Published by Oxford University Press on behalf of the International Epidemiological Association *International Journal of Epidemiology* 2010;**39**:i7–i10

doi:10.1093/ije/dyq016

Spectrum: a model platform for linking maternal and child survival interventions with AIDS, family planning and demographic projections

John Stover,* Robert McKinnon and Bill Winfrey

Futures Institute, 41-A New London Tpke Glastonbury, USA.

*Corresponding author. Futures Institute, 41-A New London Tpke Glastonbury, CT 06033, USA.
E-mail: jstover@futuresinstitute.org

Background LiST is implemented in Spectrum, a modular computer program designed to examine the impact of interventions on health outcomes. A typical LiST application uses three other modules in Spectrum addressing demography, family planning and HIV/AIDS.

Methods The demographic module projects the population by single age and sex over time and uses LiST calculations of the mortality rates by age group to calculate the number of deaths. The family planning module uses the proximate determinants of fertility framework to calculate the effects of increasing contraceptive use on the total fertility rate and, thus, the number of births. The HIV/AIDS module calculates the consequences of HIV epidemic trends on child mortality and the effects of programs to prevent mother-to-child transmission of HIV, cotrimoxazole prophylaxis and antiretroviral treatment on the number of AIDS deaths.

Results These modules provide LiST with estimates of the number of children and number of deaths by single age as they are affected by changes in fertility through family planning and interventions to prevent the transmission of HIV or delay AIDS death.

Conclusions Integrating LiST within the existing Spectrum system of planning models expands the scope of LiST to include the effects of demographic change, family planning and HIV interventions.

Spectrum system of policy models

Spectrum is a modular computer program used to examine the consequences of current trends and program interventions in health. The core of Spectrum is a demographic projection model, called DemProj,[1] which projects the population by age and sex. LiST and other modules interact with the demographic projection and are included as required for each application (Figure 1). These modules address a variety of issues in additional to maternal and child survival. The two additional modules used with LiST are the cost and impact of family planning programs (FamPlan)[2] and the impacts of HIV/AIDS.[3] Spectrum contains a database of population information that provides instant access to the population estimates and projections for 193 countries and regions from the United Nations Population Division[4] (using their projection without AIDS because the Spectrum AIDS module will add AIDS mortality) and a database of family planning information drawn from Demographic and Health Surveys.[5]

