0.40

TABLE 6.14

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE					
	212		221		222	
	Mean	SE	Mean	SE	Mean	SE
1	0.4	0.14	0.2	0.14	0.2	0.11
2	1.1	0.23	0.4	0.14	0.3	0.11
3	1.3	0.08	0.4	0.16	0.7	0.12
4	1.9	0.11	1.0	0.17	0.9	0.08
5	2.9	0.19	1.1	0.15	1.3	0.12
6	2.8	0.26	1.4	0.28	1.5	0.19
7	2.9	0.26	1.4	0.20	1.5	0.17
8	2.7	0.24	1.9	0.18	1.5	0.24
9	3.2	0.11	1.9	9.23	1.8	0.17
10	3.2	0.40	2.2	0.21	2.2	0.31

TABLE 6.15

MEAN AND STANDARD ERROR OF PERCENT CURRENTLY MARRIED WOMEN AGED 15-44 ADOPTING IUD BY YEAR AND FAMILY PLANNING STRATEGY (SIMULATION RESULTS)

YEAR	FAMILY PLANNING STRATEGY CODE									
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	3.3	0.26	3.1	0.15	1.4	0.19	1.5	0.15	2.6	0.28
2	5.4	0.34	5.9	0.39	2.6	0.24	2.4	0.37	5.6	0.41
3	7.3	0.30	7.6	0.60	3.7	0.25	4.0	0.15	7.5	0.24
4	8.7	0.42	9.7	0.38	4.6	0.48	5.9	0.69	8.3	0.38
5	8.8	0.35	11.5	0.49	5.4	0.62	5.7	0.41	11.0	0.69
6	9.5	0.35	10.0	0.31	6.6	0.09	6.6	0.43	9.9	0.45
7	10.1	0.63	10.7	0.49	7.0	0.33	5.2	0.35	10.9	0.25
8	9.5	0.62	12.0	0.19	7.0	0.35	7.1	0.48	12.0	0.49
9	9.5	0.39	11.6	0.51	7.1	0.52	7.4	0.23	11.0	0.14
10	10.2	0.50	11.8	0.48	7.4	0.58	7.7	0.40	11.8	0.51

TABLE 6.15

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE					
	212		221		222	
	Mean	SE	Mean	SE	Mean	SE
1	3.1	0.51	1.2	0.11	1.6	0.18
2	6.5	0.44	3.1	0.19	3.3	0.36
3	8.2	0.32	3.1	0.26	4.2	0.34
4	10.7	0.48	5.2	0.59	5.3	0.39
5	11.2	0.28	4.8	0.35	6.0	0.36
6	11.3	0.63	6.4	0.29	6.6	0.43
7	11.3	0.24	6.9	0.48	6.6	0.36
8	12.0	0.26	6.8	0.38	9.0	0.56
9	11.2	0.21	7.0	0.32	7.9	0.31
10	11.8	0.63	6.9	0.50	8.1	0.35

TABLE 6.16

MEAN AND STANDARD ERROR OF PERCENT CURRENTLY MARRIED WOMEN AGED 15-44 ADOPTING STERILIZATION, BY YEAR AND FAMILY PLANNING STRATEGY (SIMULATION RESULTS)

YEAR	FAMILY PLANNING STRATEGY CODE									
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	0.8	0.06	0.8	0.11	0.3	0.13	0.2	0.13	0.8	0.12
2	1.7	0.25	1.2	0.18	0.8	0.11	0.6	0.12	2.0	0.20
3	3.4	0.21	1.9	0.19	0.9	0.20	1.0	0.14	2.0	0.24
4	3.9	0.13	2.4	0.19	1.8	0.19	1.0	0.09	3.2	0.19
5	3.8	0.32	2.8	0.39	2.2	0.23	1.6	0.15	2.8	0.17
6	3.7	0.22	3.3	0.16	2.8	0.39	1.9	0.22	3.3	0.30
7	3.3	0.13	3.0	0.32	2.6	0.21	2.2	0.13	3.1	0.15
8	3.4	0.29	3.0	0.28	2.3	0.15	2.0	0.24	3.1	0.16
9	3.2	0.26	2.5	0.24	2.2	0.13	2.0	0.16	3.2	0.28
10	3.1	0.37	2.6	0.21	2.5	0.24	2.5	0.17	2.7	0.25

