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A Model for Managing a Family-Planning System

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This paper describes a planning model designed to be *used* by managers of family-planning systems to improve understanding, forecasting, and planning. The macro-flow model describes the patient movement through post-partum and nonpost-partum programs. The flows model the phenomena of: outreach recruitment, continuance, post-partum checkups, switching methods, referral, migration, contraceptive-use experience, private protection, method effectiveness, advertising response, follow up, abortion, and medical services. Strategic variables can be linked to the flow parameters to produce capacity requirements and budgetary implications. The model output includes benefit measures of total active patients, couple years of protection, 'births protected,' and unwanted births prevented. The fertility aspects of births prevented are modeled through a nonstationary Markov process submodel that considers demographic phenomena without burdening the basic flow structure. The input procedures used to process patient-visit, outreach, clinic-survey, and experimental data are discussed and some empirical results are reported. The combination of data-based estimates and subjective judgment is done by 'fitting' the model to past observed data. Testing and control are done by 'tracking' model performance through conditional prediction, diagnosis, and updating. The model is implemented in an on-line, conversational program that facilitates evolutionary model building by allowing the user to specify his model options. The application and testing of the model in the Atlanta Area Family Planning System are discussed and the experiences of managers in using the model to gain new insights, forecasts, budgets, and plans are reported.

FROM A MACRO point of view, the question in population is: "What should the population growth rate be?" Growth rates in the U.S.A. in the last five years imply our population will double each 70 to 80 years—a rate considered excessive by many. At the micro level, the question a family faces is: "How can we have the number of children we want and at the times we want them?" Families are not very successful in planning births. Fifty percent of births do not occur when wanted (i.e., represent timing failures) and 20 percent are unwanted births.[1] In the poor and near-poor groups where private medical care and contraceptives are generally not available, the problem is more severe, with 40 percent of births being unwanted.[2] These births can and usually do produce undesirable sociological, psychological, or medical effects on the child or mother. This paper addresses the problem indigent families face in planning their families in the United States.

The need for family planning has been recognized by Congress and the President. Over one hundred million dollars per year have been appropriated through the Tydings bill to make contraceptives available to the indigent. The National Center for Family Planning Services of the Department of Health, Education, and Welfare grants money to metropolitan and rural areas to develop local family-planning services. In addition, state health departments, county health departments, hospitals, and private groups, such as Planned Parenthood, provide funds and services at the local level.

The recipients of the grants have the tasks of planning and controlling a system that best serves the needs of its clientele who wish to prevent unwanted births. Managers plan and budget for post-partum and nonpost-partum programs. They allocate resources for recruiting new patients through outreach workers, but trade off this allocation against resources used to maintain high rates of continuing contraceptive usage. They determine the contraceptive methods to be used and implement policies on such matters as abortion and sterilization.

The purpose of this paper is to describe a model designed to be used by managers of family-planning delivery systems to: help them better understand their systems; enable them to make better forecasts; and, provide them with a tool for planning. The paper begins with a description of the model structure, output, and input procedures. Then it discusses the evolutionary implementation of the model and presents an application of the model to the Atlanta Area Family Planning System. The paper closes with a discussion of future work and the applicability of the model's method to developing countries.

MODEL STRUCTURE

THE BASIC APPROACH of this work is to build a macro process model,[3] a deterministic-flow model that allows an effective evolutionary approach to implementation and a reasonable trade-off between the richness of behavioral content and the difficulty of model estimation and testing.[4] The process notions are particularly attractive in this setting, since the basic clientele behavior can be represented by a patient flow that managers can understand and internalize. This type of model is feasible, since, in most US family-planning programs, a record is made of each patient visit, and therefore detailed flow parameters can be estimated. The process model traces movement from the target-group population through post-partum and nonpost-partum family-planning program events. It links strategic-resource and policy variables to the flow, so that after data basing the model parameters, overall acceptance and birth-rate effects can be encompassed.

Overall Flows

The model begins with the concept of a *target group*, the population that managers define for program development and attempt to serve. For example, the target group may be all fertile women ages 15 to 45 who live in a specific metropolitan area and are poor by OEO standards. The model divides the target group into two basic sections: (1) those active in the family-planning system, and (2) those not active in it. *Active* persons are defined as those who accepted contraceptive supplies at their last visit (e.g., accepted a three-month supply of pills or retained their IUD) and have not missed their next appointment. The not-active group is divided into pregnant and not pregnant. The flows between target-group sections that occur within one period are shown in Fig. 1.

People flow from pregnant to active or not active by acceptance or nonacceptance of family planning upon delivery at a hospital with a post-partum program. Movement from not-active/not-pregnant to active occurs owing to new-patient requests for contraceptives or outreach-generated acceptance. Actives return to the not-active class by discontinuing contraception (not returning for an appointment)

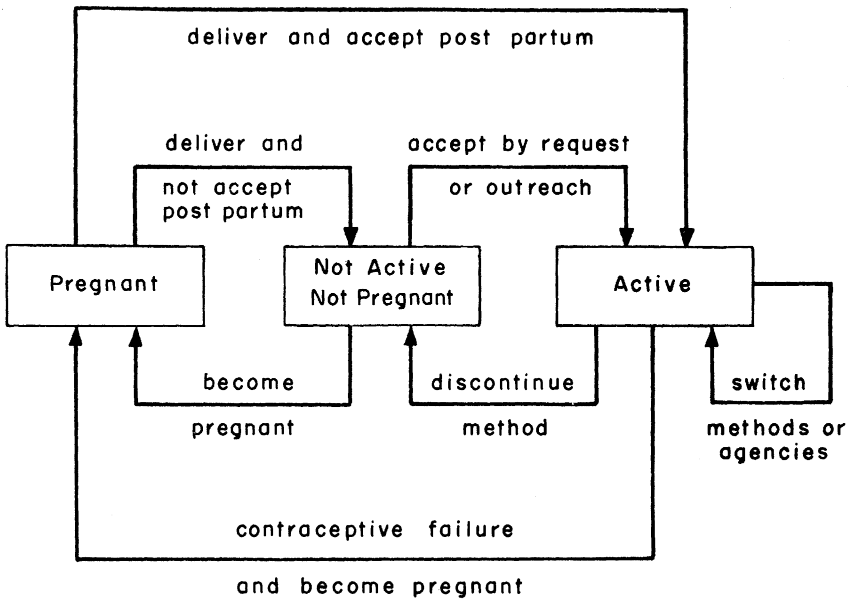

Fig. 1. Target-group sections and their interactions.

or by becoming pregnant. Likewise, not-active/not-pregnant people may become pregnant. The final flows are actives switching methods, referral between agencies, and migration rates into and out of the target group.

For the purposes of model development, the not-active section of the target group is denoted by NSTATE and further divided into mutually exclusive and collectively exhaustive subsections as follows:

$\mathrm{NSTATE}_{t,s}$ = Number of people at time t in STATE s.

- $s=1$: Pregnant.
- $s=2$: Never active in the system.
- $s=3$: Ever active (were active at one time but not now) and have no negative attitude towards contraception,
- $s=4$: Outreach exposure (visited by outreach worker but did not accept an appointment or did not appear for one).

$s=5$: Advertising aware (aware of appeal of message).
$s=5+m$: Ever active and have a negative attitude with respect to method m $(m=1, 2, \cdots, NM)$.

NS is defined as the last state and $NS=5+NM$. In this notation $s=2$ to $s=5+NM$ are the not-active/not-pregnant group. The division into these additional states is made, since people who have had differential experience in the system will behave differently in terms of acceptance and continuance. For example, those never in the system $(s=2)$ may respond differently to a visit from an outreach visitor than those who have been in the system and dropped out $(s=3)$ or those who have had negative experience with a method $(s=5+m)$. Those who are aware of advertising $(s=5)$ may be more likely to request an appointment at a family-planning clinic. Likewise, those who are visited by an outreach worker and did not accept an appointment $(s=4)$ may be more likely to request an appointment. This is an indirect outreach effect due to the receipt of communication, but the reluctance to commit to an appointment at that time. The state of being pregnant is $s=1$ and it contains all people currently pregnant.

Nonpost-Partum Flow

The detailed nonpost-partum flow is represented in Fig. 2. New patients enter from the not-active/not-pregnant group as the result of a home visit from an outreach worker or a request for an appointment. The flow traces the initial acceptance and continuance process.