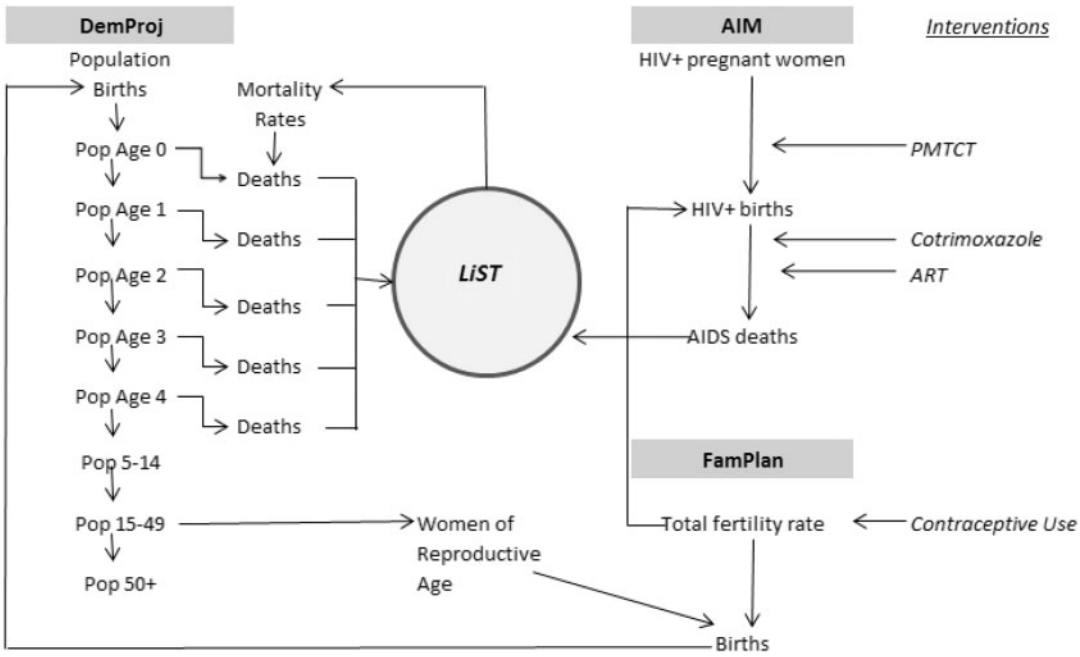

Figure 1 Interactions between LiST and other modules in Spectrum

The program and manuals can be downloaded free of charge from www.HealthPolicyInitiative.com or www.FuturesInstitute.org. Futures Institute has developed Spectrum in collaboration with other organizations, including Futures Group International, USAID, UNAIDS, WHO and UNICEF.

Demographic projections

The demographic projection component of Spectrum, DemProj, is a full-featured cohort component projection model. The inputs are the population by age and sex in the base year and, for all years in the projection, the total fertility rate, the age distribution of fertility, the sex ratio at birth, the life expectancy at birth in the absence of AIDS, the age pattern of mortality and the number and distribution by age and sex of international migrants.

A standard demographic projection with DemProj includes a model life table that provides information on mortality by single age for any value of life expectancy at birth. The standard tables are the four Coale–Demeny tables (north, south, east and west) and the five United National tables (General, Latin America, Chile, South Asia and East Asia). When used with LiST, DemProj searches for the value of life expectancy at birth that corresponds to the correct infant and under-five mortality rates within the chosen life table.

At the beginning of each projection year, DemProj provides LiST with the number of deaths for children aged 0, 1, 2, 3 and 4 years. LiST disaggregates those deaths into its age bands: 0–1, 1–5, 6–11, 12–23 and 24–59 months by fitting a double log function to the neonatal, infant and under-five mortality rates. The equation has the form $\ln(u) = a + b \times \ln(age) + c \times age \times \ln(age)$ where u is the cumulative mortality at the corresponding age.

Once LiST calculates the impact of interventions on the child mortality rates, they are converted to ages 0, 1, 2, 3 and 4 years and sent back to DemProj that uses these new rates to determine the number of children surviving to the following year.

DemProj calculates the number of births each year from the number of women 15–49 years old, the total fertility rate and the age distribution of fertility. New births are subject to the estimated mortality rates as they age each year. The number of live births is multiplied by the maternal mortality ratio from LiST to determine the number of maternal deaths.

Impact of family planning on maternal and child survival

Increased use of modern contraception reduces the number of births that would otherwise occur, and, therefore, reduces the number of child deaths. The current version of LiST does not include the effects of increased contraceptive use on child mortality rates but that relationship will be included in future versions. Family planning can affect the number of maternal deaths by reducing the total number of births (reducing exposure to the risk of maternal mortality) and by reducing the number of unsafe abortions that result from unintended pregnancies and thereby reducing the maternal mortality ratio.

The family planning module in Spectrum (FamPlan) uses the proximate determinants of fertility framework to relate contraceptive use to the total fertility rate.[6] This framework describes the factors that determine the observed total fertility rate: marriage, postpartum insusceptibility, abortion, pathological sterility and contraception. The basic model is:

$$\mathrm{TFR} = C_m \times C_i \times C_a \times C_p \times C_c \times \mathrm{TF} \quad (1)$$

where C_m is the index of marriage, C_i is the index of postpartum insusceptibility, C_a is the index of induced abortion, C_p is the index of pathological sterility, C_c is the index of contraception and TF is total fecundity. Total fecundity is the average number of births women would have during their lifetimes if there were nothing acting to restrict their fertility. It is generally estimated to be around 13–18. The other proximate determinants act to produce an observed TFR that is lower than the total fecundity rate.