TABLE 6.16

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE					
	212		221		222	
	Mean	SE	Mean	SE	Mean	SE
1	0.7	0.19	0.5	0.09	0.4	0.15
2	1.4	0.38	0.6	0.14	0.7	0.11
3	1.8	0.28	1.0	0.13	0.7	0.11
4	2.4	0.47	1.8	0.34	1.2	0.11
5	3.1	0.30	1.7	0.26	1.8	0.16
6	2.9	0.32	1.8	0.22	2.0	0.24
7	2.7	0.25	2.1	0.23	1.7	0.19
8	2.6	0.25	2.0	0.15	1.8	0.27
9	2.6	0.37	2.4	0.45	1.6	0.14
10	2.5	0.19	2.1	0.23	2.0	0.21

These proportions can be used to estimate the number of couples requiring different contraceptive supplies and services in a ten year family planning program for India. The population of India is assumed to have grown from 1961 at the same rate, until 1970, as that observed in the sample population under the present simulation. These estimated population values for 1961-1970 are used in computing the numbers of couples requiring contraception. The numbers of couples (in millions) requiring supplies and services for conventional contraceptive, IUD, and sterilization are presented in Tables 6.17, 6.18 and 6.19, respectively.

From the point of view of the decline in the crude birth rate, the first strategy may be considered as the best strategy. For this strategy the percentage of couples adopting a conventional contraceptive is 0.4 in the first year of the program which increases to 3.3 in the tenth year. The percentage of couples adopting IUD increases from 3.3 percent in the first year to 10.2 percent in the tenth year. For sterilization, the percentage of couples adopting this method is 0.8 in the first year, which increases to 3.8 in the tenth year.

If the first family planning strategy were implemented for ten years starting from 1961, under the assumption that the population of India had grown from one year to the next at the same rate as that of the sample population under simulation, it may be seen that 0.3 million couples would have adopted conventional contraceptive in the first year of program and this number would have increased to 2.7 million. The IUD users would have increased from 2.6 million in the first year to 8.2 million in the tenth year. The number of couples accepting

TABLE 6.17

NUMBER (IN MILLIONS) OF COUPLES ADOPTING CONVENTIONAL CONTRACEPTIVES, BY YEAR AND FAMILY PLANNING STRATEGY, INDIA, 1961-1970 (BASED ON TEN-YEAR SIMULATION)

	FAMILY PLANNING STRATEGY CODE									
YEAR	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	0.3	0.07	0.2	0.09	0.1	0.04	0.2	0.06	0.2	0.10
2	0.7	0.17	0.8	0.12	0.4	0.13	0.4	0.07	0.9	0.09
3	1.1	0.21	1.1	0.07	0.5	0.10	0.5	0.09	1.2	0.10
4	1.5	0.17	1.3	0.12	0.9	0.12	0.9	0.17	1.4	0.16
5	1.6	0.15	1.8	0.25	1.0	0.14	0.9	0.13	1.5	0.27
6	2.1	0.11	2.0	0.09	1.2	0.28	1.2	0.23	2.2	0.35
7	1.8	0.16	2.1	0.23	1.3	0.16	1.3	0.18	2.3	0.15
8	2.6	0.19	2.2	0.32	1.6	0.21	1.6	0.18	3.1	0.15
9	2.2	0.14	2.7	0.17	1.5	0.17	1.8	0.16	2.4	0.28
10	2.7	0.35	2.7	0.16	1.6	0.17	1.3	0.15	3.3	0.33