Outreach Recruitment

Outreach workers are usually women who are similar to the members of the target group, but who have been trained in family planning. These women work in the community. For example, they may go door to door in a low-cost-housing development. If they find someone home who is in the target group, they talk to them about family planning. The number of people seen by outreach workers from agency a, who are in an eligible state s, $s=2, 3, \cdots, NS$ (*see* box 1 in Fig. 2), is:

$$\text{OUTSEE}_{t,a,s}=\text{NRCALL}_{t,a}\text{PRFIND}_a\text{NSTATE}_{t,s}/\text{TARGP}_t, \qquad (1)$$

$\text{OUTSEE}_{t,a,s}$ = number of people in state s that OUTreach workers from agency a SEE in month t

$\text{NRCALL}_{t,a}$ = Number of Recruitment outreach CALLs made in month t by agency a

PRFIND_a = PeRcent of outreach calls of agency a that result in FINDing a person in target group

$\text{NSTATE}_{t,s}$ = Number of people at time t in STATE s

TARGP_t = number of people in the TARGet grouP at time t

The number of calls is reduced by the percent of people found that are in the target group (PRFIND). The states of those called upon are determined in proportion to the number of people in each state relative to the target group [*see* the third term of (1)]. This assumes a random calling pattern with respect to states within the target group. Equation (1) also reduces effectiveness by the fraction of ineligible

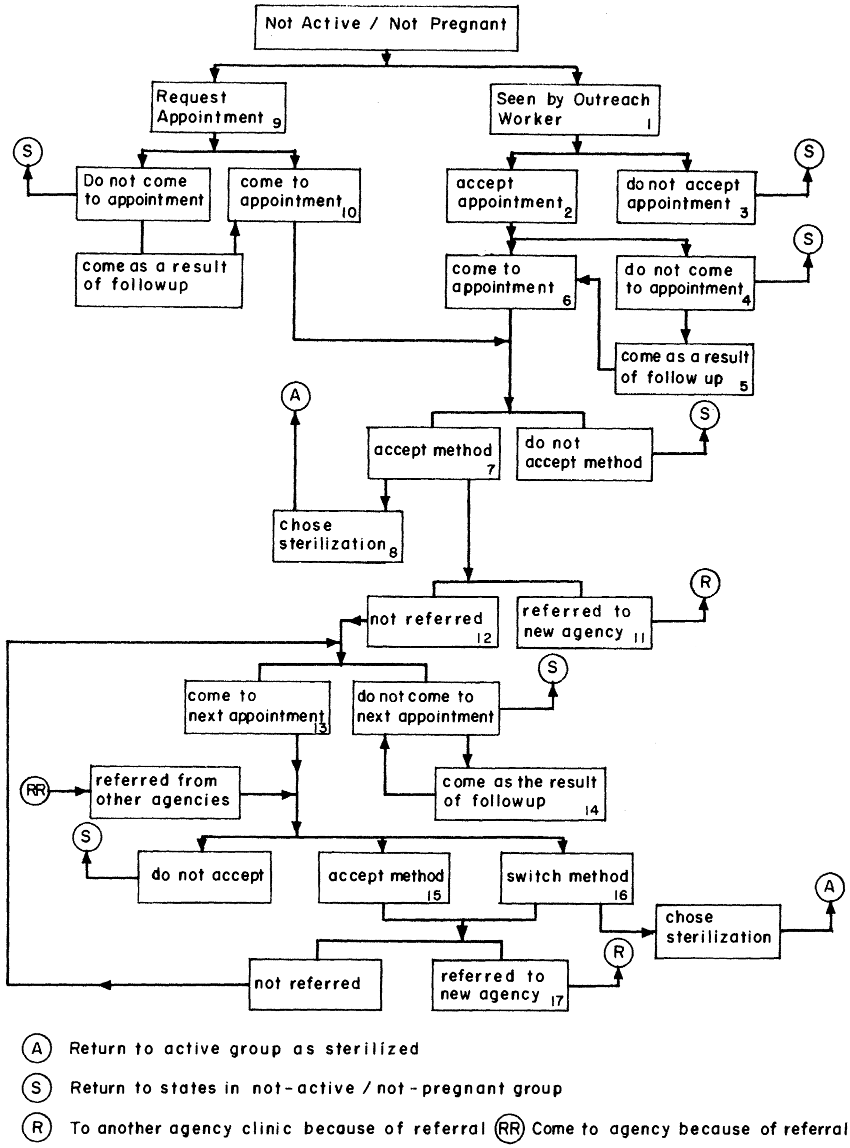

Fig. 2. The nonpost-partum agency-flow structure.

people (active or pregnant) since $\mathrm{NSTATE}_{t,s}$ over $s=2, 3, \cdots, NS$ does not include the active or pregnant sections of the target group.

After removing those seen from each state (NSTATE), the number who make an appointment with the outreach worker (*see* box 2 in Fig. 2) is specified as

$$\mathrm{OUTAPT}_{t,a}=\sum_{s=2}^{s=NS} \mathrm{OUTSEE}_{t,a,s}\mathrm{PDESIR}_{a,s}, \tag{2}$$

$OUTAPT_{t,a}$ = Number of people visited by OUTreach worker who make an APpoinTment in month t at agency a

$PDESIR_{a,s}$ = Percent of people visited who are in state s and who DESIRe an appointment at agency a

PDESIR is subscripted by state, since people may respond differently based on their past experience, and subscripted by agency to allow differences between the outreach workers of the agencies.

The number who came to the appointment made through the outreach worker before any follow-up effort (*see* box 6) is:

$$COMO_{t,a} = OUTAPT_{t,a} PCOMO_a, \tag{3}$$

$COMO_{t,a}$ = Number of people who COMe in month t to Outreach-generated appointment at agency a before follow-up effort

$PCOMO_a$ = Percent of people who COMe to their appointment made with Outreach worker from agency a

Those who do not come may receive another outreach visit, so the number who come is adjusted for follow up (*see* boxes 4–5) as

$$COMOFU_{t,a} = (OUTAPT_{t-1,a} - OUTCOM_{t-1,a}) (NFCALL_{t,a}/TNCOM_{t-1,a}) PFFIND_a PCOMFU_a, \tag{4}$$

$COMOFU_{t,a}$ = Number of people to COMe to Outreach-generated appointment after Follow Up in month t and agency a

$OUTCOM_{t,a} = COMO_{t,a} + COMOFU_{t,a}$

$NFCALL_{t,a}$ = Number of Follow-up CALLs by outreach workers of agency a in month t

$TNCOM_{t-1,a}$ = Total number of people who do Not COMe to a scheduled appointment in month t in agency a

$PFFIND_a$ = Percent of Follow-up visits that result in FINDing the person who did not come

$PCOMFU_a$ = Percent who COMe of those contacted by a Follow-Up visit

The first term of the equation is the number who did not come to their outreach-generated appointment last month. The second term is the percent of all people who did not come to a scheduled appointment last month who received a follow-up visit. Lags are specified, since follow up does not occur until the list of people who missed their appointment last month is known. Those who missed last month are called on this month. The last terms in (4) reflect the ability to find the person again (PRFIND) and her response in terms of coming to the appointment. Follow-up outreach visits are modeled explicitly, but the basic rates of coming to an appointment [e.g., PCOMO in (3)] may reflect mail, phone reminders, or other nonoutreach follow up. Those who do not come to their appointments are returned to state four—the state defined to include people who had some outreach experience, but did not come.

Those who come will decide to accept or reject family planning and those who accept will select a specific method (*see* box 7).

$$ACCPTO_{t,m,a} = (COMO_{t,a} + COMOFU_{t,a}) PACPTO_a FACPTO_{m,a} \tag{5}$$

$ACCPTO_{t,m,a}$ = Number of people in month t who ACCePT method m at agency a as a result of recruitment Outreach

$PACPTO_a$ = Percent of people who ACcePT a contraceptive method after visit from Outreach worker of agency a [*see* (6)]

$FACPTO_{m,a}$ = Fraction of those who ACcePT after Outreach who accept specific method m at agency a

The percent who accept a method may be less than one because: (1) the person learns something about contraception that is viewed negatively, (2) she is treated poorly and does not receive quality care, (3) the clinic surroundings are not acceptable, or (4) the wait for service is intolerably long. The first three effects can be encompassed in the reference-acceptance value. The waiting-time phenomenon is modeled by making the reference fraction that accept a function of the degree of capacity utilized.

$$PACPTO_{t,a} = PACTOC_a \overline{RCAP}_a (UCAP_{t,a}/TCAP_{t,a}), \qquad (6)$$

$PACTOC_a$ = Percent of people who would ACcepT a contraceptive method after a visit from an Outreach worker at agency a if the service is Convenient.

$\overline{RCAP}_a$ = Response function for CAPacity at agency a
= defines an index between zero and one dependent on the percent of capacity utilized at agency a.

$UCAP_{t,a}$ = Utilized CAPacity in month t at agency a

$TCAP_{t,a}$ = Total CAPacity in month t at agency a

The response function (RCAP) will usually have values near one until capacity is exceeded, at which point the index will drop rapidly. Those who do not accept are returned to state 2 (never) or 3 (ever) depending on whether they had a previous record of acceptance.

Request for Service

Requests for an appointment may be due to advertising, the indirect effects of outreach, word-of-mouth communication, or spontaneous action. These are modeled by assigning a request rate to each state and a time-varying index, so that the number of people requesting (*see* box 9) is:

$$REQ_{t,a,s} = NSTATE_{t,s} PREQ_{a,s} INDREQ_{t,a}, \qquad (7)$$

$REQ_{t,a,s}$ = Number of people from state s who REQuest an appointment at agency a in month t

$NSTATE_{t,s}$ = Number of people at time t in STATE s

$PREQ_{a,s}$ = Percent of people in state s who REQuest an appointment at agency a in month t

$INDREQ_{t,a}$ = Time INDex for REQuests (nominally 1.0)

Recall that state five ($s=5$) was defined as awareness, so that a higher request rate, due to media expenditures, could be considered. The gain of awareness is modeled as a movement from other states to state 5 as a function of the advertising expenditure. The number of people in state 5 is:

$$NSTATE_{t,5} = \sum_{s=2,s\neq 5}^{s=NS} NSTATE_{t,s} \overline{RADV}_s (ADV_t) + NSTATE_{t,5}, \qquad (8)$$

$\overline{RADV}_s$ = Response function to advertising expenditure (ADV_t). It is the percent of people in state s who become aware of the advertising in a month with advertising expenditure ADV_t. The usual form shows decreasing returns to advertising and a saturation level.

A decay of awareness is specified to reflect forgetting. For states $s=2$ to NS:

$$NSTATE_{t+1,s} = NSTATE_{t,5}ADFGET_s + NSTATE_{t,s}, \tag{9}$$

$ADFGET_s$ = Percent of ADvertising-aware people who ForGET from state 5 to s in a month

A similar function is applied to the population of state 4 (indirect outreach), since the outreach impact decays over time.