The indexes for the other factors are calculated as follows:

$$C_m = \text{proportion married or in union} \quad (2)$$

$$C_i = 20/(18.5 + i) \quad (3)$$

where i = average duration of postpartum insusceptibility in months

$$C_a = \mathrm{TFR}/\{\mathrm{TFR} + 0.4 \times (1+u) \times \mathrm{TAR}\} \quad (4)$$

where TAR = total abortion rate

$$C_p = (7.63 - 0.11 \times s)/7.3 \quad (5)$$

where s = percentage of women 45–49 years of age who have had no live births

$$C_c = 1 - 1.08 \times u \times e \quad (6)$$

In the equation for the contraception index, C_c, u represents contraceptive prevalence, the proportion of married women of reproductive age using contraception, whereas e represents the average effectiveness of contraception, which is a weighted average of the effectiveness of each method and the proportion of women using each method. Standard values for method effectiveness are shown in Table 1.[7]

Equation (1) is rearranged to calculate the total fecundity, TF, in the base year from all of the other inputs. The value of TF is assumed to remain constant during the projection period. Thus, for future years, Equation (1) can used to determine the total fertility rate from the other inputs. If the other proximate determinants remain constant, then TFR is determined by contraceptive prevalence and the distribution of women by the contraceptive method.

Most of the data required for FamPlan are available from national household surveys such as the Demographic and Health Surveys. These provide information on TFR, the proportion married or in union, the duration of post-partum insusceptibility, the proportion of women aged 45–49 years with no live births, the proportion of women using contraception and the method mix. Information on the total abortion rate is difficult to get in most countries, but it can also be modelled as the percentage of unintended pregnancies terminated by abortion, where unintended pregnancies are those occurring to women who do not want another birth now. Regional estimates of abortion rates may be used where country-specific estimates are not available.

Table 1 Contraceptive method effectiveness

Method	Effectiveness (%)
Pill	92
IUD	96
Barrier methods	81
Withdrawal or rhythm	50
Norplant	100
Injectable	100
Sterilization	100

Stover *et al.*[7]

Impact of AIDS interventions on child survival

The AIDS Impact Module (AIM) uses a projection of adult HIV incidence derived from surveillance and survey data to project the course of the HIV epidemic.[8,9] It estimates new adult infections by age and sex and tracks them as they progress from initial infection, to need for treatment and to AIDS death. HIV-infected mothers can pass infection to their children at the time of birth or post-natally through breastfeeding. Infected children progress over time from new infection to AIDS death with those infected perinatally progressing more rapidly than those infected through breastfeeding.

AIM contains three interventions that affect the number of AIDS deaths among children: anti-retroviral prophylaxis to prevent mother-to-child transmission, cotrimoxazole to reduce susceptibility to infectious diseases and anti-retroviral therapy (ART) to slow the progression of HIV disease.

Births to HIV-positive women are calculated from the number of HIV-positive women by age, the total fertility rate and the proportion of lifetime births that occur in that age group. The fertility of HIV-positive women is adjusted for the effects of HIV infection on fertility.[10]

The transmission of HIV from mother to child is divided into two components: transmission during gestation and delivery, and postnatal transmission through breastfeeding. The probabilities of HIV transmission are shown in Table 2.

Table 2 Probabilities of mother-to-child transmission

Type of prophylaxis	Probability of perinatal transmission (%)
None	20
Single-dose nevirapine	11
Dual ARVs	4
Triple ARVs	2
Type of infant feeding	Monthly probability of HIV transmission (%)
Exclusive breastfeeding, 0–5 months	0.75
Mixed feeding (breastfeeding and other foods), 0–5 months	1.5
Mixed feeding, 6–35 months	0.75
Mother receiving ART	0.3

Consultative Meeting on Data Collection and Estimation Methods Related to HIV Infection in Infants and Children.[14]

Table 3 Reduction in AIDS mortality due to cotrimoxazole

	Year 1	Year 2	Year 3	Year 4	Year 5
Cotrimoxazole alone (%)	33	33	33	33	33
Cotrimoxazole and ART (%)	33	16	8	0	0