TABLE 6.17

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE 212		221		222	
	Mean	SE	Mean	SE	Mean	SE
1	0.4	0.01	0.2	0.11	0.2	0.09
2	0.9	0.18	0.4	0.11	0.3	0.09
3	1.1	0.07	0.4	0.13	0.5	0.09
4	1.5	0.09	0.8	0.14	0.7	0.07
5	2.3	0.15	0.9	0.12	1.1	0.09
6	2.2	0.21	1.1	0.22	1.2	0.15
7	2.3	0.21	1.2	0.16	1.2	0.14
8	2.2	0.19	1.5	0.15	1.2	0.19
9	2.6	0.09	1.6	0.19	1.5	0.14
10	2.6	0.33	1.8	0.18	1.8	0.25

TABLE 6.18

NUMBER (IN MILLIONS) OF COUPLES ADOPTING IUD, BY YEAR AND FAMILY PLANNING STRATEGY, INDIA, 1961-1970 (BASED ON TEN-YEAR SIMULATION)

YEAR	FAMILY PLANNING STRATEGY CODE									
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	2.6	0.20	2.4	0.12	1.1	0.15	1.1	0.12	2.1	0.22
2	4.2	0.26	4.6	0.31	2.0	0.19	1.9	0.29	4.4	0.32
3	5.6	0.23	6.0	0.47	2.8	0.19	3.1	0.11	5.8	0.19
4	6.7	0.33	7.6	0.30	3.5	0.37	4.5	0.53	6.4	0.29
5	6.8	0.27	9.0	0.39	4.2	0.47	4.4	0.31	8.5	0.53
6	7.3	0.27	7.9	0.24	5.1	0.07	5.2	0.33	7.7	0.35
7	7.8	0.49	8.5	0.39	5.4	0.26	4.1	0.27	8.5	0.19
8	7.4	0.49	9.6	0.15	5.5	0.28	5.7	0.38	9.4	0.38
9	7.5	0.31	9.4	0.42	5.6	0.41	6.0	0.18	8.8	0.11
10	8.2	0.40	9.7	0.39	5.9	0.46	6.2	0.33	9.5	0.41

TABLE 6.18

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE					
	212		221		222	
	Mean	SE	Mean	SE	Mean	SE
1	2.4	0.40	1.0	0.09	1.3	0.14
2	5.1	0.34	2.4	0.15	2.5	0.27
3	6.3	0.25	2.4	0.20	3.2	0.26
4	8.3	0.37	4.0	0.46	4.0	0.30
5	8.7	0.22	3.7	0.27	4.5	0.28
6	8.8	0.49	5.0	0.23	5.0	0.33
7	8.9	0.19	5.4	0.38	5.1	0.28
8	9.6	0.21	5.4	0.30	7.1	0.44
9	9.0	0.17	5.7	0.26	6.2	0.25
10	9.6	0.51	5.7	0.41	6.5	0.28

TABLE 6.19

NUMBER (IN MILLIONS) OF COUPLES ADOPTING STERILIZATION, BY YEAR AND FAMILY PLANNING STRATEGY, INDIA, 1961-1970 (BASED ON TEN-YEAR SIMULATION)

YEAR	FAMILY PLANNING STRATEGY CODE									
	111		112		121		122		211	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	0.7	0.05	0.6	0.08	0.2	0.10	0.2	0.10	0.6	0.10
2	1.4	0.20	0.9	0.14	0.6	0.08	0.5	0.09	1.6	0.16
3	2.7	0.16	1.5	0.15	0.7	0.15	0.8	0.11	1.6	0.18
4	3.0	0.10	1.9	0.15	1.4	0.14	0.8	0.07	2.4	0.15
5	2.9	0.25	2.2	0.31	1.7	0.18	1.2	0.11	2.1	0.13
6	2.9	0.17	2.6	0.13	2.1	0.30	1.5	0.17	2.5	0.23
7	2.6	0.10	2.4	0.26	2.1	0.16	1.7	0.10	2.5	0.12
8	2.7	0.22	2.4	0.23	1.8	0.12	1.6	0.19	2.4	0.12
9	2.5	0.21	2.0	0.20	1.7	0.10	1.6	0.13	2.6	0.22
10	2.5	0.30	2.1	0.17	2.0	0.19	2.0	0.14	2.2	0.20