The number of people who come to the requested appointment (*see* box 10) is:

$$COMR_{t,a,s} = REQ_{t,a,s}PRCOM_a, \tag{10}$$

$COMR_{t,a,s}$ = Number of people in state s who COMe in for a Requested appointment in month t at agency a

$REQ_{t,a,s}$ = Number of people from state s who REQuest an appointment at agency a in month t

$PRCOM_a$ = Percent of those who Request an appointment who COMe without follow up at agency a

The number who accept a method after coming (*see* box 7) is:

$$ACCPTR_{t,m,a} = \sum_{s=2}^{s=NS} REQCOM_{t,a,s}PACPTR_{a,s} \cdot \overline{RCAP}_a(UCAP_{t,a}/TCAP_{t,a})FACCPT_{m,a,s}, \tag{11}$$

$ACCPTR_{t,m,a}$ = Number of people in month t who ACCePT method after Requesting an appointment at agency a

$REQCOM_{t,a,s}$ = $COMR_{t,a,s}$ if there is no outreach follow up of requests for appointments, or $COMR_{t,a,s}$ adjusted for follow up as in (4) if there is outreach follow up.

$PACPTR_{a,s}$ = Percent of people in state s who ACcePT a contraceptive method after coming to Requested appointment if service is convenient at agency a

$\overline{RCAP}_a$ = Response function for CAPacity at agency a [*see* (6) for further explanation]

$FACCPT_{m,a,s}$ = Fraction of people in state s who ACCePT a method who accept specific method m at agency a

Referral and Switching Methods

Referral in family-planning systems usually operates on the total first-time accepters. This number of nonpost-partum accepters is the sum of those due to outreach and requests.

$$ACCPT_{t,m,a,d} = ACCPTO_{t,m,a} + ACCPTR_{t,m,a}, \tag{12}$$

$ACCPT_{t,m,a,d}$ = Number of people who ACCePT in month t method m at nonpost-partum agency a for the first time ($d = 1$).

$ACCPTO_{t,m,a}$ = ACCePTance from Outreach [*see* (5)]

$ACCPTR_{t,m,a}$ = ACCePTance from Request [*see* (11)]

Referral may take place because the patient lives near a clinic or because the capacity of a particular clinic is stressed. For example, a post-partum hospital may refer patients to a local county health department. The referral process is modeled by a referral rate between agencies and a percentage of the patients who go to the new agency. In the model, patients are not moved from one agency to another when referred, but rather when they appear at the new agency. The equation to update acceptance for referral (*see* box 12) is:

$$\begin{aligned} \mathrm{ACCPT}_{t-A,m,a,d} = {} & \mathrm{ACCPT}_{t-A,m,a,d} \\ & + \sum_{aa=1,aa\neq a}^{aa=NA} \mathrm{ACCPT}_{t-A,m,aa,d}\mathrm{PREF}_{a,aa,m}\mathrm{PRCOM}_{a,aa} \\ & - \sum_{aa=1,aa\neq a}^{aa=NA} \mathrm{ACCPT}_{t-A,m,a,d}\mathrm{PREF}_{aa,a,m}\mathrm{PRCOM}_{aa,a}, \end{aligned} \tag{13}$$

$A = \mathrm{APT}_{m,a,d}$ = Interval between APpoinTment d and $d+1$ for method m at agency a

$\mathrm{PREF}_{a,aa,m}$ = Percent of initial acceptors of method m REFerred to agency a from agency aa in a month

$\mathrm{PRCOM}_{a,aa}$ = Percent of those Referred to agency a from agency aa who COMe to the new agency

Although referral usually takes place at the initial visit ($d=1$), (13) can be used to refer people of any depth of experience when PREF is further subscripted by d. Such alternative on-line subscripting will be discussed later in this paper.

Switching of methods (*see* box 16) is simply modeled by a first-order Markov transition from one method to another within an agency, where the rate of switching can have different values for women using different methods and with different numbers of past acceptances of the method.

Continuance

Continuation is modeled by specifying the number of people who will return for their next visit. The alternative would be to use time as the basic unit of continuance (i.e., percent of patients active n months after acceptance). In this model visit continuation is preferred, since (1) costs and service are incurred at visits, (2) client data are visit based, (3) phenomena such as referral and switching are visit related, and (4) managers think in terms of the visit as the underlying program event. In situations where patient visit records are not available, time-dependent rates could be derived from survey data and be converted into visit-to-visit rates by dividing the time axis into visit intervals and calculating the percent who continue from visit d to $d+1$.

The number of people who return for their next visit (*see* box 13) is:

$$\mathrm{COMC}_{t,m,a,d} = \mathrm{ACCPT}_{t-A,m,a,d}\mathrm{PCOMC}_{m,a,d}, \tag{14}$$

$\mathrm{COMC}_{t,m,a,d}$ = Number of people COMing to their Continuing appointment in month t having last accepted method m d times at agency a

$\mathrm{ACCPT}_{t-A,m,a,d}$ = Number of people who ACCePTed in month $t-A$ method m at agency a for the dth time

$\mathrm{PCOMC}_{m,a,d}$ = Percent of people who COMe for Continuing appointments for method m at agency a after d visits

A = $APT_{m,a,d}$ = Interval between APpoinTment d and $d+1$ for method m at agency a

This number is then updated to reflect follow up (*see* box 14) in a manner similar to (4) to define:

$CONCOM_{t,m,a,d}$ = After outreach follow up the number of people with CONtinuing appointments COMing in month t to agency a having accepted d times and using method m

Those who do not come may have lost interest in contraception or they may have had a negative experience with their method. Those who do not come are divided into not-negative and negative groups and returned to the appropriate states. The updating for state 3 that has been defined as 'ever in system but not negative' is:

$$NSTATE_{t,3} = \sum_{d=1}^{d=ND} (ACCPT_{t-A,m,a,d} - CONCOM_{t,m,a,d})(1 - PERNEG_{m,d}) + NSTATE_{t,3}, \quad (15)$$

$PERNEG_{m,d}$ = PERcent of people who have accepted d times and last accepted method m who have a NEGative experience

The first term defines those due for an appointment in month t ($ACCPT_{t-A,m,a,d}$) less those who came (CONCOM), while the second term defines the nonnegative percentage. For the negative states ($s = 5+m$, $m = 1, \cdots, NM$, where NM is the number of methods):

$$NSTATE_{t,5+m} = \sum_{d=1}^{d=ND} (ACCPT_{t-A,m,a,d} - CONCOM_{t,m,a,d}) PERNEG_{m,d} + NSTATE_{t,5+m}. \quad (16)$$

Those who come may accept [*see* boxes 15 and (7)], switch methods (box 16), and be referred [*see* boxes 17 and (13)]. Those who do not come to their appointment may obtain contraceptives through private channels and they are identified as a separate group, but they are not included in the public system manager's definition of 'active.' At the end of the period all people are in a nonactive ($NSTATE_{t,s}$) or active ($ACCPT_{t,m,a,d}$), so, in the next period, equations (1) to (15) again process them through the nonpost-partum flow.

Post-Partum Flow

Figure 3 describes the detailed post-partum-acceptance and continuance flow. If a woman delivers at a hospital with a post-partum family-planning program, she may be seen by a family-planning worker (box 2) and may accept a method immediately (box 3), or subsequently at a six-week post-partum check up (boxes 6, 7). If a woman is not seen immediately post partum, but comes to the six-week check up, she may become an accepter. In all cases of acceptance except sterilization (box 1), the repeat visits (boxes 9, 5) are modeled as in the nonpost-partum flows with follow-up, referral, and method-switching opportunities. Those who accept immediately are followed separately until they have made two visits (boxes 4, 5), at which point they are aggregated with other people who have made two post-partum visits (box 10). The equations documenting these flows are analogous to equations (1) to (16). Parameters are defined for each flow rate and appointment lags are considered. Because of the similarity to previous equations and space restrictions, these equations are not included here.[5]

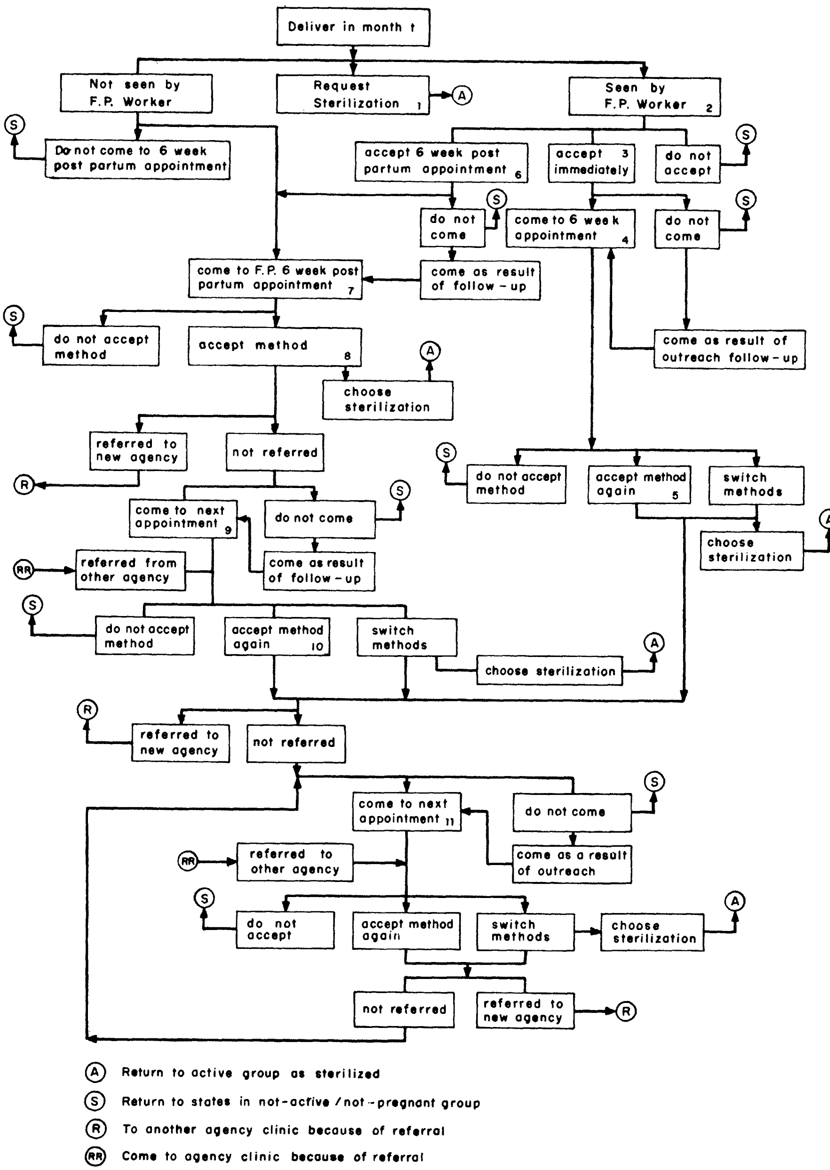

Fig. 3. A post-partum-agency flow structure.