Consultative Meeting on Data Collection and Estimation Methods Related to HIV Infection in Infants and Children.[14]

In the absence of treatment, children infected at birth progress to AIDS death at a rapid rate (median of 1 year) with only ~5% surviving to age 5 years, whereas those infected through breastfeeding progress at a much slower rate (median of 15 years).[11]

Cotrimoxazole is recommended for all HIV-exposed children under the age of 18 months (i.e. uninfected children with an infected mother and still breastfeeding) and all HIV-infected children under the age of 5 years.[12] The effectiveness of cotrimoxazole in averting AIDS deaths among children is shown in Table 3.

All HIV-positive children under the age of 1 year are in need of treatment. After the age of 1 year, children need treatment once they progress to moderate-to-severe disease.[13] Annual survival on ART is 80% for children under the age of 1 year. For those over the age of 1 year, it is 85% in the first year on ART and 93% in each subsequent year.[14]

Discussion

Integrating LiST within the existing Spectrum system of planning models expands the scope of LiST to include the effects of demographic change, family planning and HIV interventions. This also expands the data requirements to fully utilize LiST and users involved in planning child survival interventions may not be expert in family planning or HIV. To address this issue, LiST includes prepared datasets for FamPlan and AIM for most countries. This allows a fuller exploration of the actions that can be taken to reduce child mortality in resource-limited settings.

Conflict of interest: None declared.

References

[1] Stover J, Kirmeyer S. *DemProj: A Computer Program for Making Population Projections*. Washington, DC: Futures Group International/Health Policy Initiative, 2008.

[2] Stover J, Heaton L, Ross J. *FamPlan: A Computer Program for Projecting Family Planning Requirements*. Washington, DC: Futures Group International, 2006.

[3] Stover J. *AIM: A Computer Program for Making HIV/AIDS Projections and Examining the Demographic and Social Impacts of AIDS*. Washington, DC: Futures Group International/Health Policy Initiative, 2009.

[4] United Nations Population Division. *World Population Prospects: The 2008 Revision*. New York: United Nations Department of Economic and Social Affairs, 2008.

[5] Measure DHS. Demographic and Health Surveys. www.MeasureDHS.com.

[6] Bongaarts J. A framework for analyzing the proximate determinants of fertility. *Popul Dev Rev* 1978;**4:**105–32.

[7] Stover J, Bertrand JT, Shelton JD. Empirically based conversion factors for calculating couple-years of protection. *Eval Rev* 2000;**1:**3–46.

[8] Stover J, Johnson P, Zaba B, Zwhalen M, Dabis F, Ekpini R. The Spectrum projection package: improvements in estimating mortality, ART needs, PMTCT impact and uncertainty bounds. *Sex Transm Inf* 2008;**84:** i24–i30.

[9] Stover J, Walker N, Grassly NC, Marston M. Projecting the demographic impact of AIDS and the number of people in need of treatment: updates to the Spectrum projection package. *Sex Trans Inf* 2006;**82:**45–50.

[10] Kongnyuy EJ, Wiysonge CS. Association between fertility and HIV status: what implications for HIV estimates? *BMC Public Health* 2008;**8:**309.

[11] Collaborative Group on AIDS Incubation and HIV Survival. Time from HIV-1 seroconversion to AIDS and death before widespread use of highly-active antiretroviral therapy: a collaborative re-analysis. *Lancet* 2000; **355:**1135–37.

[12] WHO. *Guidelines on Co-Trimoxazole Prophylaxis for HIV-Related Infections Among Children, Adolescents and Adults in Resource Limited Settings: Recommendations for a Public Health Approach*. Geneva: World Health Organization, 2006.

[13] WHO. *Antiretroviral Therapy for HIV Infection in Children: Toward Universal Access: Recommendations for a public health approach*. Geneva: World Health Organization, 2007.

[14] Consultative Meeting on Data Collection and Estimation Methods Related to HIV Infection in Infants and Children, 8–10 July 2008, New York: UNICEF, 2008.