TABLE 6.19

CONTINUED

YEAR	FAMILY PLANNING STRATEGY CODE					
	212		221		222	
	Mean	SE	Mean	SE	Mean	SE
1	0.5	0.15	0.4	0.07	0.3	0.11
2	1.1	0.30	0.5	0.11	0.6	0.08
3	1.4	0.21	0.7	0.10	0.5	0.08
4	1.8	0.36	1.4	0.26	0.9	0.08
5	2.4	0.23	1.3	0.20	1.4	0.12
6	2.3	0.24	1.4	0.17	1.6	0.19
7	2.1	0.19	1.7	0.18	1.3	0.15
8	2.1	0.20	1.6	0.12	1.4	0.21
9	2.1	0.30	2.0	0.37	1.3	0.11
10	2.0	0.15	1.7	0.19	1.6	0.17

sterilization would have been 0.7 million in the first year and 2.5 million in the tenth year.

The work-loads in terms of adopters of conventional contraceptive, IUD, and sterilization in each of the ten years of family planning program under other alternative strategies can be seen from Tables 6.17, 6.18, and 6.19.

Some conclusions based on the results discussed in this chapter are presented in Chapter VII.

CHAPTER VII

CONCLUSIONS

7.1 Conclusions

The factorial analysis of the eight family planning strategies and comparisons of these strategies with the control were presented in Chapter VI. From the factorial analysis, it was clear that the main effect 'adoption' was very highly significant. The significance level of the main effect 'switching' was between five and ten percent for crude birth rate. The main effect 'eligibility' was not significant even at the ten percent level.

As was pointed out in Section 1.2 (Chapter I), the two levels of eligibility for sterilization were not very different. The main difference between the two levels is that one level specifies a minimum of three living children as the criterion, and the other level further places a restriction on the sex and ages of children. This slight distinction between the two levels of eligibility was made for the following reasons. Lowering the eligibility to one child or two children without specifying the age and sex of children would be an unrealistic assumption for the Indian population. There would be very few couples with such a family size and composition who would volunteer for sterilization. Considering three children as an eligibility criterion in an intensive family planning program situation may not be an unrealistic assumption since couples who have volunteered for sterilization in India so far have an average family size of 4.5 children [8]. Thus the only point of interest in the present experiment was to know whether a restriction on the age and sex of children would be of importance in terms of fertility decline.

The two levels of 'switching' were described by the two sets of conditional probability matrices given in Table 5.6 in Chapter V. These two levels are called 'sterilization oriented' and 'IUD oriented.' As was seen from the magnitude of the probabilities, least emphasis was placed on 'conventional contraceptive' in the present study. The two levels of 'switching' were found not significantly different. The maximum probability of switching to sterilization from any other state was fixed at 0.4, since sterilization is considered an irreversible method of family planning in the present study.

It was known before the conduct of the experiment that the levels of eligibility and switching were not as different as the levels of adoption. What was not known was how the levels of these three factors would interact.

The analysis in Chapter VI of the results of the present experiment showed that interactions were not as highly significant as the main effect 'adoption.' The three-factor interaction was significant around the five percent level, a criterion which is reasonable for an experiment of this kind with only six replications.

The conclusions based on the results of the present experiment may be summarized as follows:

(i) The two levels of adoption (of family planning) were significantly different from one another in terms of their impact on all five fertility indices.

(ii) The two levels of switching (between contraceptive methods) were significantly different from one another in terms of their impact on the birth rate though the level of significance was lower than that of adoption levels.

(iii) The two levels of eligibility (for sterilization) though not significantly different (at the five percent level) in terms of impact on the birth rate did have a significant interaction with the levels of adoption.