Pregnancy-Abortion-Birth Flow

With the changes in the populations of actives and nonactives determined by acceptance and continuance of post-partum and nonpost-partum patients, the next step is to specify the pregnancy rates based on demographic fertility data and model the effects of abortion in order to define the number of deliveries and live births in the target group. This flow is described in Fig. 4.

Actives become pregnant owing to method failures (boxes 4, 5) and nonactives become pregnant (boxes 1, 2, 3) at rates dependent upon whether they use private (nonsystem-dispensed) contraceptives. If people drop out of the public system and use private channels of distribution, the model tracks this phenomenon and its demographic impact.

The pregnancy rate from actives depends on the fraction of people who are using the method properly (e.g., taking a pill each day) and the effectiveness of the methods, given that they are used properly. The number of actives who become pregnant in a month is (*see* boxes 4, 5):

$$\begin{aligned}\text{PREGA}_{t,m} = {} & \sum_{a=1}^{a=NA} \sum_{d=1}^{d=ND} \text{ACTIVE}_{t,m,a,d}(1\text{-EFFMTH}_m)\text{EFFUSE}_{m,d} \\ & \cdot \text{AFERA}_t \text{SEAFER}_t \text{ILF} \\ & + \sum_{a=1}^{a=NA} \sum_{d=1}^{d=ND} \text{ACTIVE}_{t,m,a,d}(1\text{-EFFUSE}_{m,d})\text{AFERA}_t \\ & \cdot \text{SEAFER}_t \text{ILF},\end{aligned} \tag{17}$$

$\text{EFFUSE}_{m,d}$ = Percent of actives of method m who have accepted d times who EFFectively USE method

EFFMTH_m = EFFectiveness of MeTHod m, probability of preventing a pregnancy of fecund women properly using method m in a month

AFERA_t = Average FERtility of Actives, probability of pregnancy in a month

SEAFER_t = Index of SEAsonality on FERtility[6]

ILF $\begin{cases} = \text{Index value to reflect lower fertility during amenorrhic post-partum period (when } d=1,\ a=\text{post partum)} \\ = 1.0, \text{ otherwise} \end{cases}$

The first term in (17) reflects actives using methods properly and the second term defines those not using methods properly. The rate of proper usage (EFFUSE) varies by method.[7] A loop is properly used if it is in place, while pills must be taken every day. EFFUSE is also circumscribed by the number of times the method has been accepted, since, particularly for the first acceptance, contraceptives can be obtained with little commitment to regular usage. For example, a woman at the post-partum checkup may accept pills, but not have as great a desire to use them as a woman who has returned for her second supply and proved her commitment to contraception.

The number of pregnancies within the nonactive group is the number of not active and unprotected women times their fertility rate plus the number of nonactives using privately dispensed methods times the method ineffectiveness and their fertility rate.

The model defines two average fertility rates, one for actives and one for nonactives. The average fertility of actives (AFERA) in a family-planning system is higher than the nonactive rate, since many actives enter through the post-partum

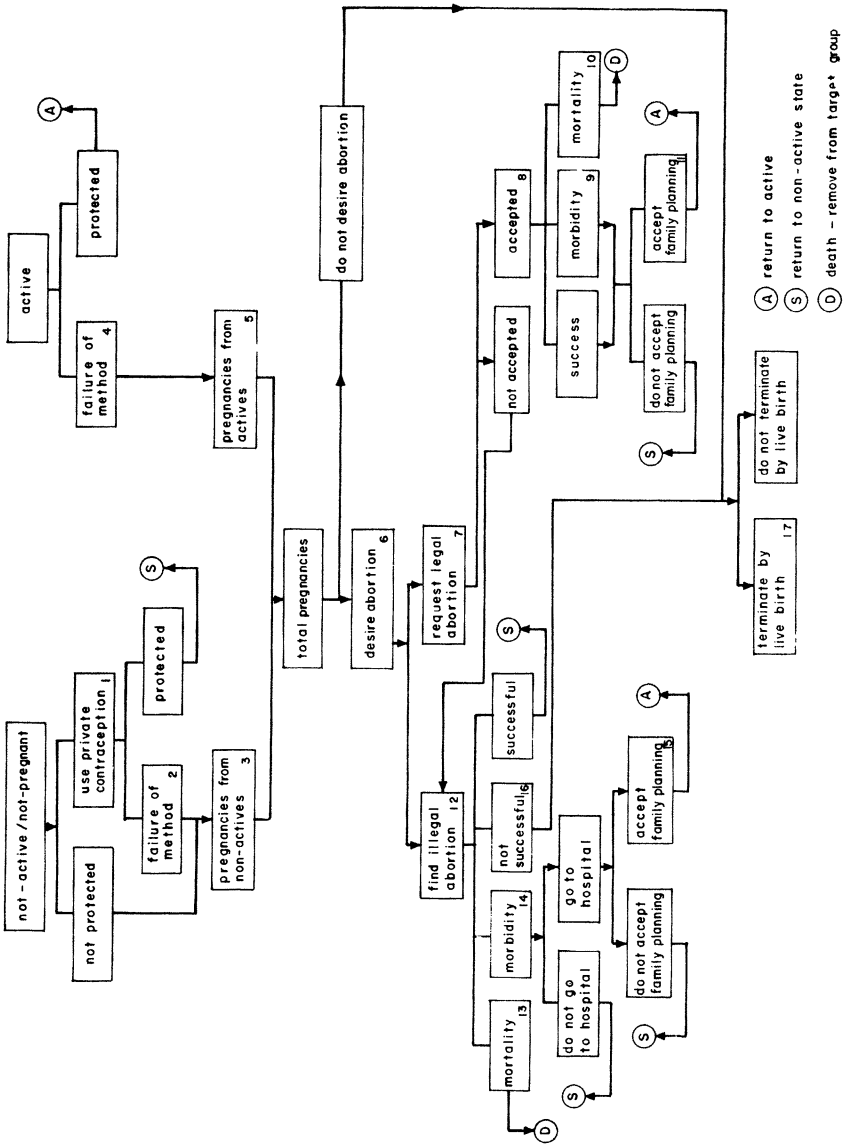

Fig. 4. Pregnancy and birth flows.

program. The fertility of women varies by parity (i.e., the number of births). After one birth, the conditional fertility rate is approximately 75 percent greater than no births, so actives have a higher fertility than nonactives.[8] In addition to parity differences, other demographic effects may cause the average fertility of actives to be different from that of nonactives. For example, actives may tend to be older, so that age and parity cohorts may need to be considered. In order to include demographic effects and still maintain the efficiency necessary for on-line use and managerial acceptance, a submodel is used to specify appropriate average fertilities for actives by considering the demographic composition of the active and nonactive groups, the fertility of each demographic cohort, and the acceptance and continuance response of each cohort. The basic approach is to define demographic units and track the number of people in each demographic cohort in the active and nonactive group each month. Given these compositions, the appropriate fertility is a weighted average of the uncontracepted fertility rates for each demographic cohort.

The number of people from each cohort in the active (A) and nonactive (NA) groups in each period used in the weighted average is specified by a nonstationary Markov process. The Markovian states are denoted by k, where

$k=1, NC$	for nonactive in each cohort (NC=total number of cohorts),
$k=NC+1$ to $2NC$	for active in each cohort,
$k=2NC+1$ to $3NC$	for pregnant in each cohort.

The number in each Markovian state at time t is

$$N_{t,k}=\sum_{kk=1}^{kk=3NC} N_{t-1,kk}P_{k,kk}^{t}, \qquad (18)$$

$N_{t,k}$=Number of people in Markovian state k at month t

$P_{k,kk}^{t}$=Transition Probability to state k from state kk in month t

The transition probabilities are determined from the model-flow outcomes and the cohort-fertility rates. For example, the transition from nonactive to active is specified by the overall nonpost-partum first acceptance rate of the model multiplied by an index to reflect differential acceptance rates for each cohort. Similarly, other transitions are defined by internally generated model-flow rates. In this manner, the cohort composition of actives and nonactives can be tracked and an appropriate average fertility for actives and nonactives can be calculated.

The abortion flows shown in Fig. 4 represent the desire for abortion (box 6) and the rates of legal and illegal abortion (boxes 7 and 12). They interact, since, if the acceptance rate (box 8) for legal abortion increases, illegal abortion may decrease. Abortion outcomes (boxes 13, 14, 16, 9, and 10) and post-abortion contraceptive-care (boxes 15 and 11) flows are modeled similarly to previous equations.

The resulting pregnancies not terminated by abortion (box 17) become the input after nine months to the post-partum flow described in Fig. 3. This completes the model-flow structure description.

MODEL OUTPUT

THE MOST COMMONLY used measures of family-planning-system performance are the number of total active patients and the number of new patients per period.

The model output includes these measures, as well as the numbers of births, the numbers of pregnancies, the agency visit-capacity utilized, the costs, and a detailed analysis of the sources of new patients.

Accepters are processed to obtain active patients, those who accepted at their last visit and are not late for their next visit.

$$\text{ACTIVE}_{t,m,a,d} = \sum_{T=t-A+1}^{T=t} \text{ACCPT}_{t,m,a,d}, \qquad (19)$$

$\text{ACCPT}_{t,m,a,d}$ = Number of people who in month t ACCePTed method m at agency a for the dth time

$A = \text{APT}_{m,a,d}$ = Actual number of months between APpoinTments for method m at agency a for those who have accepted d times

In order to compare the model output to client-record-system output, it is also useful to define another active measure as those who complete an appointment less than X months (usually 2 months) after the scheduled appointment date. Equation (19) is theoretically more correct, since it uses actual appointment intervals, but in the real data systems scheduled appointment intervals are more operational. The model produces the number of actives by both definitions for ease of tracking actual data and planning. The numbers of actives are subscripted by time, method, and agency, so totals can be made on any dimension to allow comparisons between agencies, methods, or agencies and methods. Since active patients also are known by the number of times they have accepted, the number of acceptances can be multiplied by the monthly appointment interval to find the time in the system for each group of actives. This allows an output profile of the percent of people continuously in the system for X months (e.g., $X = 3, 6, 9, 12, \cdots, 36$ months). Other outputs, such as the number of abortions, mortalities, and morbidities due to legal and illegal abortion, also may be displayed. The volume of medical services dispensed may be assessed. These are specified by multiplying the number of people who make a visit ($\text{ACCPT}_{t,m,a,d}$) times the percent who receive a particular service on that particular visit. Medical outputs can include the number of PAP tests, breast exams, pelvic exams, annual medical checkups, VD screens, and sickle-cell tests.

Although these outputs are valuable, they do not allow a cost/benefit trade off. Three benefit measures are defined to allow direct tradeoffs of policy, budget, and allocation changes. The first is couple-years of protection. If one hundred women were sterilized, they would be completely protected in each year, so one hundred couple-years of protection would be generated. For other methods, the degree of protection depends upon how effectively people use the method and the underlying clinical effectiveness. The number of couple-years of protection is determined by summing the actives in each month weighted by their effectiveness of use and method effectiveness and divided by 12 to convert months to years:[9]

$$\begin{aligned}\text{CYP}_{y,a} = [&\textstyle\sum_{m=1}^{NM-1} \sum_{T=t-12}^{T=t} \sum_{d=1}^{d=ND} \text{ACTIVE}_{T,m,a,d}(\text{EFFUSE}_{m,d}) \\ &\cdot (\text{EFFMTH}_m) + \textstyle\sum_{T=t-12}^{T=t} \text{ACTIVE}_{T,NM,a,1}]/12,\end{aligned} \qquad (20)$$

$\text{CYP}_{y,a}$ = Couple Years of Protection in year y at agency a

$\text{EFFUSE}_{m,d}$ = Fraction of acceptors EFFectively USE method [*see* (17) for further discussion]

EFFMTH_m = EFFectiveness of MeTHod m [*see* (17)]

$\text{ACTIVE}_{t,m,a,d}$ = Number of ACTIVE patients in time t at agency a that have accepted method m at the dth visit

The first term is the couple-years of protection produced by actives of all methods except sterilization. The second term adds the protection from sterilization (method NM, $d=1$). Since IUD users may be protected even if they do not return for their appointments, there is an option in the model to increment the couple-years of protection by a pseudo-active class of IUD users who missed appointments. The number of privately protected people could be added in (20) if the total couple-years of protection were desired.

Although the couple-years of protection is a good benefit measure and would allow comparison between methods, agencies, and systems on the basis of couple-years of protection per dollar, it does not capture the prevention of unwanted births. What is needed is a measure of the incremental number of unwanted births prevented. This depends upon: (1) the uncontracepted fertility of the active group, (2) the protection that results during the term of pregnancy, and (3) the practices people would have followed to prevent or terminate pregnancy if the system did not exist. The first effect can be captured by modifying couple-years of protection to produce what shall be called *births protected* (BP). The number of births protected is the couple-years of protection multiplied by a reference average fertility rate that represents the average fertility before the contraception system began to operate. All three effects are included in the incremental unwanted births prevented, which can be obtained by comparing two runs of the model, the first with the family-planning system and the second without any system programs (no acceptance or continuance), but with the appropriate parameters for rates of private protection and abortion. By subtracting the number of births in the first run from those in the second, the incremental number of unwanted births prevented can be obtained.[10] When the cost for an incremental birth prevented is calculated, realistic budgeting decisions can be made if the value of a birth prevented can be estimated.[11]

MODEL INPUTS

IN MOST FAMILY-PLANNING systems, patient-visit records are maintained that document the clinic visits longitudinally. From a modeling point of view, a sample of longitudinal histories is sufficient, so the availability of exhaustive data is an unexpected advantage and it allows estimation of parameters within detailed subgroups of the model flow (e.g., post-partum immediate accepters versus six-week first accepters). These data can be processed by a large-classification analysis to determine acceptance, continuance, referral, and switching rates, as well as average visit intervals. This section presents some of the results of analyzing the Atlanta client-record data.

A client record includes, among other data, (1) patient ID number, (2) clinic code, (3) method selected, (4) date of visit, (5) date of next appointment, (6) date of last pregnancy termination, and (7) indication of referral action, if taken.

In processing client-record data, a time period must be specified over which the parameters are assumed to be stationary. In the Atlanta analysis, a sixteen-month period was used, since nonstationarity was expected over a longer period. At the end of this period three possible states exist for people: (1) prospective—next appointment date has not yet arrived, (2) delinquent—less than two months late for appointment, and (3) inactive—more than two months late for appointment. These end effects are critical in the estimation of continuance rates. The continuation rate in the model is the percent of people who return for their next visit [$PCOMC_{m,a,d}$, *see* (14)]. Calculating the continuation rate was complicated, since prospectives and delinquents had not completed their next visit. One alternative was to ignore any information contained in the end of the tape. However, this was deemed unwise, since, with a visit interval of six to twelve months as occurs for IUD's, much information would be lost. Rather, estimates were made for the continuance rates of the people in the end-point states.

The estimation equation for continuance rates is:

$$\begin{aligned} PCOMC_{m,a,d} = [&RETURN_{m,a,d+1} + PP_{m,d}PROSP_{m,a,d+1} \\ &+ PD_{m,d}DELINQ_{m,a,d+1}]/TOTAL_{m,a,d}, \end{aligned} \tag{21}$$

$PCOMC_{m,a,d}$ = Percent of people who COMe for their $d+1$ Continuing appointment for method m at agency a after completing d visits

$RETURN_{m,a,d+1}$ = Number of people using method m at agency a who RETURN for their $d+1$ visit before the end of the estimation period

$PROSP_{m,a,d+1}$ = Number of people who completed visit d, but whose $d+1$ appointment data has not arrived by end of the estimation period; they are PROSPective

$DELINQ_{m,a,d+1}$ = Number of people who completed visit d and are less than two months late for their $d+1$ visit at the end of the estimation period; they are DELINQuent

$TOTAL_{m,a,d}$ = TOTAL number of people who completed visit d during the estimation period

$PP_{m,d}$ = Percent of Prospective patients who will return for their $d+1$ appointment after making d visit

$PD_{m,d}$ = Percent of Delinquent patients who will return for their $d+1$ appointment before their scheduled appointment date plus two months

The best estimate of $PP_{m,d}$ is the continuation rate itself, PCOMC. This is because all patients (TOTAL) were at one time 'prospective.' PD is estimated by examining the records of a group of delinquents and finding the percent who return empirically. Substituting PCOMC for PD, (21) becomes

$$\begin{aligned} PCOMC_{m,a,d} = [&RETURN_{m,a,d+1} + PD_{m,d}DELINQ_{m,a,d+1}]/ \\ &[TOTAL_{m,a,d} - PROSP_{m,a,d+1}]. \end{aligned} \tag{22}$$

This is the equation used to estimate continuance rates.

Table I presents the visit-continuation rates for each method, agency, and visit number. The continuance rates in almost all cases increased as the number of visits increased. There were real differences between agencies. The counties (Dekalb and Fulton) had the highest continuation rates. This was probably due to the good service and follow-up rendered by public health nurses trained in epidemiology. Planned Parenthood pill continuance was high, but IUD continuance

TABLE I

VISIT-CONTINUATION RATES: 1971, ATLANTA, GEORGIA

	Visits			
	1 to 2	2 to 3	3 to 4	4 to 5
GRADY—post partum				
Pill	0.59[a]	0.72	0.76	0.85
IUD	0.76[a]	0.77	0.79	0.87
Injection	0.76[a]	0.90	0.89	0.94
GRADY—nonpost partum				
Pill	0.59	0.72	0.75	0.84
IUD	0.71	0.78	0.80	0.86
Injection	0.78	0.89	0.89	0.94
Planned Parenthood				
Pill	0.67	0.78	0.81	0.89
IUD	0.65	0.66	0.74	0.78
Fulton County				
Pill	0.69	0.87	0.90	0.92
IUD	0.87	0.93	0.90	0.91
DeKalb County				
Pill	0.75	0.84	0.87	0.91
IUD	0.71	0.77	0.78	0.80

[a] Includes only those whose first visit was at a six-week appointment.