(iv) The interaction of the three factors was also significant (at the five percent level).

(v) Based on all the fertility indices considered in the analysis in Chapter VI, all eight family planning strategies were significantly different from the control.

The above conclusions may be translated into guidelines for action in family planning program implementation. Based on the findings of the present experiment, getting more couples to accept and adopt family planning is the most important aspect in the implementation of a family planning program. A slight difference in the criterion for eligibility for sterilization, as that incorporated in the present study, does not produce a difference in the birth rate which is of great significance. The program planners should adopt an eligibility criterion which has greatest acceptance among married couples. Also a difference, in the switching levels, as assumed in the present study, is not of great consequence in reducing the birth rate.

7.2 Implications for family planning program in India

The two levels of eligibility considered in the present study follow closely the operation of the sterilization program in India. The two switching levels on the other hand, were made up according to certain considerations with the least emphasis placed on the conventional contraceptive as compared to IUD and sterilization. The IUD was given the maximum emphasis in terms of switching.

The adoption levels assumed in the present study are to some extent based on the experience of the Taiwan program.

A question that may be asked is "How realistic are the assumptions on switching and adoption for India's family planning program?" The IUD is a method of high use-effectiveness which unlike other conventional contraceptives requires only an initial application. Unlike sterilization it is a reversible method of family planning and could probably become the most popular method in India unless a better method is devised and introduced into the Indian family planning program.

It is difficult to answer whether the Indian family planning program is likely to achieve even the lowest of the adoption levels in the near future. The number of couples who adopted sterilization, IUD and conventional contraceptive during 1961-69 in India [9] are shown in Table 7.1. A comparison of these achievements with the targets presented in Tables 6.17-6.19 for specified declines in the crude birth rate (Table 6.2) shows that the achievements are considerably short of the targets especially for IUD. While the number of sterilizations done during 1961-69 in India are close to the targets of some of the alternative strategies in Table 6.19, we do not know how the age-family size composition of those sterilized compares with that of the targetted couples. Taking 4.5 as the average family size of a sterilized couple in India, we may note that the couples sterilized so far in India had, on the average, a larger family size than the target couples based on the present experiment.

The target numbers in Tables 6.17-6.19 were computed for India for the ten-year period 1961-70. When the age-sex-marital status distributions of the 1971 census of India become available, the target numbers can be recomputed for the period 1971-80. The achievements in Table 7.1 of India seem to indicate that if the number of IUD insertions can be raised considerably in the future, it may be possible to reach the targets of one of the four alternative strategies in Tables 6.17-6.19, which specifies a decline in the birth rate to approximately 30 per thousand in a ten-year program.

In 1963, the Government of India expressed as its goal the reduction of the national birth rate to 25 per thousand population in the following ten years, by accelerating the rate of adoption of family planning [32]. There are four alternative family planning strategies in the present simulation study which lead to a birth rate around 26 per thousand by the tenth year of simulation. The targest specified by these four strategies are indicative of the work-loads involved in achieving such a goal.

7.3 Recommendations

In the present study eight family planning strategies were considered. In future studies, a large number of family planning strategies, differing mainly in their adoption and switching levels, may be considered. Some of these strategies may yield birth rates which ap-

TABLE 7.1

NUMBER (IN MILLIONS) OF COUPLES WHO ADOPTED CONVENTIONAL CONTRACEPTIVE,

IUD AND STERILIZATION, INDIA, 1961-1969

YEAR	NUMBER OF COUPLES ADOPTING		
	STERILIZATION	IUD	CONVENTIONAL CONTRACEPTIVE
1961	0.104		
1962	0.157		
1963	0.170		
1964	0.269		
1965-1966*	0.670	0.812	
1966-1967**	0.887	0.909	0.463
1967-1968**	1.839	0.668	0.475
1968-1969**	1.664	0.478***	0.847

Source: Govt. of India, "Progress of family planning in India," Ministry of health and family planning and works, housing and urban development, Dept. of family planning.