Note: The maximum standard deviation of estimate is 0.02. No continuation rates were reported if there were less than 25 people.

was relatively low. Grady injection and IUD continuance rates were high, while pill rates were low.

Continuance rates define whether a person will return for a next visit and visit intervals describe when a person returns. Table II describes the overall distribution of visits relative to the scheduled appointment interval. Over 80 percent of the women came early. IUDs had the longest visit interval of approximately five months. Pills had an interval value of about four months and injections had an interval of a little under three months. These averages were substantially less than the suggested appointment intervals of twelve months for IUDs, six months for pills, and three months for shots. The mean visit intervals did not vary substantially by the number of visits. Although the model allows for variation by depth ($APT_{m,a,d}$), the Atlanta data did not indicate the need for variation over the depth subscript.

TABLE II

OVERALL DISTRIBUTION OF VISIT INTERVALS

Class		Percent
1	Less than 25% of scheduled appointments	13.1
2	25% to 75% of scheduled appointments	22.2
3	75% to 100% of scheduled appointments	46.5
4	Within 2 months of appointment (delinquent)	13.3
5	Between 2 months and 6 months after appointment	4.9

If a woman returns for a visit, she can continue use of the same method or switch methods. Table III presents the method-switching rates. Over 10 percent of the women using IUDs switched from IUDs to pills at each visit. These rates continued high throughout the visit sequences and reflected a continuing occurrence of side effects. The switching rate of IUDs to pills was especially high at Planned Parenthood (25 percent). The highest rates of switching from IUDs to pills were observed for those who also switched agencies from Grady to Planned Parenthood or counties. Apparently these agencies are less loop prone than Grady. Switching from pills to IUDs was low (about 1 to 3 percent) at all agencies except Grady. At Grady the rate was 10 percent on the first visit, but dropped to 5 percent by the fifth visit. In general, the switching rates reflected the attempts by women to find the best contraceptive method for themselves.

TABLE III

METHOD-SWITCHING RATES FOR PATIENTS CONTINUING FROM VISIT d TO $d+1$

	Grady, %	Planned Parenthood		Counties	
		Last visit at Planned Parenthood, %	Last visit at Grady, %	Last visit at County, %	Last visit at Grady, %
Visit 1–2					
IUD-pill	10.2	25.6	54	6.6	20.5
Pill-IUD	10.7	2.8	2.9	2.6	2.6
Visit 2–3					
IUD-pill	12.0	25.1	43	10	13
Pill-IUD	8.1	1	3.9	1.2	1
Visit 3–4					
IUD-pill	13.9	29.1	35.8	11	33
Pill-IUD	6.6	0.9	2.3	2.2	6
Visit 4–5					
IUD-pill	12.6	33	43	6.7	6.7
Pill-IUD	5.5	1	1.4	1.2	1

In addition to continuance and switching, the client-record data were used to estimate the conditional probabilities of the post-partum flow. Overall, high post-partum acceptance rates were found. Seventy percent of pregnancy terminations led to acceptance. Within the process of acceptance it was found that a little less than one-half of the women were seen immediately postpartum by a family-planning worker. Seventy percent of those seen immediately returned for a six-week checkup. However, 63 percent of those not seen immediately postpartum also returned. Virtually all women who returned for a visit accepted a method. The acceptance rate for those who experienced a method failure ('evers') was almost equal to the rate of new-patient ('never') acceptance, but 'evers' tended to accept more reliable methods. Referral was high at the Grady Clinic, where 25 percent of the new patients were referred to the county clinics at the six week visit. Another 20 percent switched from Grady to Planned Parenthood clinics.

The analysis of the client-record data yields estimates of the model's acceptance and continuance parameters. In the United States such record data are required at all agencies that receive funding from the National Center for Family Planning Services of HEW. Although the data quality may not be as high as in Atlanta, good estimation of the flow parameters can be obtained in most US programs.[12]

In addition to client-record data, outreach records, special sample surveys, demographic studies, and experiments can be used to estimate parameters of use experience [equations (15) and (16)], private protection, advertising, migration, and fertility.

When all these data sources are exhausted, an initial estimate of each parameter is obtained; it can then be checked against managerial subjective estimates. This checking of subjective and empirical estimates helps managers to learn about their systems, identifies biases in the data, and provides a basis for defining 'best' estimates. These best estimates are inserted in the model and the model output is compared to a historical set of data on total active patients, new patients, births, and actives by method and agency. If the model does not fit as well as desired, parameters are adjusted until a best fit is obtained. This is a nonlinear estimation procedure that forces a best fit to the historical data, and it is called 'fitting.'

'Tracking' is then used to test the estimates and identify dynamics in the system. The best-fitting parameters are used to make conditional predictions of system performance. As the new data are obtained, the predicted and actual values are compared. If they differ, an attempt to find out why is made. This problem finding is an important managerial act. For example, if the number of actives is lower than expected, is it because acceptance rates fell, continuance rates decreased, outreach visits were not made, or initial parameter estimates were wrong? If, after an attempt to find the problem, no reasons for system nonstationarity are discovered, parameters are updated to best fit the new data and new predictions are made. If a problem is found (e.g., the number of outreach calls is below expectation) corrective program action is taken, the input is adjusted, and the model refitted to the data. This adaptive procedure continues along with changes in strategy and planning.

In addition to the straightforward estimation and adaptive procedure, another method of resolving the input issues is to aggregate the model. For example, aggregation could occur by ignoring all nonactive state distinctions. If advertising were not considered, this would remove the need for experimentation and awareness surveys. Abortion and demographic cohort fertility effects could be ignored, so that only the direct hospital birth rate would be needed. These aggregations reduce the input burden and simplify the model.

The underlying philosophy of the model is evolutionary. It is visualized that its application begins at a very simple level where data are available; then it is elaborated as managers desire more detail and input data become available.

EVOLUTIONARY IMPLEMENTATION OF THE MODEL

THE MODEL IS computerized as an on-line, conversational program, so that it is easy to use and managers can feel in control of the system.

The basic approach to evolution is through a series of on-line questions that specify the nature of the model to be considered. First, the number of agencies to be considered is identified and then the types of programs (post-partum or non-post-partum, or both) they offer are defined. Next the contraceptive methods available in the system are indicated. The options to be included in this version of the model are then selected; they are: (1) outreach recruitment, (2) outreach follow up, (3) referral, (4) method switching, (5) migration, (6) private protection, (7) advertising, (8) abortion, (9) agency capacity, (10) cost-effectiveness, (11) medical services, and (12) demographics. Next, the state specification for nonactives is begun with an initial definition of two stages: pregnant and all other nonactives. The manager can select to divide this further into 'never' and 'ever' in the system, or 'ever' can be further divided into 'ever' with negative experience, and 'ever' but not negative. The state specification described in the model-structure section of this paper can be obtained by dividing the nonactives fully and indicating the desire for considering indirect outreach and advertising. The specification section is used to set up the model structure and generate the conversational input questions that are required. All inputs are requested by English-language questions and only the questions relevant to the selected options are asked.

The specification section can be used to build a very simple mod I model. For example, if two agencies (one post-partum and one nonpost-partum), two methods (pill and loop), no options, and two nonactive states (pregnant and all other non-active) are selected, the on-line input conversation is very short. Only the basic acceptance, continuance, and birth rates are needed. The input demands are small and the flow structure simple. This type of model is a good first starting point for a manager.

The manager can then evolve his model. If he has more input data or is willing to make subjective estimates, he can add options such as outreach, referral, or capacity. As each option is added, he can make his own judgment about the time and cost tradeoffs of further elaboration.

More technically trained users of the model can access variables directly and change their subscripting. For example, if outreach records do not include the states of the nonactives (e.g., never or ever in the system), the state subscript on the percent who will make an appointment [$\text{PDESIR}_{a,s}$ in (2)] can be dropped. Although the model structure is reasonable in its subscripting, it is foreseeable that conditions may exist that could require considering new subscripts for almost any input. As another example, it may be that the composition of method selection is trending toward pills, so that the faction accepting each method [e.g., FACCPT in (11)] requires a time subscript. Finally, a subscript can be added to the appointment interval ($\text{APT}_{m,a,d}$) to allow specifying a distribution about the average appointment interval. This would allow the model to encompass skewed patterns of visits (e.g., very long intervals between visits for some loop users). The capabilities to change subscripting on line allows rapid and efficient customization of the model to specific decision environments.

APPLYING AND TESTING THE MODEL

THE MODEL DESCRIBED in this paper has been applied, developed, and tested in cooperation with the Atlanta Area Family Planning System.

Atlanta Background

Atlanta has three basic service granting agencies: (1) Grady Charity Hospital, (2) Planned Parenthood and World Population, and (3) the Fulton and Dekalb County Health Departments. A group called the Atlanta Area Family Planning Council (AAFPC) acts to help in coordinating and planning the system. The Council has a full-time director and three staff members; it was formed in 1969 with funding from an OEO grant of $750,000.

Owing to the fortuitous fact that the Center for Disease Control (CDC) of HEW has its national headquarters in Atlanta and to the interest of some members of its staff, a client-record system was instituted in Atlanta in 1968. The data were obtained carefully and processed by CDC, so the model estimation and testing described in the previous section could be carried out effectively.

The model application took place at two levels: at the service-granting level it was used to develop plans and forecasts for agencies, and at the AAFPC level it was used to develop integrated plans and budgets for the system.

Model Evolution

The first model considered was a simple mod I flow model.[13] It did not contain any of the options except recruitment by outreach, but it was an understandable structure and allowed managers to begin to use a model. It was not long before the inadequacies of the mod I model were found, and, in response to managerial requests, capacity, cost-effectiveness (couple-years of protection per dollar), sterilization, referral, and migration were added in an evolutionary manner over six months. The detail of the model also increased when the Grady Hospital program was modeled as one post-partum and one nonpost-partum program. The mod I model had only one state for nonactive/not-pregnant women. Mod I use led to elaboration of a 'never' and an 'ever' in the system-state definition. Evolution is continuing to include advertising, abortion, follow-up outreach, indirect outreach, private protection, and demographics. The rate of evolution is less restricted by the model than the availability of data and the managers' rate of internalization and desire for comprehensiveness. As the evolution proceeds, different levels of models will exist for different users. In Atlanta, the mod I model is used by first-time users and some agency administrators, while the more elaborate model is used by the AAFPC staff and some of the more analytical agency managers.

Model Input and Fitting

The basic source of input was the Center for Disease Control and its client-record system. Outreach data were collected on a sample basis and manual tabulations were made to find the response rates [e.g., percent who make an appointment, PDESIR, equation (2)]. Contraceptive-method failure rates were based on a private study by Christopher Tietze of 2000 post-partum patients from 1968–69. Since the current state of evolution at the applied level did not include abortion, advertising, or demographics, many of the more difficult input problems were avoided. The approach in Atlanta has been to add detail as reasonable data sources can be cultivated. For example, the outreach data are now being systematized. This will allow better data basing of the recruitment parameters and enable follow-up outreach parameters to be estimated.

Initial data estimates were made based on the client-record data of June 1969 to June 1970. After these flow-parameter estimates were put in the model, changes were made so that the model output of active and new patients fitted the actual June 1969 to June 1970 figures. Most of the changes were in the continuance rates. Within the tolerance produced by alternate data-analysis assumptions and statistical variance, the model was very sensitive. Therefore, the estimates were tuned to produce the best fits. The fit for the total number of actives is shown in Fig. 5. Fitting was also done to assure that the model replicated the real data for each method and for new patients at each agency.

Tracking Results

Although the model fitted past data encouragingly well, such fits from the nonlinear estimation procedure were the result of considerable massaging of the data. Testing the model was based on comparing actual and predicted patient flows over a six-month period of saved data and over a real twelve-month period.

Saved Data

June 1970 to December 1970 data were not used in the data-estimation procedures and were saved for predictive testing. Conditional forecasts were made for the July 1970 to December 1970 period based on the June 1969 to June 1970 data estimation. This initial prediction is shown in Fig. 5.

The prediction was lower than the actual figure. This was particularly true at Planned Parenthood, where the prediction was for stable performance and the total active curve increased sharply. The Grady Clinic prediction was also low. The question to be answered was: is the lack of accuracy due to poor input, random error, inadequate model structure, or changes in the real system itself? Answering this question is an exercise in problem finding, or, in this case, finding the reasons for unexpected success. A detailed analysis of the July 1970 to December 1970 data showed that the number of requests (walk-in appointments) at Planned Parenthood increased from 100 a month to about 250 a month during this time. The initial tracking prediction was based on the past average of 100 per month. Revising the input to reflect the actual new patient inflow produced a curve that tracked very well. This implies that the other inputs were probably good and that the structure of the model was reasonably sound. However, the rapid increase of new patients called for diagnosis. There had been an increase in the number of outreach recruitment calls, but very few additional appointments had been made with outreach workers. The hypothesis being investigated was that there was an indirect outreach effect [*see* (7)]. Data were collected for new-patient clinic arrivals to see if outreach calls correlated with voluntary requests for appointments.

The lack of correspondence between actual and predicted patient loads at

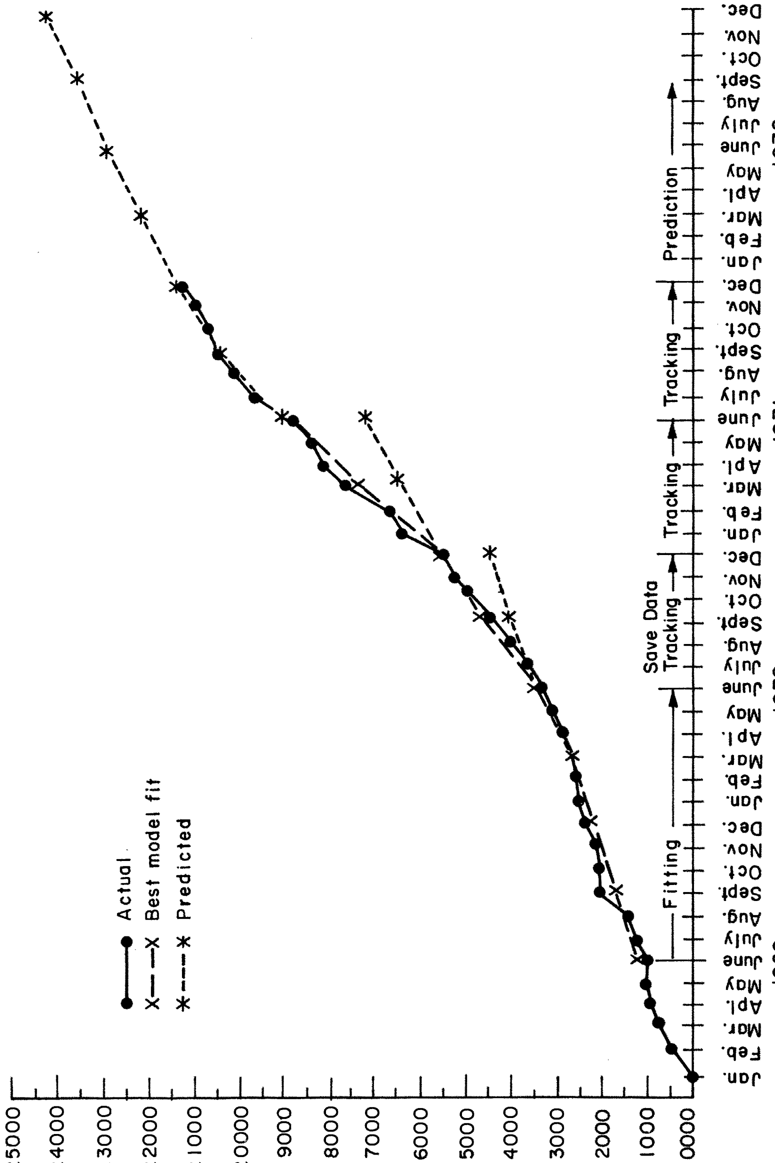

Fig. 5. Active family-planning patients using modern methods at major service agencies in Atlanta, Georgia.

Grady was found to be due to a new volunteer-run clinic opened to serve the hippie community and the subsequent increase of about fifty new patients per month. After these adjustments for new patients at Planned Parenthood and Grady, the active tracking appeared good (see Fig. 5). Tracking was also carried out at the specific-method level. This tracking and a new analysis of the July 1970 to December 1970 data indicated a shift in the composition of method selection toward the pill.

Tracking 1971

The tracking over the saved-data period (July 1970 to December 1970) was encouraging, but additional tracking over the period January 1971 to December 1971 allowed for additional refinements to the model input and structure. The conditional prediction made in December 1970 is shown in Fig. 5. Again the prediction was low. The Planned Parenthood agency increased its new-patient rate to 450 a month, or 200 more than predicted. It was found that Grady referred 50 percent more people per month to the county clinics than expected. New nonpostpartum clinic growth added 50 more patients per month. Finally, county-health-department outreach was more effective than anticipated. The volatility of the system reflected in these changes emphasizes the need for tracking and an effective adaptive planning model. With the input updated, the model tracked well, but again the question of why the new-patient rate increased was asked. Data indicated the indirect outreach effects to be real. Four times as many people contacted by outreach workers came without an appointment than came with an appointment. Inputs were revised and new predictions made for the last six months of 1971.

In January 1972, examination of predicted and actual values for the period June 1971 to December 1971 showed close correspondence. This was encouraging and reflected good predictive performance at the total system level. This was generally true at the agency level except at Planned Parenthood, where actual was less than predicted. Refitting indicated that a decay in continuance rates could explain this. Additional diagnosis showed that the decay was due to an increasing proportion of white college girls. This raised questions of priority between college girls and indigent mothers, since clinic capacity was limited. Grady actual was 3 percent higher than predicted, owing to less referral in December and more new patients in November and December. In summary, the 1970–1971 fitting and tracking helped diagnose problems, raised new issues, provided new insights, and improved confidence in the model inputs and structure.

Managerial Use of the Model

The model is being used by the Director of the AAFPC.[14] He is using it to develop an overall system plan and as a tool to aid agencies in their planning. Special planning sessions are being conducted with member agencies so that these managers can better understand their patient response, improve forecasts, and develop goals and plans. Although formal measurement of this impact is difficult, the managers using the model have reacted positively and are beginning to use the model as a tool in their planning and control. For example, one agency used the model to determine the effects of outreach workers and was able to predict the number of new patients and the change in the cost per year of protection that would result from undertaking an outreach program. In another agency, the outreach data and model runs indicated weakness in the success of outreach workers in making appointments. The process of education and usage is not yet complete at all agencies, but agency-level use is showing potential. Most of the implementation has occurred at the coordinating-council level.

The model-usage process has produced some new insights. In particular, the fitting and tracking exercise has been valuable, since it required a detailed analysis of why predictions were not as good as desired. The indirect-outreach effect was one such new insight that resulted from the model use. Another resulted from tracking birth flows. It was found that 25 percent of the deliveries from the target group were not done at the Grady Hospital. Originally, managers had believed that virtually all target-group deliveries were done at Grady. This insight has resulted in a new outreach program to the maternity wards of these hospitals. The analytic approach fostered by the model led to this new insight and change in the system behavior.