* During the 15-month period: Jan. 1965- Mar. 1966.
** During the 12-month period beginning with April
*** Provisional figure.

pear to be infeasible for India in the near future. Yet they may provide information on the work-load and cost involved in implementing such programs and may help the program planners to set feasible targets. A variety of fertility indices may be used to measure the impact of such strategies. In the present study the work-loads were discussed in terms of the number of couples adopting the three family planning methods. These numbers could be translated into 'supplies,' 'facilities,' 'personnel,' and 'costs' and could be used as service-requirements. Since a program-planner is usually interested in choosing a strategy which will yield the maximum decline in the birth rate with the minimum service-requirements, evaluation of alternative family planning strategies may be done with the help of an index so constructed.

As was mentioned in Section 5.8 in Chapter V, the main limitation of the present study with respect to the practice of family planning by women was that no distinction was made between women who had never used a family planning method and women who having ever practiced family planning returned to the Null state. It may be more realistic for the use-effectiveness, the continuity of use and the choice of switching method to depend on the specific contraceptives previously used and the number of times, as well as the length of time each contraceptive was used.

The contraceptive behavior of couples in the present study was based partly on Taiwan data and partly on assumptions. If data could be collected for India, on adoption of family planning by couples, continuity of use of specific contraceptives, and switching between different methods, more realistic assumptions can be made with regard to the family planning practice of couples.

Due to the limitation on the computer time available, the present study was conducted on females only and the number of replications was restricted to six. If such limitations are not present, it would be more informative to include males and increase the number of replications in the experiment. The number of contraceptives may also be increased.

It may be noted that the present study was conducted with certain restrictive assumptions mentioned in Section 2.4 in Chapter II. When adequate data become available, divorces and widow-remarriages, however negligible, may be incorporated in the simulation. Also use of past trends and/or reasonable assumptions may be made to incorporate changes in birth, death and marriage probabilities from one year to another during the period of simulation. When the 1971 census data for India become available, many of the initial distributions may be based on such data instead of the 1961 census data as were used in the present study.

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APPENDIX TABLE 1

SMOOTHED SINGLE-YEAR AGE DISTRIBUTION OF WOMEN, INDIA, 1961 (IN THOUSANDS)

Age	Number	Age	Number	Age	Number
Under 1	8409	30	3122	60	919
1	7504	31	3027	61	868
2	6970	32	919	62	817
3	6601	33	2814	63	766
4	6318	34	2708	64	715
5	6083	35	2606	65	665
6	5874	36	2512	66	613
7	5683	37	2421	67	562
8	5500	38	2332	68	510
9	5324	39	2242	69	458
10	5152	40	2158	70 & above	3784
11	4984	41	2082		
12	4825	42	2011		
13	4677	43	1941		
14	4536	44	1873		
15	4404	45	1807		
16	4280	46	1740		
17	4163	47	1672		
18	4052	48	1607		
19	3946	49	1543		
20	3851	50	1481		
21	3767	51	1420		
22	3690	52	1359		
23	3616	53	1299		
2	3544	54	1240		
25	3474	55	1183		
26	3405	56	1128		
27	3335	57	1075		
28	3266	58	1022		
29	3200	59	970		

APPENDIX TABLE 2

AGE-MARITAL-STATUS DISTRIBUTION OF WOMEN, INDIA

1961 (IN THOUSANDS)

Age group	Marital status		
	Single	Married	Widowed
Under 15	83 043	4 425	29
15-19	5 044	12 024	90
20-24	1 143	17 557	248
25-29	341	16 997	522
30-35	154	13 581	954
35-39	87	10 320	1 322
40-44	66	8 366	2 226
45-49	41	5 802	2 400
50-54	37	4 248	3 628
55-59	19	2 210	2 285
60-64	23	1 626	3 851
65-69	9	646	1 709
70 & over	17	657	3 749