After fitting the model for the period of January 1971 to June 1971, a conditional forecast was made for the period July 1971 to December 1972. This was the basis for the next tracking period, but also was needed for the budget request for 1972. Owing to the planning system, the 1972 budget was required in September 1971. The model proved valuable to managers in generating the forecast for the remainder of 1971 so past funds could be accounted for. It should also be mentioned that the environment surrounding the 1972 budgeting was frantic owing to proposal dead lines. The on-line features of the model allowed rapid simulation and predictions, so that an effective proposal could be formulated on time. The first 1972 forecast was based upon a budget sufficient to meet capacity requirements. The forecast showed 24,600 actives by December 1972 and for a cost per year of protection of $69.91 over three years. However, the funding agency in Washington had requested that last year's budget amount be held for 1972. In order to show the effects of this constrained budget, the model was run again with the arrival rates decreased until existing capacity could serve the active groups. This budget-constrained run indicated 11.7 percent fewer actives, 240 women per month being refused service, and an increase of 1.6 percent in the cost per couple-year of protection. These forecasts were included in the 1972 budget request and the explicit cost/benefit justification was cited as a contributing factor in the subsequent granting of the larger budget amount. Although the larger budget was obtained for 1972, the model forecast for 1973 indicated doubt that needed funds could be obtained from existing sources. This led to more attention to generating new funding sources (welfare, Medicare), procedures for allocation between agencies, and methods of screening for only the target-group members most in need.

In addition to an orderly forecasting procedure, various strategic alternatives were considered. First, an outreach program to postpartum non-Grady patients was simulated. With an estimate of the number of calls allocated to this new program and their effect, it was found actives increased 1 percent over three years and the cost per year of protection decreased slightly. The second strategy was to increase the capacity to do sterilizations. Requests had been twice the capacity. This strategy resulted in a small increase in actives in three years, but a 5 percent reduction in the birth rate. However, the cost per year of protection increased, since sterilizations were priced at $300 each and they did not pay back in three years (recall an overall figure of $70 per year of protection); in fact, at this rate it would take five years to pay back. Sterilization in the short run was not very attractive as a method with this cost. New technology, more efficient procedures, or negotiations to reduce the cost could make sterilization more attractive. Other strategies were tried, but the gains due to the new strategies, although significant, were small (less than 5 percent). It became clear to program managers that the target group was being saturated. This insight has led them to widen their program to include more of Georgia. The improvements due to strategic analysis were important, but an equal benefit of the analysis has been a better perception of the system and how it works.

CONCLUDING REMARKS

Applying and testing the macro-flow model in Atlanta indicate that it can fit and track data satisfactorily and can aid managers in understanding, forecasting, and decision making. The model is now being implemented in five sites in the US (e.g., Los Angeles, Memphis, State of Georgia) under a new contract.

The model proposed in this paper is an intermediate-term planning model. Many other useful models could be built for clinic location, inventory planning, staffing, work scheduling, or long-term economic planning. In building such a collection of models, care should be taken to ensure that they function in a compatible manner. The planning model described in this paper could specify the overall capacity needs that could then be converted into a specific number of clinics and locations by a detailed facilities model. This family-planning model is useful, but not sufficient for the total management needs of a family-planning system.

As well as interfacing this model with others in family planning, the interaction with health services should be considered. Can family-planning systems be added successfully to comprehensive health services? Should family planning extend to include maternal and child-health-care services? These questions raise issues more macro than this planning model can entertain, but this interface will become more important as categorical funds for family planning decrease. The issues of phasing a categorical program such as family planning into the comprehensive health system will be investigated in future research.

A final activity envisioned for the future is applying this model-building method to developing countries. The model has been developed for use in a metropolitan US city, but, if the flows can be appropriately modified, it could be used in international settings. Early work with the Population Commission in the Philippines indicates that the basic flow notions are useful to managers in developing countries. In this application, attention has been focused on demographic impact, improving continuance rates, and the need for new programs. Initially, an aggregate mod I flow model and time-based continuation rates are being utilized. Although client-record systems exist in several developing countries (e.g., Philippines, Taiwan, Guatemala), the Philippines experience indicates it may be more expedient to estimate time-based continuance rates obtained from survey data, since client records are not as complete as one would like and the concept of an appointment cycle is not as well structured as in the US. Future work in the Philippines, Korea, and Afghanistan will determine if a macro-flow model can help improve management in a developing country where population growth is one of the most important problems.

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NOTES

1. FREDRICK JAFFE AND ALAN F. GUTTMACHER, "Family Planning Programs in the United States," *Demography* **5,** 922 (1968). "Unwanted" was defined by either the mother or father or both answering negatively to the question: "Before you became pregnant this time, did you want a (another) child?"

2. Ibid.

3. Many other theoretical and conceptual planning models have been proposed, but few, if any, have been applied to operating programs. Some models have reflected attempts to cram family planning inappropriately into linear programming formats. *See* HÉCTOR CORREA AND JOSEPH A. BEASLEY, "Mathematical Models for Decision Making in Population and Family Planning," *Journal of Public Health* **61,** 138–157 (1971), and CHARLES E. LAWRENCE, AXEL I. MUNDIGO, AND CHARLES S. REVELLE, "A Mathematical Model for Resource Allocation in Population Programs," *Demography,* vol. IX, No. 3 (August 1972).

A model developed by G. E. TEMPO is used at USAID and other locations, but it is directed at population policy rather than managing a family-planning system. *See,* USAID Contract Reports: 68TMP-119 to 121 and 70MP-87. A model developed by KENNETH F. SMITH (unpublished M.S. thesis, Massachusetts Institute of Technology, 1970) is also being used in a similar manner at AID and some universities.

Recently JACK REYNOLDS has proposed a forecasting model for an operating system. *See,* Jack Reynolds, "Methods for Estimating Future Caseloads of Family Planning Programs," *Family Planning Perspectives* **3,** 56–61 (1971). This is a simple model with a constant annual discontinuance rate and a given new-patient arrival input. The model is so simple that hand calculation is appropriate, but it is similar to the model proposed in this paper in its view of a patient flow. No usage experience has yet been reported.

4. *See* Glen L. Urban, "Sprinter mod III: A Model for the Analysis of New Frequently Purchased Consumer Goods," *Opns. Res.* **18,** 805–854 (1970); and Alfred Blumstein and Richard Larson, "Models of a Total Criminal Justice System," *Opns. Res.* **17,** 199–232 (1969), for examples of this type of model.

5. A complete set of equations can be obtained from the author.

6. Fertility rates display significant seasonality. *See, Natality Statistics Analysis,* National Center for Health Statistics, Series 21, No. 1, (HEW, Public Health Service), p. 36–38. Twelve percent more births occur in August, September, and October than in April, May, and June. The seasonal pattern varies geographically.

7. The term EFFUSE should not be confused with Tietze's "use-effectiveness." Christopher Tietze and Sarah Lewit, "Statistical Evaluation of Contraceptive Methods: Use-Effectiveness and Extended Use-Effectiveness," *Demography* **5,** 931–940 (1968). Tietze is referring to the probability of pregnancy in a group of women accepting and using supplies at a clinic. "Extended use-effectiveness" includes the pregnancies during the period of nonuse that occurs at discontinuation. In the model presented in this paper, Tietze's use-effectiveness is roughly equivalent to the total rate ((1-EFFMTH) (EFFUSE) AFERA) of pregnancies from actives as in equation (17). Tietze's life-table rates can be used to 'fit' EFFMTH and EFFUSE.

8. *Natality Statistics Analysis,* National Center for Health Statistics Series 21, Number 1 (HEW, Public Health Service, 1964), pp. 54–55.

9. Note that this use of couple-years of protection is based on a simulated projection forward in time. The simulated output is rather complete. This is in contrast to the demographic use of couple-years of protection, which is based on retrospective examination of rather incomplete past data from a real system. *See,* Lee L. Bean and William Seltzer, "Couple-Years of Protection and Births Prevented—A Methodological Examination," *Demography* **5,** 947–959 (1968), for a description of demographic issues.

10. Potter has suggested the use of a stochastic model to determine births averted; *see* R. G. Potter, "Births Averted by Contraception: An Approach Through Renewal Theory," *Theoretical Population Biology* **1,** 251–272 (1970). He models two renewal processes and uses the differences to estimate births averted. The assumptions underlying the model are significant. There must be homogeneity of women, homogeneity in time, and a long (i.e., infinite) reproductive period. The last assumption implies births averted are due only to increased spacing and not due to reaching menopause before the desired number of children is exceeded. The homogeneity over time implies that fertility does not change with age and therefore parity and fertility are not related (*see* note 6 for contrary evidence). Homogeneity in time also applies to contraception, so that second- and third-visit continuance must be the same. The model also does not include sterility, mortality, migration, abortion, or private protection.

11. *See* S. Enke, "The Economic Aspects of Slowing Population Growth," *Economic Journal* **76,** 44–56 (1966).

12. For more detail, *see* Philippe A. Naert and Srinivasa Murthy, "Visit Continuation Rates, Intervisit Times, and their Managerial Implications for Family Planning Administrators: A Case Study of Atlanta," Sloan School of Management Working Paper, #560–71; and, Lesley E. Markman, "Management Information Systems: An Application to Family Planning," unpublished Master of Science thesis, M.I.T., 1972.

13. *See* Ronald O'Connor and Glen L. Urban, "Using a Model as a Practical Management Tool for Family Planning Programs," *American Journal of Public Health* **62,** 1493–1500 (1972), for a description.

14. *See* Peter B. Tamblyn, Russell H. Richardson, and Elizabeth S. Ruyle, "Planning for Family Planning," *American Journal of Public Health* **62,** 142–143 (1973), for the model experiences as stated by the users in Atlanta.

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